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Specialization:	Production Engineering and Logistics
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Title:	Design of inventory control for the justification and reduction of stock
Author:	K Aberkan

Title (in Dutch)	Het ontwerp van voorraadbeheer voor de verantwoording en vermindering van voorraad

Assignment:	Masters thesis
Confidential:	yes, until March 03, 2021
Initiator (university):	prof.dr.ir. G. Lodewijks
Initiator (company):	T.C. van Doorn
Supervisor:	Dr. ir. H.P.M. Veeke
Date:	March 03, 2016

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Supervisor (TUD):	Dr. ir. H.P.M Veeke	Report number:	2016.TL.8010
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Subject: Design of inventory control for the justification and reduction of stock

Introduction

Edilon)(sedra is active in the rail infrastructure as a supplier of rail systems, rail-isolation systems and solutions in the field of damping sound and vibration for train, metro, light rail and industrial applications. Components of the various systems are partly in-house produced and partly produced elsewhere on the basis of the specifications provided. Sales take place through its international offices directly, through agents and strategic partners.

The following products can be distinguished:

Incoming:

- Raw materials (factory Haarlem and Winschoten)
- Packaging (factory Haarlem and Winschoten)
- Trade goods (warehouse Amsterdam)

Outgoing

- Finished goods/in-house produced (warehouse Amsterdam)
- Trade goods (warehouse Amsterdam)

Problem definition

This research arises from the need to reduce working capital of which the inventory is an important component. Edilon)(sedra would like to have investigated how the stock level per product group can be reduced and justified in order to reduce working capital. Aim is to optimize the relationship between inventory and customer arrangements.

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Research question

How can edilon)(sedra justify the stock levels per product group and reduce inventory in order to reduce working capital without compromising the lead time?

This question should be answered by performing the following steps:

- Analyze the current processes according the Delft Systems Approach
- Analysis of which contributes to stockpiling
- Justify inventory by applying the ABC-analysis and calculation of safety stock
- Implementing KPIs for performance measuring
- Constructing an inventory control model
- Study relevant literature

The report should comply with the guidelines of the section. Details can be found on the website.

The professor,

Prof. Dr. ir. G. Lodewijks

The supervisor,

Dr. ir. H.P.M. Veeke

Summary

EdilonSedra is an international supplier of rail track systems, rail insulating systems and systems for the reduction of noise and vibration. These systems require trade goods that are supplied by different suppliers and products produced by EdilonSedra BV. EdilonSedra BV holds two production facilities, one in Haarlem-Spaarnwoude and one in Winschoten, where the epoxy- and polyurethaan types of products are manufactured. Packing and raw materials are needed to produce the required products. These packing and raw materials are purchased and stored in the warehouses at the location of the production facilities. The finished goods and the trade goods are stored in a warehouse of a third party located in Amsterdam where space and service is hired. The produced batches are transported the same day or the day after the manufacturing has taken place to this location to be stored. From this warehouse, all the materials are transported to the desired destination.

Since the year 2012, the turnover and profit margin are under pressure with the result that EdilonSedra BV received, from the upper management, the question concerning the reduction of working capital on the basis of inventory. EdilonSedra BV thus wanted to have investigated how the inventory can be reduced in order to reduce working capital and how the inventory should be categorized to justify the quantities stored.

The evaluation of the inventory is done on the basis of profound data analysis. From this analysis it was found that the average value stored in the year 2014-2015 was equal to 5 million euros, which is considered significant compared to the turnover. The analysis of the current order process and production process were done by the use of the Delft Systems Approach. Due to the process analysis it was found that there was lack of inventory control.

To improve the quality of inventory control, the following aspects are introduced:

- Key Performance Indicators
- Service Level Agreement
- Product rating
- Order methods
- Safety stock for packing and raw materials
- Reduction of safety stock of finished goods
- Postponements

The use of KPIs makes sure that the company is able to evaluate the performance of inventory control and can be considered as vital navigational instruments by setting targets. The KPIs are *Inventory Turnover Ratio, Service Level, Supplier's reliability* and *Inventory Accuracy.* The introduction of SLA has provided some clarity concerning postponement of orders and the lead time of finished goods.
The product rating aspect is relevant for categorizing products in which finished goods are responsible for the highest turnover. These few A-ranked products, which provide 80% of the turnover, are therefore the most important and hence require the most attention in terms of inventory control. In contrast with the C-ranked products, which only provide 5% of the turnover. The raw materials needed for the production of the A-ranked products are automatically A-ranked. Instead of purchasing the raw materials intuitively, the packing and raw materials have to be bought on basis of data and known information. Therefore heuristic order (lot sizing) methods can be used in order to minimize the corresponding order and carrying cost. These methods are known as the *Economic Order Quantity, Silver-Meal, Least Unit Cost* and *Part Period Balancing.*
Safety stock of the A-ranked raw materials are maintained in order to absorb irregularities in demand. Other raw materials (especially C-ranked materials) must be bought the moment an order enters the system. Because there is enough production capacity and a short throughput time of the production

(excluding QC), the safety stocks of the finished goods can be reduced to zero, which makes the company fully “pull” oriented instead of “push/pull”.
Clear agreements have been implemented in the SLA concerning postponements of orders by the customers. This ensures that the additional costs, caused by postponement, is not affecting the profit and working capital.
By the implementation of these inventory control aspects a better overview of the inventory can be attained. A yearly savings of €14.885,- can be realized by the reduction of safety stocks of finished goods. Thereby eliminating dead inventory of €477010,-. As well as a yearly savings of €50.872,- from postponed orders.

Samenvatting

EdilonSedra is een internationale leverancier van spoorsystemen, spoorinsulatie systemen en systemen voor de reductie van geluid en vibratie. Deze systemen vereisen handelsgoederen die geleverd worden door verschillende leveranciers en producten die door EdilonSedra BV zelf worden geproduceerd. EdilonSedra BV beschikt over twee productiefaciliteiten waar de epoxy- en polyurethanen producten gefabriceerd worden, gelokaliseerd te Haarlem-Spaarnwoude en Winschoten. Voor het produceren van de benodigde producten zijn verpakkingsmaterialen en grondstoffen nodig. De verpakkingsmaterialen en grondstoffen worden opgeslagen in het magazijn van de productiefaciliteiten. De eindproducten en handelsgoederen worden opgeslagen in een magazijn van een derde, gevestigd in Amsterdam, waar ruimte en service worden gehuurd. De geproduceerde batches worden na productie, of een dag na de productie, getransporteerd naar het magazijn in Amsterdam. Alle materialen worden dan uiteindelijk vanuit Amsterdam getransporteerd naar de gewenste bestemming.

Na het jaar 2012 stond er druk op de omzet en de marge waardoor EdilonSedra BV de opdracht van het hogere management heeft gekregen om de werkkapitaal te reduceren op basis van voorraad. EdilonSedra BV wilde onderzocht hebben hoe de voorraad kan worden verminderd om werkkapitaal te reduceren en hoe de voorraad gecategoriseerd dient te worden om de hoeveelheid opgeslagen materialen te verantwoorden.

De evaluatie van de voorraad is gedaan op basis van een grondige data analyse. Uit deze analyse bleek dat in het jaar 2014-2015 de gemiddelde voorraadwaarde gelijk was aan 5 miljoen euro, wat wordt beschouwd als significant in verhouding met de omzet. De analyze van de huidige order en productie proces zijn gedaan middels de Delftse Systeemkunde. Uit deze analyze bleek dat er een gebrek is aan voorraadbeheer.

Voor het verbeteren van de kwaliteit van het voorraadbeheer zijn de volgende aspecten geintroduceerd:

- Key Performance Indicators
- Service Level Agreement
- Product Classificatie
- Bestelmethodieken (grondstoffen)
- Veiligheidsvoorraad voor grondstoffen en verpakkingen
- Reductie van de veiligheidsvoorraad van eindproducten
- Uitstel van orders

Het gebruik van KPIs zorgt ervoor dat het bedrijf de mogelijkheid krijgt om de prestaties van het voorraadbeheer te evalueren. KPIs kunnen dus beschouwd worden als belangrijke navigatie-instrumenten door het stellen van doelen. De KPIs zijn *Inventory Turnover Ratio, Service level, Supplier's reliability* en *Inventory Accuracy.* De introductie van de SLA heeft voor meer helderheid gezorgd omtrent uitstel van orders en de doorlooptijd van eindproducten.
Het classificeren van producten is relevant voor het categoriseren waarbij de eindproducten verantwoordelijk zijn voor het grootste deel van de omzet. De enkele A-geclassificeerde producten, die 80% van de omzet verschaffen, zijn daarom de belangrijkste producten en vereisen dus de meeste aandacht op het gebied van voorraadbeheer. In tegenstelling met de C-geclassificeerde producten die alleen 5% van de omzet verschaffen. De benodigde grondstoffen voor het produceren van A-geclassificeerde producten zijn automatisch A-geclassificeerd. In plaats van de intuitieve inkoop van grondstoffen moet het inkopen gebeuren op basis van gegevens en bekende informatie. Voor het minimaliseren van de voorraad- en orderkosten dient er gebruik gemaakt te worden van 1 van de heuristieke bestelmethodieken. Deze methoden zijn bekend als de *Economic Order Quantity, Silver-Meal, Least Unit Cost* en *Part Period Balancing.*

Veiligheidsvoorraad van de A-geclassificeerde grondstoffen dient er te zijn voor het absorberen van de onregelmatigheden in de vraag. Andere grondstoffen (met name C-geclassificeerde producten) moeten worden ingekocht op het moment dat er een order binnen komt.
Omdat er voldoende productiecapaciteit is en de doorlooptijden kort zijn (exclusief QC tijden) kunnen de veiligheidsvoorraaden gereduceerd worden naar nul. Dit maakt het bedrijf volledig “pull” georienteerd in plaats van “push/pull”.
Er zijn duidelijke afspraken geimplementeerd in de SLA betreft uitstel van orders door de klanten. Dit verzekert dat de additionele kosten, veroorzaakt door de klant, niet van invloed is op de winst en het werkkapitaal.

Door de implementatie van deze aspecten voor voorraadbeheer kan men een betere overzicht verkrijgen van de voorraad. Een jaarlijkse besparing van €14.885,- kan worden gerealiseerd door de reductie van veiligheidsvoorraad van eindproducten. Daarbij wordt €477010,- aan dode voorraad geëlimineerd. Ook bespaart men jaarlijks een bedrag van €50.872,- door uitgestelde orders.

Table of Contents

1. Introduction

EdilonSedra is a specialist in developing and supplying railsystems, rail-isolation systems and damping systems of sound and vibration for high speed and conventional trains, trams, metros, light rail transits, crane and industrial tracks. These systems consist of epoxy, trade goods and polyurethane materials, whereby the polyurethane and epoxy products are manufactured by EdilonSedra B.V. The trade goods are manufactured and supplied by third parties. The packaging and raw materials needed in order to manufacture the epoxy and polyurethane materials are purchased by the purchase department on the basis of the MRP, which is constantly updated by the planning-, sales- and warehouse department. EdilonSedra has two production facilities, one in Haarlem-Spaarnwoude and one in Winschoten which both contain a warehouse for packaging and raw materials. The produced products and trade goods are stored in a warehouse in Amsterdam where space is hired. The finished goods and the trade goods are then transported from the warehouse in Amsterdam to the required destination.

This research relates to inventory control whereby the focus lies on packaging and raw materials for the production facilities and the storage of finished goods. The trade goods are left out in this research. The sales-, engineering-, on-site installation process as well as the transport to the warehouse of the production facilities and from the warehouse in Amsterdam to end-destination are also not included in this research. This research will focus on inventory control in order to reduce working capital on the basis of inventory, as described in the research target:

Design of inventory control to determine the right order sizes, relevant KPIs and SLA which should lead to a reduction of 10 % of the working capital.

This report consists of two parts. The first part, chapter 1 to chapter 4, presents the initial problem, the analysis of the process and the research target. The second part, from chapter 5 to chapter 8, presents the solutions for the problems found based on the analysis of the first part. Chapter 2 gives a general description of the company and the inventories where this research is aimed at. In the 3rd chapter the internal processes are analyzed and bottlenecks are appointed. The foundings in chapter 3 are analyzed in chapter 4 where the research objective has resulted from. In the chapters from 5 to 7 the solutions are elaborated. The implementation of the solutions is discussed in chapter 8.
The last chapter contains the conclusion and the recommendations.

2. edilon)(sedra

EdilonSedra is a company that is active in the railway industry. EdilonSedra is an international supplier of railsystems, rail-isolation systems and damping systems of sound and vibration. They design, engineer and construct innovative and sustainable rail track solutions all over the world. These systems are applied on:

- High speed- and conventional trains
- Trams
- Metros
- Light rail transits
- Quay crane applications

EdilonSedra is specialized in providing solutions in certain fields which are:

- Tunnels, bridges and viaducts
- Stops and stations
- Level crossings
- Grass tracks and streets
- Depots, workshops and washing plants
- Industrial and crane tracks
- Transition zones and specials (floodgates, firedoors etc.)

With a number of 200 employees, 2 manufacturing plants and 15 R&D and Sales offices, EdilonSedra manages to acquire an annual turnover of about 60 million euros. Two of the manufacturing plants are located in Netherlands; Haarlem Spaarnwoude and Winschoten. Other toll manufacturers are located in different countries for strategic, logistic, financial purposes and custom reasons. Due to lack of space and to increase flexibility EdilonSedra collaborates with CJ Hendriks Group in Amsterdam, which possess a warehouse where all the end products from both manufacturing plants are stored. All the end products are distributed from this warehouse all over the world to the desired destinations. Projects have been done for instance in countries as Spain, Switzerland, Saudi Arabia, Netherlands, Germany and Austria. EdilonSedra offers as a full service partner support in designing, constructing and maintaining projects, as well as supervision to complete installation and consultation on practical and technical issues and is ISO 9001:2008 certified.
Because of the fast developing market of the railway industry 20% of the budget is spent on Research and Development for the development of new products in order to maintain a leading role in the market.

Not all products, that are needed for the installation of a system, are produced by EdilonSedra. Trade goods are provided by external parties/suppliers that are able to produce the trade good based on the technical drawings supplied by the R&D department of EdilonSedra.

EdilonSedra Contracting collaborates with EdilonSedra b.v and is responsible for on-site installation and maintenance of a system. When a project reaches the point of installing the designed system or applying maintenance, the installation or maintenance is being done as quickly as possible in favor of minimizing idle time, without this being at the expense of the quality.

2.1 Organization

EdilonSedra was founded in 1945 under the name Cirkelspoor N.V and became an independent member firm EdilonSedra b.v since 1981 of the James Walker Group Ltd (UK).
The core activities consist since 1960 of the development and production of polymer- and epoxy systems and applications for construction, railway and industry.
EdilonSedra Group is part of the Raildivision James Walker Rail Systems & Products Holding B.V within the James Walker Group Ltd. together with Tiflex Ltd.
The organogram of the complete organization can be seen below.

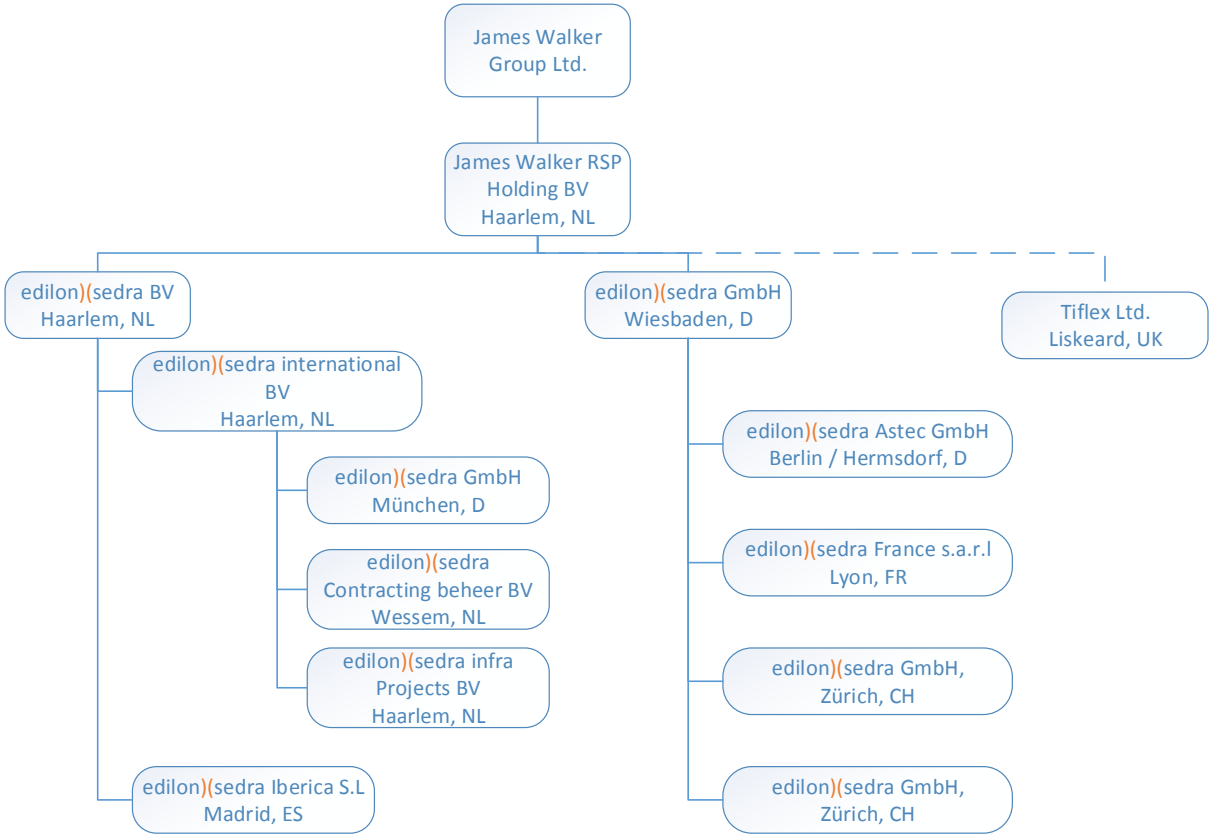


Figure 1: Organogram of complete organization (intranet 2012)

EdilonSedra Group is the overarching organization of EdilonSedra b.v.
EdilonSedra b.v is the part of the organization which ensures the engineering and manufacturing of required products for customers.
The organization of EdilonSedra b.v in Haarlem is organized according to the following organograms.

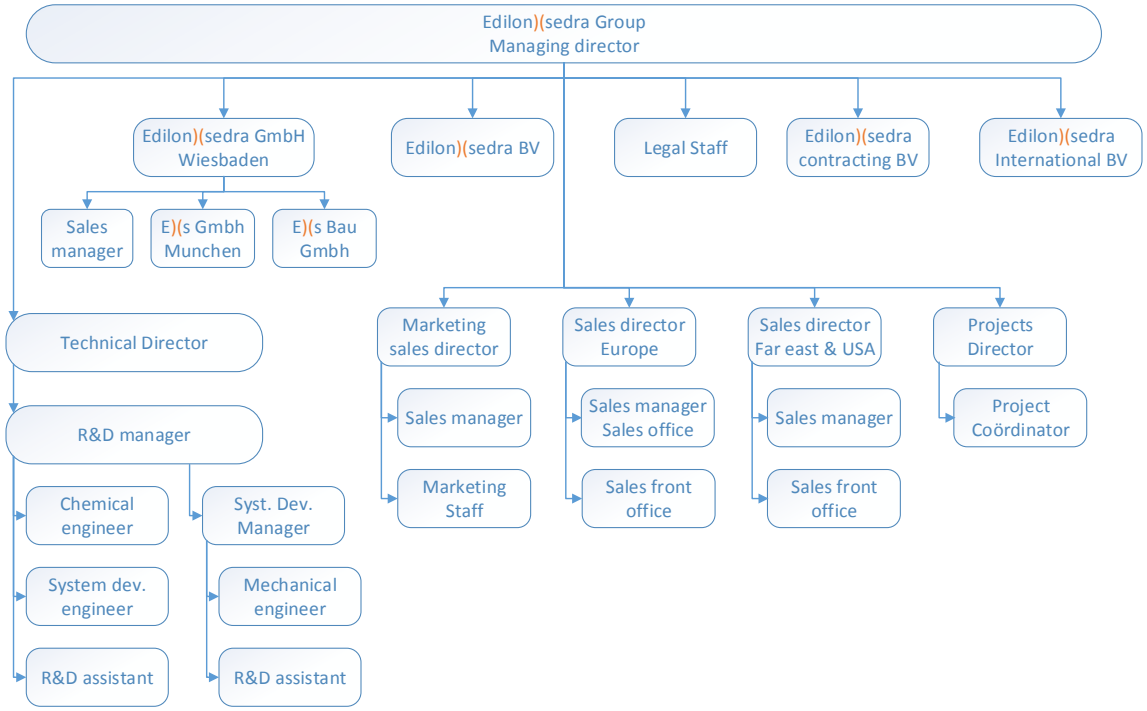


Figure 2: Organogram e)(s Group

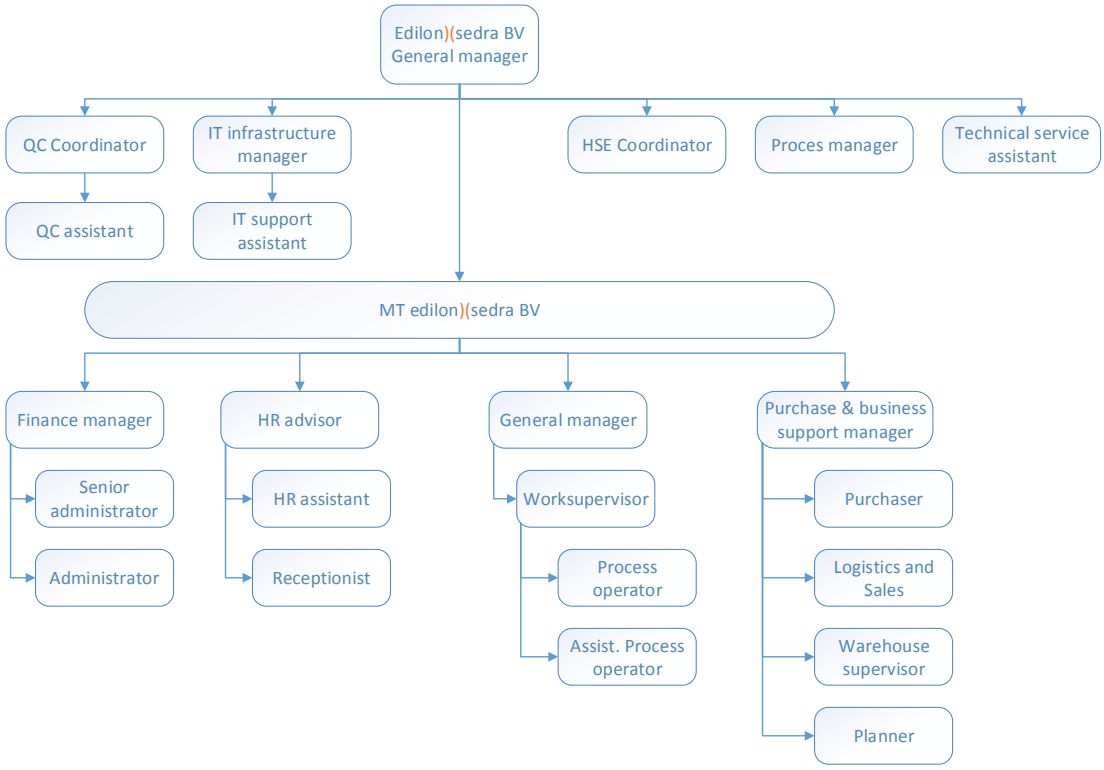


Figure 3: Organogram e)(s BV

The members of the board, which consists of the managing director, Sales Director Europe and Projects Director, set criteria which projects should meet in order to accept the project. The projects should then be approved by the board based on these criteria. These criteria are important for the

determination of the profitability of the concerning project and for that reason not every project can be accepted.
The projects are prioritized on two points:

1) Geographically feasible
2) Offering of existing systems

Countries can therefore be divided in three categories which are:

- *very* interesting (agents at location, establishment, exhibitions)
- interesting
- and *not* interesting (no establishment, geographically unprofitable etc)

The provision of systems which corresponds to known problems ensures the standardization of solutions in the field of vibration and sound reduction. An ideal project would then be a project whereby an existing system would be the solution for the respective project in an area where EdilonSedra is active.

2.2 Business profile edilon)(sedra

The vision and mission stated by the website of EdilonSedra is as follows:

2.2.1 Vision & mission

Due to the constantly changes of rail track systems the demands on rail infrastructure becomes more stringent. EdilonSedra must look ahead in order to understand the trends that will shape the business in the future.
The aim of EdilonSedra is to offer the best possible track systems for the customer. Our company stands for safe and easy accessible track systems, economic and ecologic favorable Life Cycle Costs, optimal reduction of noise & vibration and short installation times (http://www.edilonsedra.com/about-us/vision-and-mission/).

2.2.2 Strategy

The strategy is determined by James Walker Rail Systems & Products Holding B.V and is supported by EdilonSedra BV.
This strategy is summarized as follows (Intranet, Synergy):

- The expansion of the geographical coverage in the areas:
    - Europe
    - East Europe
    - North America
    - South America
    - Australasia
    - Middle east and north Africa

- Strengthen position relative to the competitors
    - Guaranteed quality
    - Price/quality ratio
    - Forerunner in product development

The strategy is adhered to by the following:

- Development of products and services
- Provision of adequate availability of products
- Improvement of knowledge and skill in the organization

- Improvement of prices of products
- Administrative support and reporting

2.2.3 Competition

The competition in the market of the rail industry is very high. Competition is based on two aspects, namely:

- Competition in price
- Regulations (in a foreign country)

It speaks for itself that companies compete in selling their products for the lowest possible price. The company with the lowest Total Cost of Ownership is the most attractive and likely to be the one in gaining the project, despite the quality in some cases. Since EdilonSedra is an international supplier of rail systems it has to deal with different types of customers with their own criteria bonded to the regulations of that specific location. Some countries are very strict in the quality of the product despite the cost and in some countries the cost may overrule the quality. Knowing this plays an important role in defining a strategy for winning a customer in a certain (foreign) area and therefore a project.
The second aspect is the regulations that are set in a foreign country. The introduction made in a foreign country may cost a lot of time. It may take months or even years to eventually produce for a country undisrupted by the regulations set by the government. Because of this, competing parties that are already established in that country have a higher chance prevailing in gaining projects.

2.2.4 Customers

The sales department is responsible for customer acquisition. There are two types of customers:

1) Intercompany
2) External customers

Intercompanies, also known as OpCo's, are sales offices around the world that work under the umbrella of EdilonSedra Group. EdilonSedra BV acts on the order, coming from sales offices, and eventually delivers to the end customer. When it goes via this route, the invoice is sent to OpCo with a certain, not very high, margin. The OpCo then sends the invoice to the end customer for the recommended selling price, which is centrally determined.
External customers are customers that do not work under the umbrella of EdilonSedra Group. These customers are often contractors. The end customer in the chain is in most cases the government.

2.2.5 Projects

EdilonSedra is a project-oriented company. The moment an interesting project emerges in its primary stage, the project management process is executed along with contract management. The classification “project” is in order when a project has the following characteristics:

- The EdilonSedra part being larger than around €100.000,- in value
- Complex in the sense of inclusion of several EdilonSedra systems, disciplines and capabilities
- Cross border influenced.

If a project qualifies for one of the above criteria, a request has to be submitted to the board accompanied with a so called “project blue print”. This blue print consists of a checklist for determining whether a project is worth considering. Assessments are made on the strategic fit, risks available capacity, investments to be made related to the expected revenue and the probability the particular project could be won. An investigation takes place to what extend the project holds interesting aspects or technical track construction challenges that fit the EdilonSedra proposition and the related stakeholders (customers, designers, engineers, involved contractors and other decision influencers).

Projects whereby EdilonSedra can be a sub-contractor within a larger project are preferred over being main-contractor. An initial check is done on contractual constraint and risks before working on a project.
Issues in respect to permits, traffic safety, safety regulations, geological aspects etc. are addressed in order to avoid unexpected influences.
Determining the total cost within a project is done by taking all activities, equipment and overheads into account to create a realistic picture. After execution a finalizing meeting with the customer takes place in order to evaluate the project.

2.2.6 Suppliers

The suppliers supply items needed for the production of products and trade goods for on-site installation.
The items they supply can be categorized in five parts:

- Raw materials
- Trade goods
- Packing materials
- Resources
- Other (not needed for production)

The purchase department has direct contact with the suppliers and can therefore negotiate price for an item depending on the volume that is purchased. EdilonSedra sets internally a cost price per item in the beginning of the year.
The time of delivery of the purchased items is not fixed and therefore varies. The agreement of delivery time is made at the moment an order is placed. The purchaser consults with the supplier when the item can be delivered.
Not every purchasing item needs terms of delivery (technical specifications), but several items, like trade goods, do and must be delivered according to those terms which is agreed upon.
The total number of suppliers that EdilonSedra has done business with amounts to 275 since 2013.

2.2.7 Supply chain

EdilonSedra is a project-oriented and inventory controlled company and estimates the demand for the upcoming year due to the unpredictability of customer demands downstream. Forecasting is relevant for suppliers for what they may expect for that year so that a planning can be made based on the forecast. There are no forecasts available which can be planned.
Raw materials, trade goods and components are therefore kept in stock which is seen as beneficial for quick responses and short lead time. EdilonSedra keeps also stock in finished goods, which means that they not only produce on orders but to stock as well. We can say that the supply chain strategy used by EdilonSedra is both make-to-order and make-to-stock. As can be seen in the figure below, the decoupling point is located in the inventory of EdilonSedra. The decoupling point is the point in the organization to where the customer order penetrates. Downstream from this decoupling point the supply chain is customer order driven and upstream forecast driven.

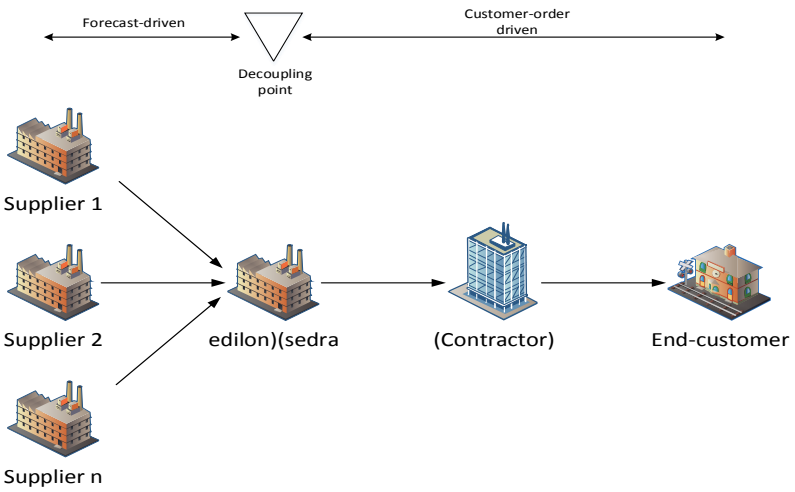


Figure 4: Supply Chain MTO/MTS

There are 3 types of start possibilities from the customer's demand:

1) Directly to the backoffice (repeat purchase)
2) Via application engineering (customization of an existing system)
3) R&D new development

In the figure below the internal supply chain of EdilonSedra is displayed with the primary activities and support activities.

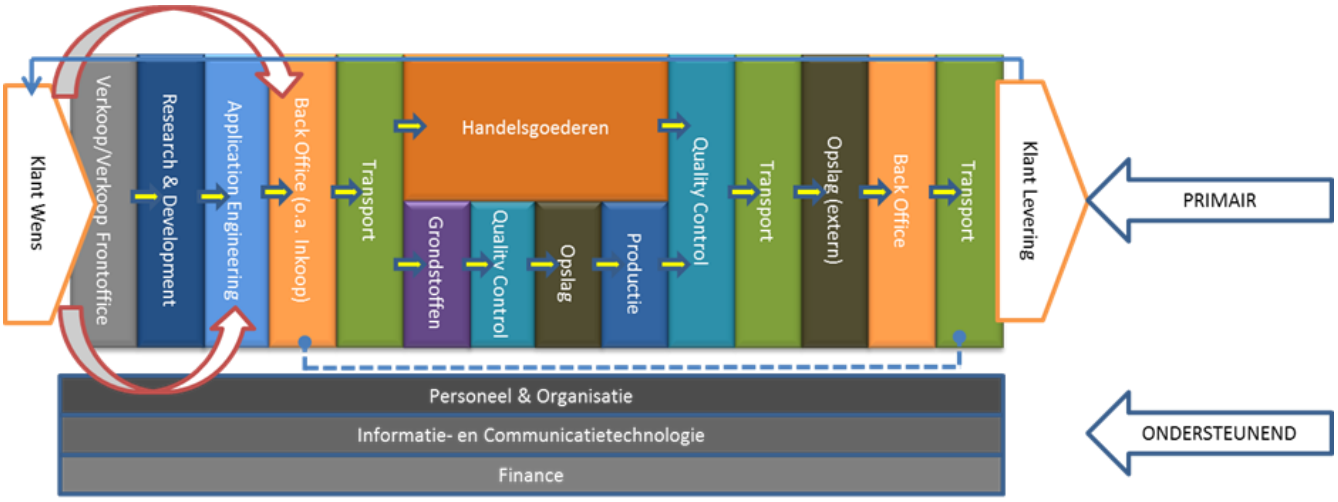


Figure 5: Internal Supply Chain e)(s

2.2.8 Development

- EdilonSedra is considering the implementation of an EDI system between warehouses MIG and MUG.
- The planning department logs the postponed projects which were not done before.
- A project started for the development of sustainable and green products.

2.3 Systems and Products

For almost 130 years rail traffic has been carried on traditional ballasted tracks. Over the years, increasingly stringent demands are made by the rail industry. This is because of the arising of high speed trains, greater axle loads, increasing train frequencies and enhanced environmental consciousness. By means of this, the development has taken place of the EdilonSedra embedded rail fastening systems and associated products in the early 1970s in collaboration with Netherlands Railways (NS). The systems and products are briefly described in this paragraph to have a better understanding of what EdilonSedra provides.

2.3.1 Systems

EdilonSedra provides different types of systems which can be categorized in:

- Embedded Rail System (ERS)
- Embedded Block System (EBS)
- Sound Damping System (SDS)
- Direct Fastening System (DFS)

These systems are applied depending on the demand of the customer.

Embedded Rail System (ERS)

The Embedded Rail System is a fastening system which is characterized by the continuous support of the rails. The implementation of this system ensured the avoidance of the support-point frequencies of traditional, discrete rail fastening systems. This system enables traffic loads to be transferred in a uniform way and reduces load peaks in the supporting track substructure.

The main product, EDILON Corkelast, in the ERS rail fastening system ensures enclosing and bonding of the rails in a concrete or steel channel. This product is applied, in accordance with specified conditions, in order to have a homogeneous rail support with a defined elasticity.

EDILON Resilient ERS Strip controls the deflection of the rail under predominant loads. The strips are available in different thicknesses and hardness characteristics and are determined depending on the requirements for system stiffness. The filling materials are primarily used to reduce the use of the embedding compound while tubes can be used for the same purpose as well for the enclosure of cables for signals and other functions.

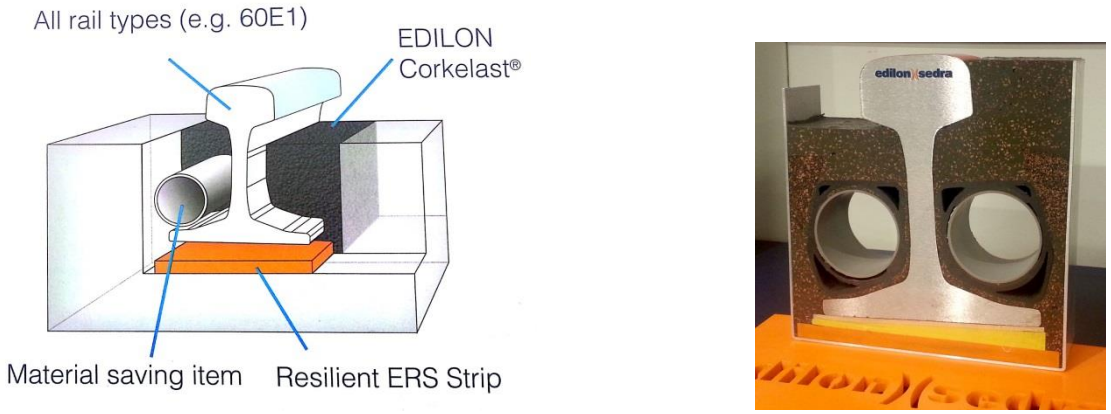


Figure 6: Embedded Rail Systems (ERS)

The ERS has been used all over the world since 1982 for various applications for heavy-rail and light-rail. The fields of application for heavy-rail systems include:

- High speed rail traffic (axle loads from 18 to 20 metric tonnes and v_{max} = 300 km/h)
- Classic standard gauge railways (axle loads from 16 to 20 metric tonnes and v_{max}= 200 km/h)
- Industrial rail traffic (axle loads up to 35 to 45 metric tonnes)

The fields of application for light-rail systems include urban environments sensitive to airborne and structure borne-noise and urban areas heavily burdened by motor-vehicle and bus traffic. This version is applied for trams, underground railways and commuter trains with axle loads up to 16 tonnes and v_{max} up to 100 km/h.

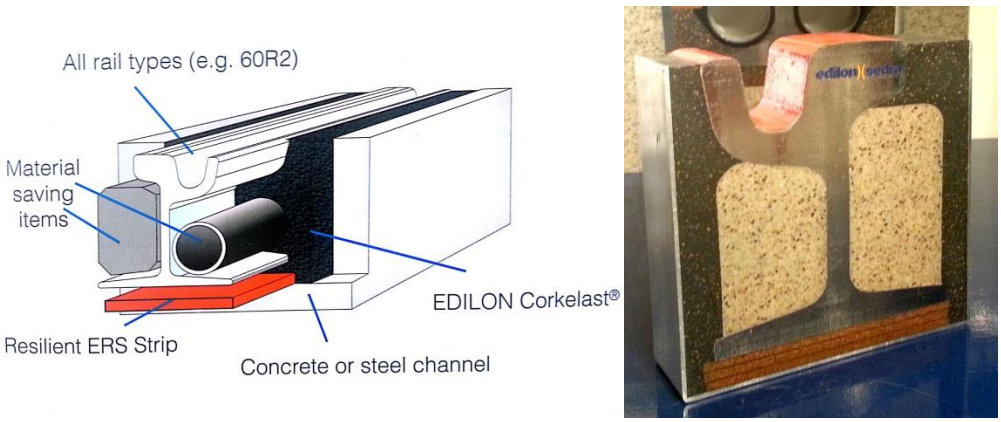


Figure 7: Embedded Rail System (ERS)

Embedded Block System (EBS)

The EBS is a system consisting of concrete slabs that contain the ERS principle. Instead of enclosure and bonding of the rail with the Corkelast, embedded blocks are precast reinforced concrete blocks which carry the individual rails supported by a railpad. The prefab concrete blocks are embedded with Corkelast in a tray and cast permanently into the slab track. This type of bonding also prevents the admission of liquids that may cause problems for traditional block systems.

Figure 8: Embedded Block System (EBS)

Sound Damping System (SDS)

The Sound Damping System is a cost-effective, electrical insulating, vibrating attenuation and airborne-noise reducing system for light rail applications. The filler blocks are made of 100% recyclable materials. Based on the elasticity, the SDS system can be adapted in order to accommodate.

Figure 9: Sound Damping System (SDS)

Direct Fastening System (DFS)

This system is suitable for many rail constructions such as open track, depots, switches, maintenance pits, station areas, tunnels and elevated structures. The rail track is supported by a rail pad and the base plate by a base plate pad. This ensures the elasticity in the system for the reduction of noise and vibration.


Figure 10: Direct Fastening System (DFS)

2.3.2 Products

There are many different products EdilonSedra produces. The products that are produced in-house can be categorized in four types (intranet synergy):

- Edilon)(sedra Corkelast
- Edilon)(sedra jointelast STP
- Edilon)(sedra Dex
- Edilon)(sedra Primer

There are also other products required to be able to install complete systems, which are not produced in-house. These products are outsourced to suppliers that are specialized and able to produce the requested trade good. These trade goods are:

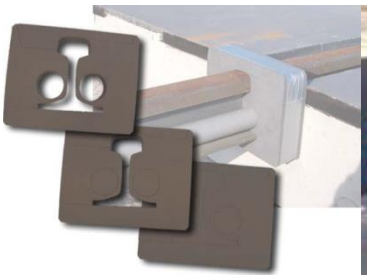
- Trackelast
- Edilon ERS End Seals
- Polymer Filler Blocks
- ERS Polymer (inclination) Shims
- ERS Polymer Wedges
- ERS Spacers

Polymer Shims

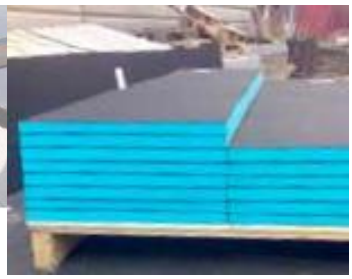
ERS Spacers

Polymer wedges

Polymer fillerblock



ERS End Seals



Trackelast

Corkelast & Jointelast STP

There are many different types of Corkelast, namely:

- VA-40, VA-40N
- VA-60, VA-60N
- VA-70
- VA-90
- M, M-85, M-95
- TO
- Sedrafer PU extra 15, Sedrafer PU extra 25
- STP-15, STP-25
- Editaan 70U

Basically all of the corkelasts are based on a 2 component polyurethane elastomer material for in situ pouring applications in civil engineering structures in general and specific rail constructions. The visco-elastic properties are designed for the absorption of dynamic loads. The product must therefore maintain its properties under cyclic loads in various climatic conditions.
The different numbers in the product names represent the hardness of that product.
Each type is developed for its specific application. The M-95 for example is especially developed for use in rail fastening systems for crane tracks where the axle loads are high compared to other type of track systems. The VA-40N is developed for use in rail fastening systems for light rail and trains. The difference between VA and the VA-(N) is that the “N”-type does not contain cork granulate and mineral fillers. The VA-60 and the VA-90 are developed for use in rail fastening systems for heavy rail, which means freight and passenger trains, including high speed. The following illustration shows how the Corkelast is being poured on-site.

Figure 11: Pouring of Corkelast in-situ

The STP is a new generation product and is not fully applied yet and should replace the VA-series eventually.

Dex

Several Dex products are produced by EdilonSedra BV just like the Corkelast and are used as adhesive materials for anchoring systems. The types are:

- Dex R 2K - Dex EA 2K - Dex R 2K
- Dex RH - Dex WR
- Dex G - Dex K 2K

The Dex R 2K is suitable for permanent and structural bonding of threaded bars and reinforcements in diamond drilled holes, water saturated drilled holes and hammer or pneumatic drilled holes. The EA 2K is for rapid bonding of structural anchors in concrete and is only suitable for dry drilled holes.
The RH is used for the bonding of steel, concrete, carbon-fiber-reinforced polymers (CFRP) and natural stone. It is extremely compression resistant and can be applied vertically or under moist conditions.
The WR stands for Wear Resistance and is often used in the offshore dredging and mining industries for repair of surfaces, which are heavily damaged by wear and tear, such as pipelines, impellers and screening plants. It is also used as a sacrificial wearing surface for dredgers.
The Dex G is developed for permanent grouting of dynamically loaded machine foundations. It is also used for perfect horizontal alignment and support of all types of structures. The Dex G is available in three types: Dex-G20, Dex-G40 and the Dex-G80. The numbers stand for the height that is to be poured. Other applications are for stress free anchoring of anchor bolts, threaded rods, the repair of concrete structures etc.
The Dex K 2K is used by railway organizations to repair collar screws and tie plates that are detached from the wooden railway sleepers. The Dex K 2K also increases the life expectancy of the full wooden sleeper. Dex R 2K is used by railway builders in order to permanently bond the fasteners to the concrete base.

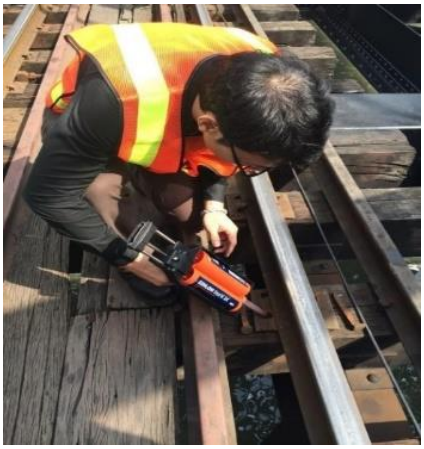


Figure 12: Application of Dex K2K

2.4 Inventory analysis

The previous paragraph shows the products and systems that are provided to the customers. To do so, EdilonSedra keeps stock to supply from. Inventory can be defined as “the raw materials, work-in-process goods and completely finished goods that are considered to be the portion of a business’s assets that are ready or will be ready for sale” (www.investopedia .com). Three types of inventory are kept, namely:

- Packing and raw materials
- Trade goods
- Finished goods

In the graph below, the stock value per product group is shown for the year 2014-2015. The stock values are expressed in cost price in euros. Per group, the cost price is determined at the beginning of each year and is determined differently. The cost price of packing and raw materials only consists of the purchase price while that of trade goods consists of the purchase price and a small surcharge to cover the general costs. This surcharge may vary between 10 and 20 percent. The cost price of finished goods includes the purchase price of packing and raw materials and a surcharge to cover the costs for manufacturing the required product. The surcharge on the cost price for finished goods varies and is dependent on the product.

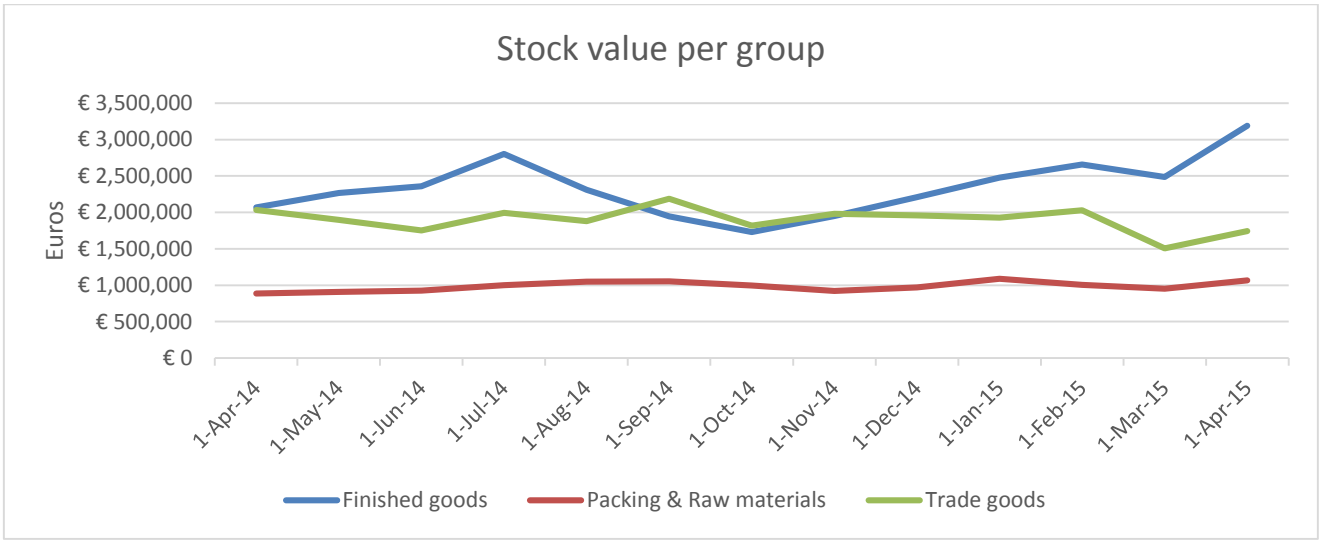


Figure 13: Stock value per group expressed in cost price

The stock value in the year 2014-2015 varied between 5 million and 6 million euros. In the figure can be seen that there was a steady stock value for the group “Packing & Raw materials”. Finished goods contain the highest stock value. Packing, raw materials and finished goods are directly related to each other because finished goods have to be manufactured with the required packing and raw materials.

These groups are stored in different warehouses. EdilonSedra has three main locations where the goods are stored, namely:

- MIG
- WIN
- MUG

MIG stands for Magazijn Ingaande Goederen. This corresponds to the warehouse in Haarlem where most of the packing and raw materials are stored for production. Samples of trade goods are stored here as well to be tested by the QC. This warehouse is owned by EdilonSedra.

WIN stands for the warehouse in Winschoten. This warehouse contains only packing and raw materials. The production facility in Winschoten does not have a QC department. The received raw materials are tested by the operators in Winschoten. Finished goods produced in Winschoten are still tested by the QC department in Haarlem.

MUG stands for Magazijn Uitgaande Goederen and is an external warehouse located in Amsterdam. This external warehouse belongs to the company CJ Hendriks group. All of the finished goods and trade goods are shipped from here to the desired location. Storing in this external warehouse is costly because space and service is hired. The price list of CJ Hendriks Group is shown in the appendix A and adjusts over certain time periods. Due to expansion of the market EdilonSedra decided to hire space at CJ Hendriks Group in 2012 to be able to store enough since the space in their own warehouse did not suffice.

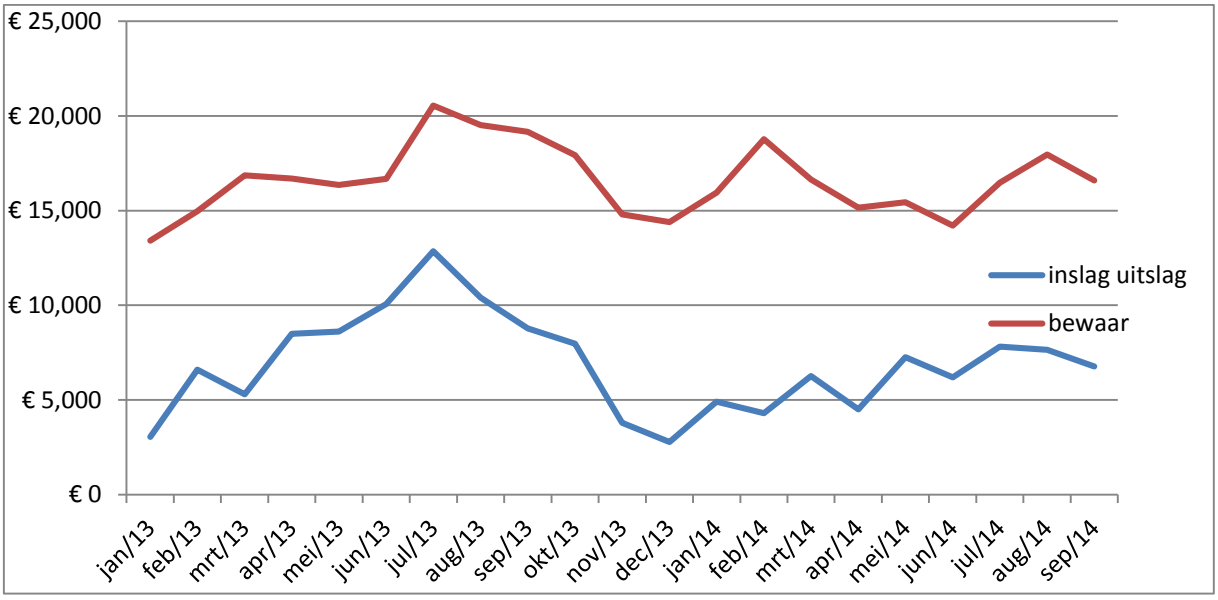
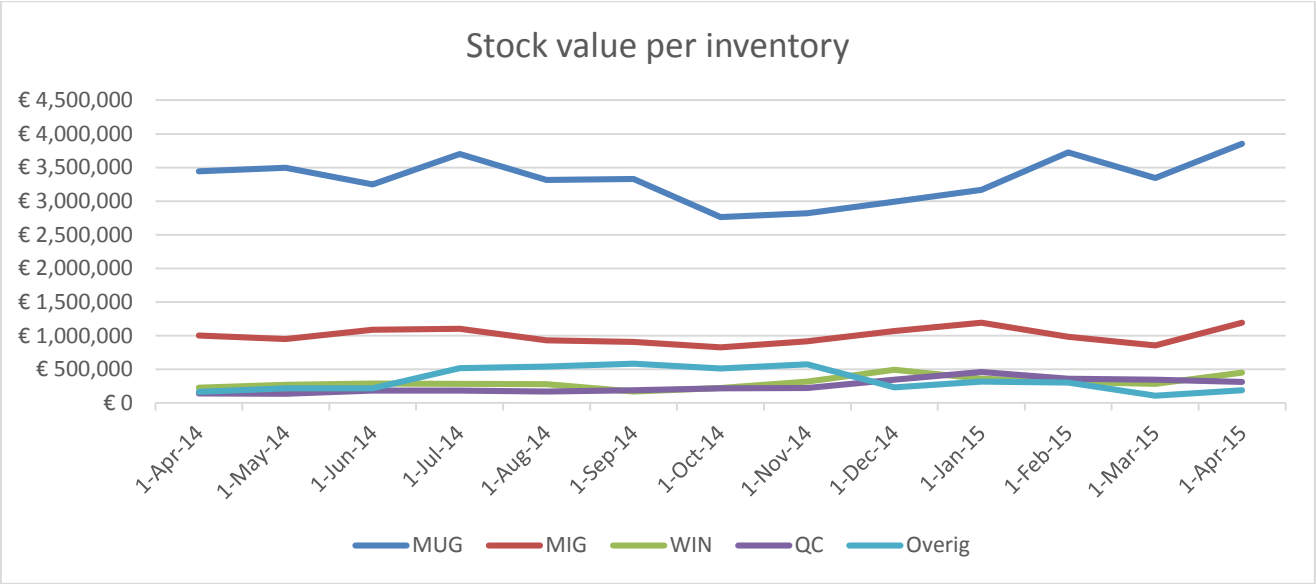


Figure 14: Service and storage costs of MUG 2013-2014

The figure shows the costs in the period of January 2013 to September 2014. The red line shows the storage costs of MUG. The blue line shows the service costs which consists of costs for stocking (inward), delivering (outward) and order picking. This resulted in 2013 in a total cost of € 289.953,31 and in 2014 (jan-sep) a cost of € 202.787,79.

In the graph below the stock value and the percentage is given per warehouse per month for the year 2014-2015.



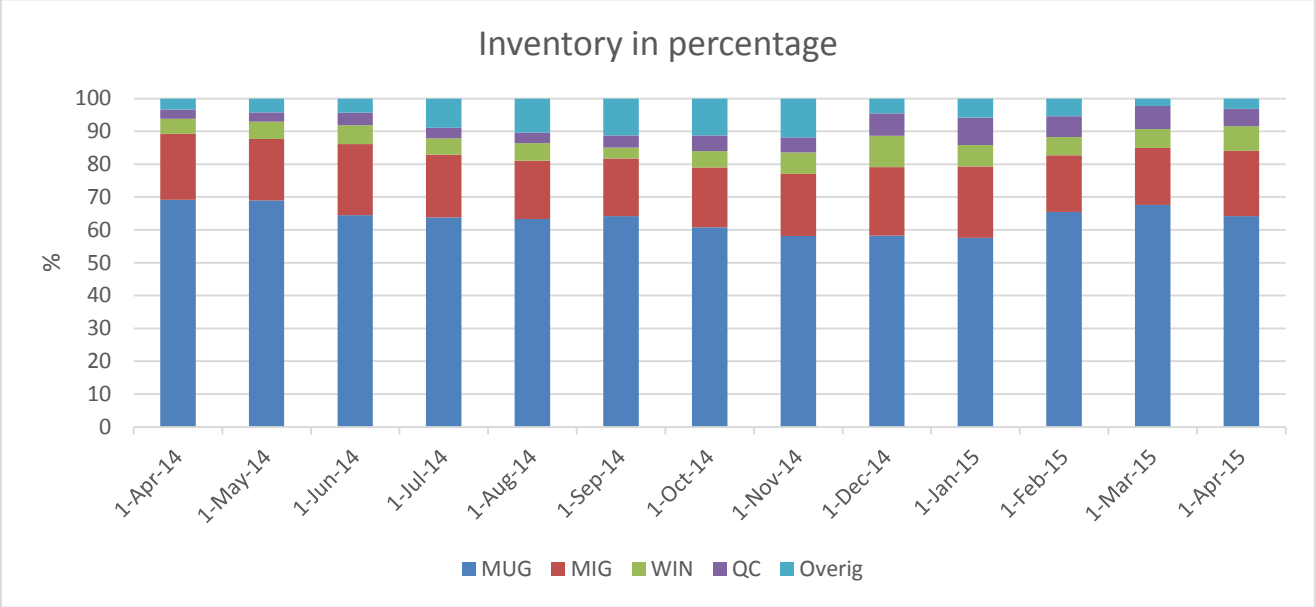


Figure 15: Inventory expressed in stock value and percentage

As can be seen in the graph, a category 'QC' and 'Overig' is present. QC is a virtual inventory that contains goods that still have to be tested and thus cannot be used for production or shipment to the customer. After approval, the product will be automatically allocated to the warehouse in the system where it is physically located. 'Overig' consists of the warehouses EXT and JPB. EXT stands for extern. This implies the storage of goods by a supplier and shipment from this location to the customer. JPB is an external warehouse where space is hired for raw materials that cannot be stored in the warehouse of Winschoten. Compared to the amount stored at Hendriks Group in Amsterdam, this is negligible.

It is noteworthy that more than 50% of the stock value was stored in MUG in the period of 2014-2015.

3. Process analysis

In this chapter the process analyses is done with the aid of the Delft Systems Approach (DSA)

3.1 The Blackbox

Before describing the processes of EdilonSedra, it is necessary to have a good overview of what EdilonSedra does. This is displayed with the aid of the blackbox shown below. The first step in DSA is defining a boundary between system and environment and the aspect flows (Veeke, Ottjes, & Lodewijks, 2008). This research does not include all logistic processes and is therefore demarcated to a part of it. This part includes the logistic processes in Haarlem, Winschoten and Amsterdam, leaving aside the processes that are not related to this topic.

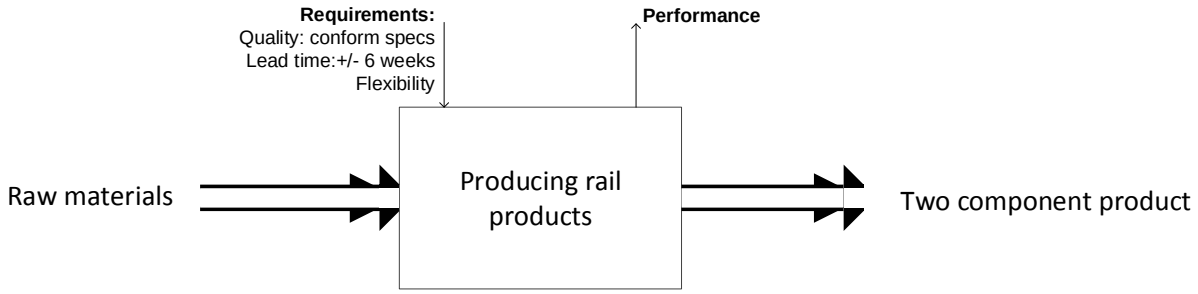


Figure 16: Blackbox model

The blackbox implies the system boundary. The aspect flow shows what goes into the system and what goes out of the system. The function of EdilonSedra is to provide customers with solutions and products for (specific) projects. Since engineering is not taken into account, the solution is not the output but the two component product is. Therefore, the black box model contains a transformation function which converts the input into the desired output (finished goods). The products manufactured by EdilonSedra consist of two components and form together a finished good for the installation of a new system or maintenance. In order to make these two component products, raw materials are needed. Therefore the input of the blackbox are raw materials.

Everything outside the system indicates the environment. The environment determines the requirements which are imposed on the blackbox and receives performance from it.
The thin arrows indicate these information flows. The requirements imposed on this system are:

- Quality: the products have to be produced conform the given quality specifications
- Lead time: from order to delivery. A standard lead time should be 6 weeks.
- Flexibility: this indicates that the system must be able to react quickly and supply on demand. This means that the lead time of 6 weeks may be overruled.

The outgoing information flow is the performance. This shows whether EdilonSedra was able to deliver what was requested, according the specifications, and on-time delivery which is not formally tracked.

3.2 Producing rail products

In the previous paragraph the black box model has been used to display a helicopter view of the company. In this paragraph this black box will be opened and zoomed into the processes within.

PROcess-PERformance model (PROPER)

When opening the blackbox, two aspect flows are made visible. The following figure depicts this zoomed-in model known as the PROPER-model.

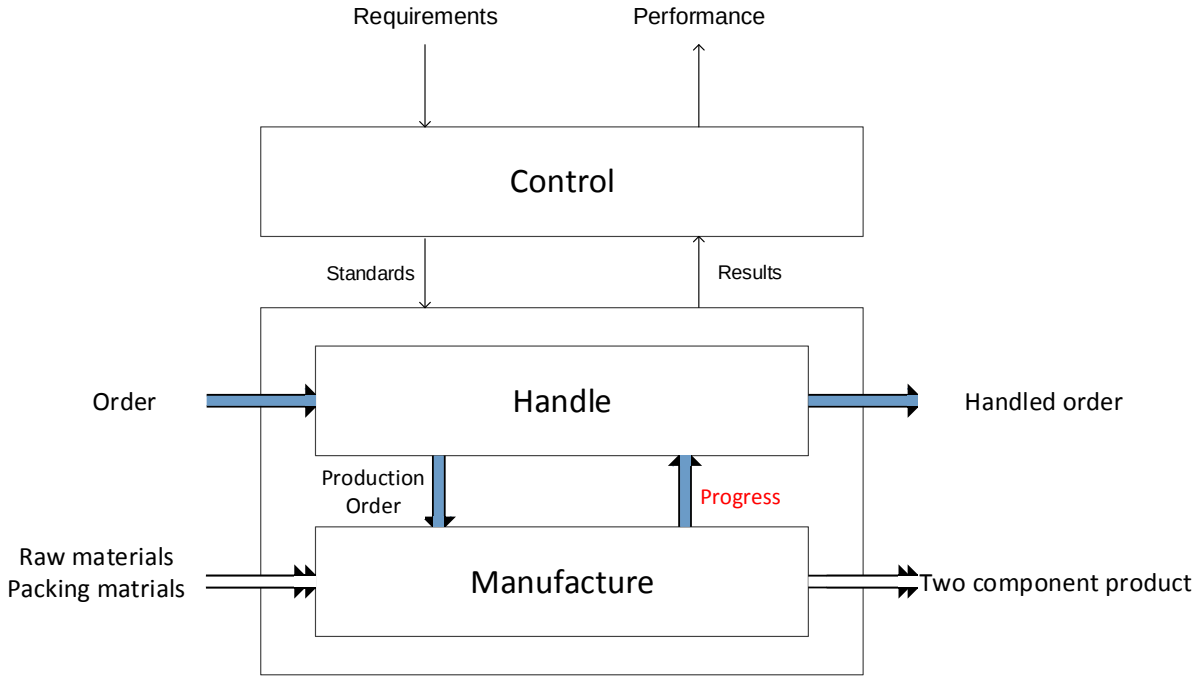


Figure 17: PROPER model

The two aspect flows represent the order flow and the material flow. The two functions within this model 'Handle' and Manufacture' have to be coordinated in order to have a controlled process. The control function converts the requirements into standards with the aim to coordinate the total process.

Based on the information shown in the MRP, a production order is planned and released to the production department for manufacturing the desired quantity. The coupling between these functions can be seen in the model.

3.3 Handle

In the order-handling function the incoming orders are processed into handled orders. Zooming into this function will show us the (sub)-functions to process the incoming orders. The figure below depicts these.

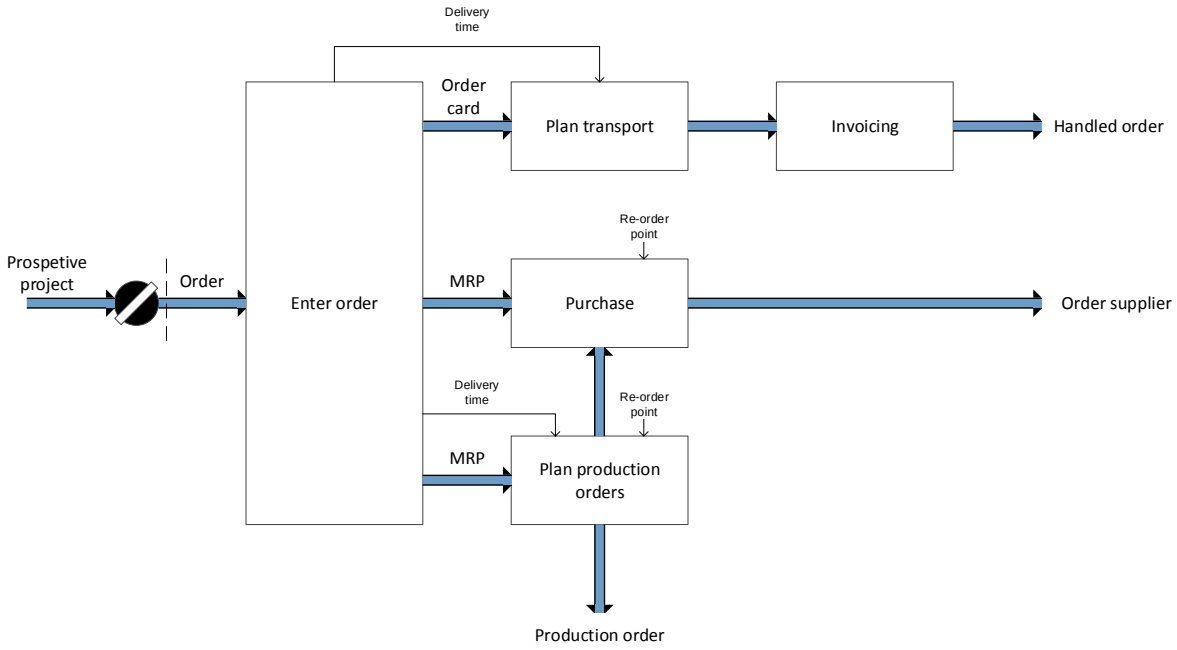


Figure 18: Handle function

Before the order enters the system, a project acquisition process takes place in order to win the project. This process will not be described in detail in this research since it falls out of the scope. Orders are derived from these projects. These orders may consist of partial deliveries, but falls under one order number. The figure above shows the necessary functions in order to handle the order.

In the function “enter order” the order is checked upon the feasibility and whether the required products are in stock. Dependent on when the product is needed by the customer the back office determines the delivery date. The delivery date is the date that the required product must be shipped from MUG to the desired location. When the demanded product is in stock and not reserved for another delivery, the order is entered and an order card is printed to pick the order. If not in stock, the back office communicates with the planning department to gain information about the possibilities. If it is not possible to deliver on time, the order is rejected. Otherwise, the order is entered to update the MRP.

After entering the order an order confirmation is sent to the customer. This confirmation handling is standard for orders above €5000,-. If below, a confirmation will be sent on request of the customer.

The number of incoming orders per month varies vastly. Below, the graph depicts the number of incoming orders in the year 2014-2015. An order may consist of one or more order-lines and the size of the orders may vary enormously.

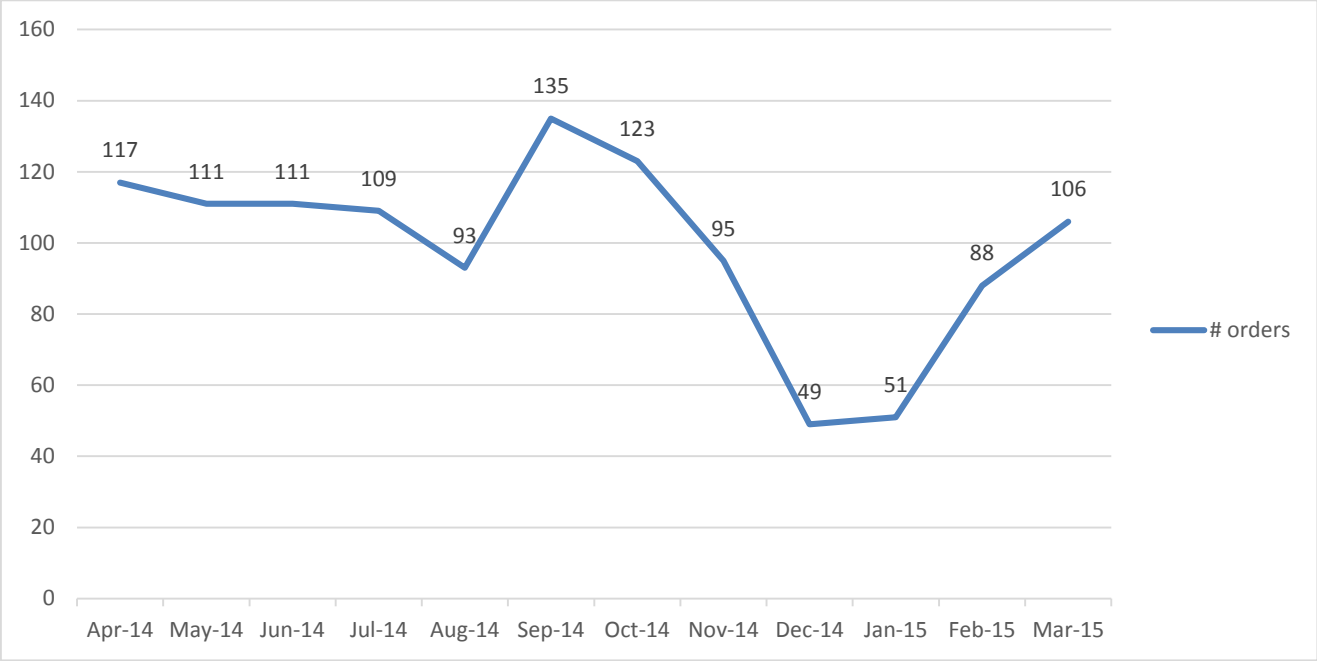


Figure 19: Number of incoming orders

3.3.1 Plan PO and purchase

The planning and the purchase department work on basis of the MRP. The MRP indicates when the stock should be replenished again. Therefore a re-order point (ROP) and maximum stock level (CAP) is known per item. On the basis of the colors in the MRP, one can see what is held in excess, sufficient, not-sufficient and not at all. Blue indicates that there is excess stock, thus more than the maximum value. Green is in the bandwidth of the re-order point and maximum. Yellow implies a stock point below the re-order point and red indicates that an item is required but is not in stock. The values in the MRP indicate the actual stock at the end of the day. Whenever an item is influenced, partly due to a production order or receipt or delivery, the new level of stock will be predicted by the MRP for that particular item for the end of that particular day. An example of the MRP schedule is shown below.

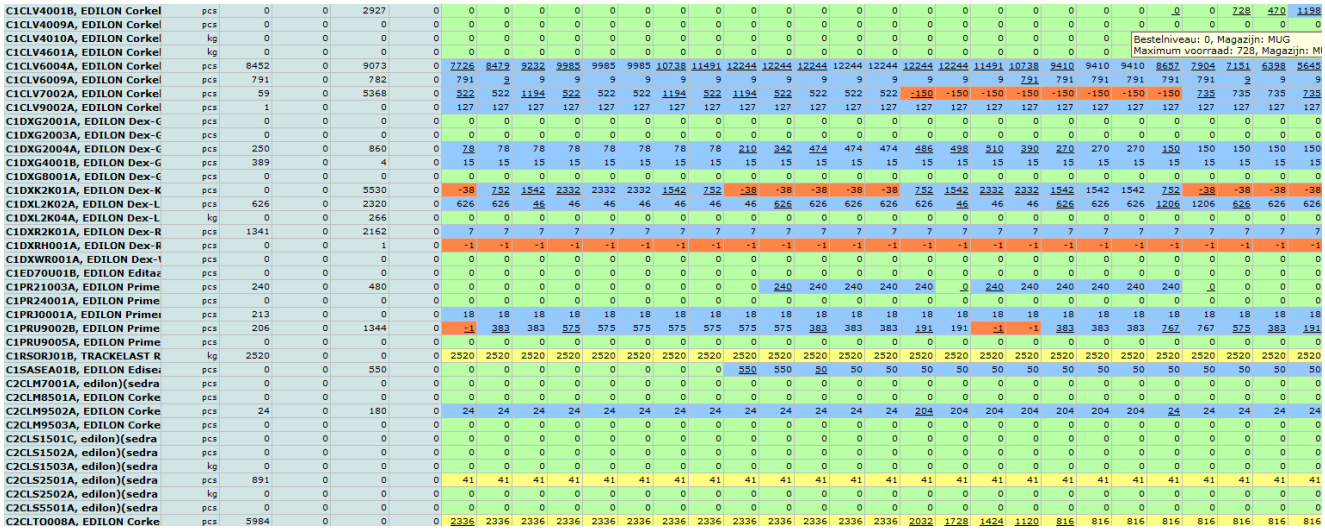


Figure 20: MRP

When purchasing an item, the purchaser takes the delivery time and the QC time into account. Each purchaser is entitled to buy up to €25.000,- per order. The approval of the manager is required whenever the purchaser needs to purchase an item that exceeds this value.

The method of placing an order differs per supplier. The activity of placing an order is mainly done by sending a purchase order by email, but some suppliers such as Shell and Bayer, require the ordering to be done online via their website. But before the order is placed, the purchaser puts the order in Exact Globe (ERP) so that the MRP will be updated.

The planning department uses the MRP to see which of the finished goods need to be replenished. The back office (sales) communicates to the planning department whenever a product is urgent so that the planning can give its attention to this item. Depending on the size of the order and the urgency, the back office may send a request to the planning department via mail, phone or verbally. The planning department schedules production orders based on what the MRP indicates and replies formally on the request from the back office. When the planner comes to the conclusion that it is not possible to deliver a product on the requested date, he discusses with the back office about the alternatives. The back office will then again turn to the customer about the possibilities concerning the determined alternatives. If replied negative by the customer, the order is rejected. When there is no communication, the planner relies on the MRP and plans the production orders based on the stock levels which are displayed by the MRP.

The stock level of finished goods deplete whenever the sales department puts a sales order in Exact. Based on this depletion, the planner may schedule production orders for replenishment. When the planner plans the production-orders, the planner takes the time of production and the time QC requires into account. Which means the time scheduled by the planner, that the finished good is ready in MUG, does not include the loading time for transport and time needed to pick an order in MUG.

When there is a change in an order, i.e postponement of an order or change in technical specifications etc, the back office communicates with the planning department to intervene in the planning process.

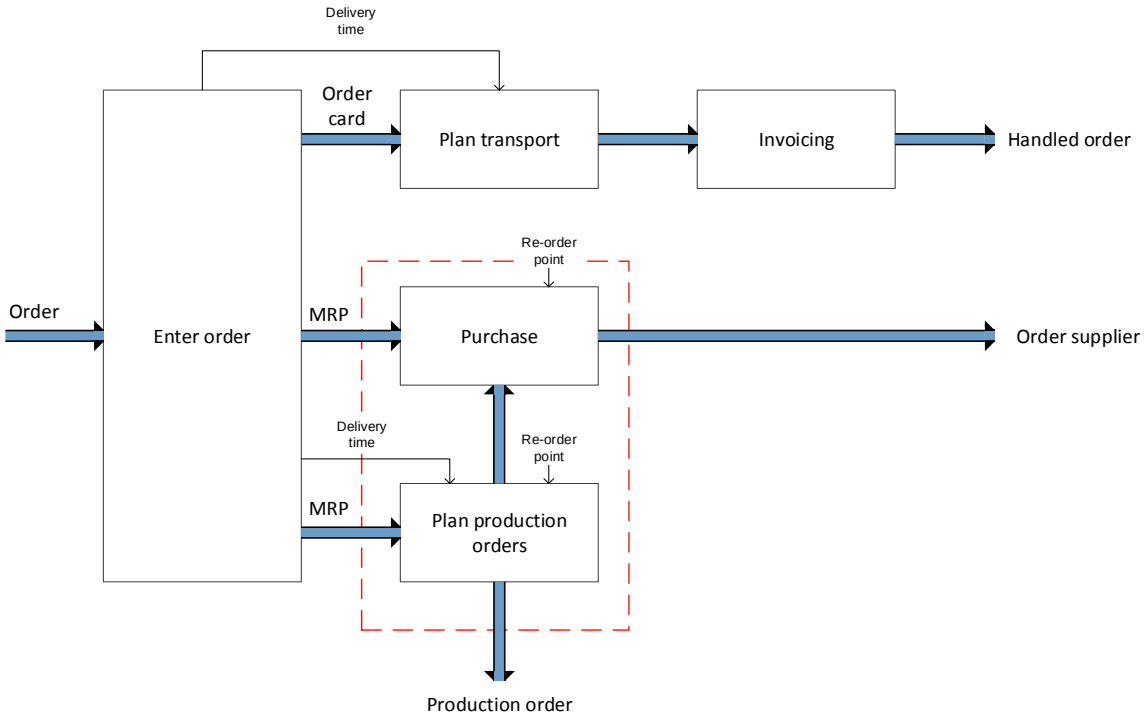


Figure 21: Purchase and planning process.

Bottlenecks

The purchase department is responsible for buying the resources needed for production and trade goods required to supply along with the requested finished good. The stock level is directly influenced by the purchase department since the purchase department determines the size of the purchase order. The procurement happens at the time one expects an item comes beneath the ordering level. The re-order points are based on gut feeling. These re-order points can be adjusted anytime by a purchaser. This adjustment is not being logged and therefore no evaluation for the benefits of past adjustments can be made.

Some raw materials that are not frequently used for production are kept in stock for a long period of time which costs space and money.

An order confirmation is not received when the purchase order is entered in the ERP. This implies that the MRP does not contain facts, but mere expectations. The inventory level of that item can be considered a fact after the receipt of the confirmation of the supplier. This confirmation process can

take up to a few days. This must be communicated with the planner for cases where the production order is planned on the day that the materials are received.

The lead times of products that are produced in Winschoten are larger than the lead time of products that are produced in Haarlem. This is due to the fact that the quality control of these produced products in Winschoten is done in Haarlem. The time of transport from Winschoten to Haarlem and acclimatization of the sample must be taken into account. This acclimatization is necessary in order to have the product at the right temperature. Only then a QC check can be done successfully.

Momentarily, postponed orders are kept in stock for the customers, without having any agreements concerning postponements with the customers. (postponed orders are not logged in the system as well).

3.3.2 Plan transport

The function 'plan transport' is parallel to the functions planning and purchasing. Based on the received information given on the order card the transport planner is able to plan the transport from MUG to the customer. This is done in consultation with the customer, sales, supplier and transporter, dependent on the size of the order. Subsequently, the freight costs are determined by contacting the transportation company in question whereby the order card is manually updated.

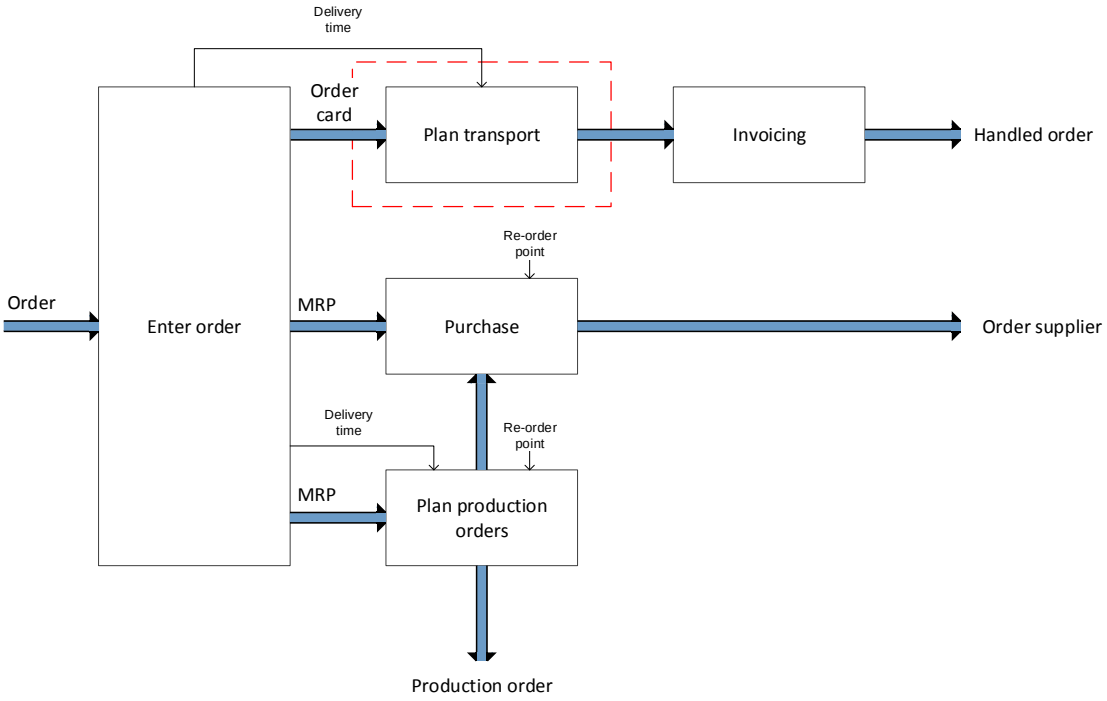


Figure 22: Transport planning

So far, the order cards are stored until the delivery date is near. The order is a day or few days earlier prepared in MUG, dependent on the destination and the volume of the order.

If an order is approved for transport, a pick list is printed and checked whether it matches the information given on the order card. The warehouse assistant in Haarlem allocates batch numbers to the pick list so that the external warehouse in MUG knows which batch to pick. In case of mixed pallets,

the items are not allocated to a batch number and are left to the external warehouse to pick. The warehouse assistant in Haarlem sends herewith a list with approved batch numbers. Thereupon, MUG sends a confirmation (pakbon) with the batches to be picked. The warehouse assistant in Haarlem compares the pakbon with the picklist and communicates with the external warehouse assistant in case of differences. If the order is picked and prepared and ready for shipment, a confirmation is sent to the warehouse assistant in Haarlem.

After the receipt of the confirmation from MUG, a delivery note is printed by the warehouse in Haarlem for invoicing and in Amsterdam for transport to the customer.

Bottleneck

In case of a discrepancy between the pick list and the order card, the transport planner gives feedback to the concerned party, so that a solution can be found in order to be able to deliver the requested items and products on time. In most cases, some of the items or products or both are still blocked in the system and must be released/unblocked by the QC. Blocked items or products cannot be prepared and delay of shipment is likely to be the consequence.

This is due to the fact that the delivery time, determined by the planning department, is based on the time of production and approval of QC. This implies that the planned delivery time displays the date the product is approved by the QC and must be ready for the start of the preparation for shipment in MUG. Due to lack of agreements between the planning department and transport department miscommunication takes place. Since preparing an order in MUG (picking orders and prepare shipment) can vary from a day to a few days, this must be taken into account. But the order picking process in MUG cannot take place when the items are blocked. The transport department sees the time the planning department has planned as the time that the item can be shipped, while the planning department plans the time when the item is released/unblocked in the system and thus ready for picking. As a result, a misunderstanding regularly occurs which directly affects the lead time.

Because EdilonSedra has no insight of where and how the items are stored in MUG, it is difficult for the warehouse assistants to allocate batch numbers to the picklist. This problem is particularly present for mix pallets.

3.3.3 Invoicing

In this sub function the delivery note and the order card are combined by an employee of the back office and checks whether the two contain corresponding information. If correct, a test invoice is printed. The test invoice is checked again and signed by an employee from the back office to handle the order. The payment is done between 30-60 days after installation.

3.4 Manufacture

The aspect flow for this function contains raw materials and packing materials whereby these two materials are transformed into the desired two component product.

When zooming in the functional content of ‘produce’, three sub functions are displayed. The required materials are needed to be able to start production for a specific order or replenishment of inventory. These materials have to be received and stored and in case of raw materials and trade goods also checked by the Quality Control. After production, the products are checked by the Quality Control which is necessary before releasing the end product to the customer. Figure 23 displays the content of the function ‘Manufacture’.

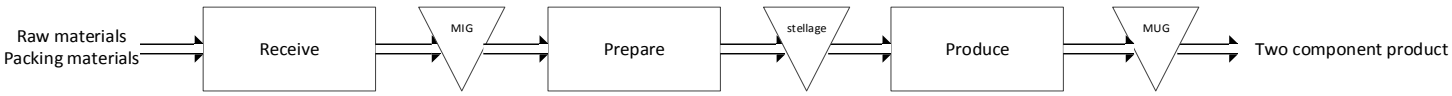


Figure 23: The three subfunctions within the function "Manufacture"

3.4.1 Receive

The first function in the manufacturing process is the receiving function. The figure below shows the detailed content of this sub function.

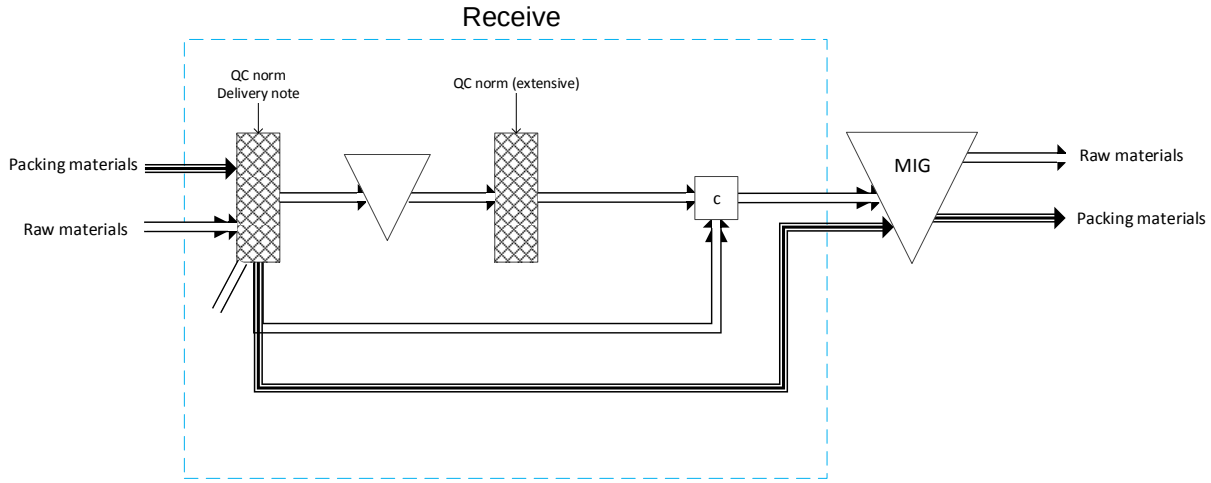


Figure 24: Subfunction "Receive"

At the beginning of this sub process the delivery of the packing materials and raw materials are received by the warehouse assistants. Some documents are included herewith, namely the freight document and sometimes the Certificate of Analysis (CoA) or Certificate of Conformity (CoC).

These documents contain technical information about the delivered products which is necessary for the QC in order to check and approve these products. The freight document contains information about the delivery and is used by the warehouse assistant to check whether the number of products that is delivered matches the number that is shown on this document. When this is the case the warehouse assistant confirms the delivery by initialing the status report. The purchase-order number

is then used for inputting the receipt in the ERP system. Until the QC has approved the materials, these materials are blocked in the system.

After receipt of the products, the QC examines the raw materials on chemical properties and tests trade goods upon its mechanical properties. Based on the results the QC can either approve or reject the tested materials. If the tested materials are approved, the QC releases (unblock) the materials in the ERP system and initials the status report.

Since there are two types of raw materials, the path that one walks differs in the process. There are powders and liquids. Powders are encoded after the QC approval and stored in MIG. During this encoding process, a batch number is allocated to the concerning raw material so that it can be used for production. Raw materials without a batch number are not allowed to be used for production.

Liquids are stored in different units. They are stored in IBC's, barrels and tanks. The tanks can store up to 21000 kilograms. These liquids are delivered by a tank-truck. For this reason QC tests a sample first before unloading it into a tank. When approved for unloading, the raw material can be filled in the tank and released in the system for production. This does not apply for the raw materials GROOD0018A and the GROOD0017A. After the first test, a second test has to be done for these two materials which may take 1 day up to 1 week. If then approved, a batch number is allocated in the system for this liquid and the QC worker initials the status report. Until then, operators are not allowed to use these liquids. Operators are only allowed to use raw materials that possess a batch number and are initialed by the QC on the status report, which means raw materials that are encoded (Unblocked) for the production process and thus ready to be processed.

Trade goods that are approved by the QC are transported to MUG and are not used for the production process, but will be delivered together with other products dependent on the customer's demands. Due to lack of space in Haarlem, a small number of raw materials are also stored in MUG. Samples of these raw materials are sent to Haarlem for testing.

Table 1: Lead time of the receiving function

raw materials	Time
GROOD0017A & GROOD0018A	1 week
Other raw materials	0-3 days
Liquids stored in tank	30 min

The table shows the time needed to approve the raw materials for production. Since the receiving function is direct, only the QC time is taken into account. As can be seen in the table, the lead time of the sub function 'receive' can vary between 30 minutes and 1 week, dependent on the raw material.

Bottleneck

Some suppliers do not deliver the CoA/CoC along with the item on time. Without these documents the QC cannot check the received materials. This may delay the start of the planned production and therefore can have a direct effect on the lead time.

3.4.2 Prepare

Before producing the required product, work preparation is done so that the production can go smoothly. The work preparation is done one to two days before the start of the production. The figure below shows the content of this sub function.

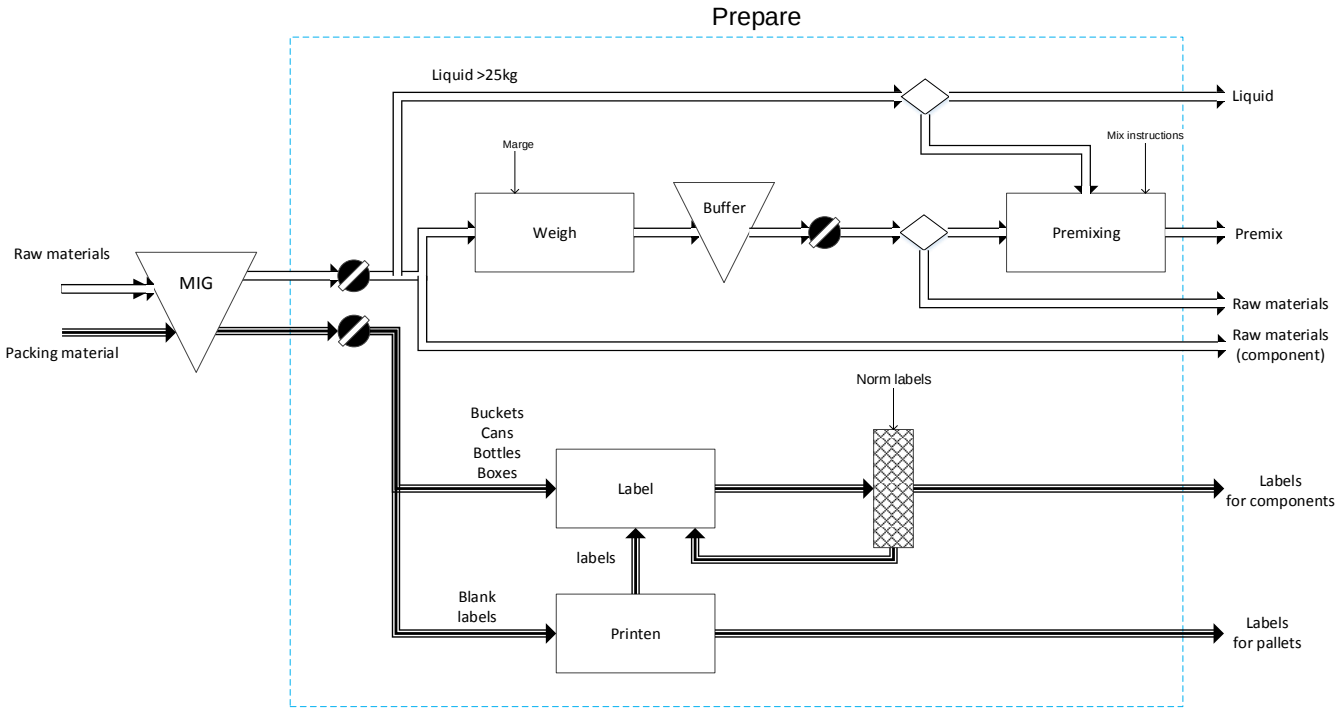


Figure 25: Subfunction "Prepare"

On the basis of a production order a preparer prepares raw materials and packing materials for the production of a component or only raw materials for a premix. The preparation is mostly done one day before it is used for mixing (premix or main product). The production order shows the required resources for the preparation of materials and production of a component. The production order for preparation shows the formats and the number needed of the packing materials. Packing materials consist of buckets, tins, bottles, boxes and blank labels. The labels are printed according to the required design and are labeled on the packing material which is needed for that production order. The labeled packing materials are checked by the work supervisor. The work supervisor checks if the labels contain the correct information and if it is neatly pasted. If the work supervisor does not approve, the packing material should be relabeled. When approved, the work supervisor initials the status report and can be used for the tapping process. Dependent on the label, pasting of the labels on the packing materials can be done manually or by machine. When the work preparer prepared the packing materials, he will mark the production order blue in the upper left corner.

Basically, there are two preparers. One for preparing packing materials and one for preparing raw materials. On the basis of the production order, the preparer of raw materials takes an appropriate amount of powders with the corresponding approved batch number displayed on the production order. These powders come in bags and are collected on pallets. Next to powders, the preparer also collects liquids. These liquids are only prepared if the amount shown in the production order is below 25 kilograms. The work preparer taps the indicated amount in tins and stores it together with the

powders in a buffer. Thereby placing a sign with the corresponding production number and name of the component for what it is prepared for. Liquids that exceed 25 kilograms in a production order are not prepared. This will be directly tapped in the mixer by the operator during the production process. If the preparation is completed, the work preparer marks the production order yellow in the upper right corner so that operators know that materials are collected for that production order. These completed prepared production orders are then stored until the day of production.

Operators allocated to a production order may find this document marked with blue and yellow. In this case the operators know that the production order is fully prepared and can smoothly start the production process. If there was only a preparation of raw materials, the production order is only marked yellow in the upper right corner. This implies that the operators have to prepare and label the packing materials by themselves. Afterwards, the work supervisor checks whether the labels contain the correct batch numbers, expiring date and whether it is neatly pasted.

The preparation of packing materials can thus be done parallel to the preparation of raw materials or parallel to the production of a component. For the ease of modeling, this is placed in the sub function 'prepare'.

Throughput
Due to the dependency of the number of production orders planned, the throughput time of the sub function 'prepare' may vary between 0 PO's/day and 10 PO's/day. The idle time of the prepared production order in the intermediate buffer is mainly 1 day. This implies that the prepared raw materials are to be used for production, which is planned for the day after preparation.

Bottleneck
When preparing the labels, the operators have to print the labels with the correct print. At the start of this print process, some blank labels are thrown away as well as wrong printed labels. These labels are not amortized and thus result in an incorrect inventory value.

3.4.3 Produce

The subsequent function of 'prepare' is 'produce'. As shown in the previous chapter, different products are produced at the Manufacturing plants in Haarlem and Winschoten.

Because of the diversity of products, different raw materials are needed in order to produce the required product. Therefore the production facility is divided in different sections which can be identified as a jobshop-type of production. The production floor consists of 5 Nautamixers, 2 wall mixers and 3 dissolvers in which the raw materials are mixed. Three Nautamixers, with the volumes 6000 liters, 4500 liters and 1800 liters, are used to produce Corkelast. The 1800 liters Nautamenger is mainly used for the production of M-95 and the 4500 and the 6000 liters are used for the production of VA-40, VA-60, VA-70 and the VA-90. Two smaller Nautamixers, are used to produce the Dex-RH and the Dex-WR (each product allocated to a specific mixer). Three dissolvers are used to produce batches of other products like the U90WB, Dex R2k etc. The wall mixer is mainly used by the operators to produce pre-mixes for the Corkelasts and to produce color paste, Dex-G series and the corresponding component for some Primers. Due to this jobshop-type of production, the products can be produced parallel to each other.

After the materials have been prepared, which is completed day(s) earlier, the production is able to start. The operators pick up the document for which they are scheduled and pick up the prepared raw materials and packing materials. This document consists of the production-order, mixing instructions, tap- and packing instructions and the status report. The packing material may be labeled or still needs to be labeled by the (assistant) operator as mentioned before.

The operator starts the production by filling the Nautamixer or dissolver with the prepared raw materials (liquid, premix and powders) in a specific order that is indicated by the instruction manual. During the mixing process, a sample is taken from the batch to be approved by the QC. At the end of the mixing process, two samples of the batch are sent to the QC for inspection. The first sample is checked upon viscosity, reactivity and the chemical composition by means of the FTR and the second sample is used to combine with the corresponding component to check the hardness after 24 hours. If the first sample is not approved, the batch has to keep on mixing until the batch is approved by the QC. If the first sample is approved, the operator may start tapping the batch into the packing material and the QC worker initials the status report. The approval of the second sample is necessary to release (decode/unblock) the end product in Exact, which makes it possible to send this to the customer.

In case the mixing takes place in a Nautamixer, the batch will be directly tapped from the Nautamixer. If produced in a dissolver, the batch will be tapped from a big metal tub. In the tap instruction manual a norm is set which indicates how many kilos (with a margin) is allowed to tap in the packing material. Whether the operator is filling according to this norm is also checked by the work supervisor and initials the status report in case of approval.

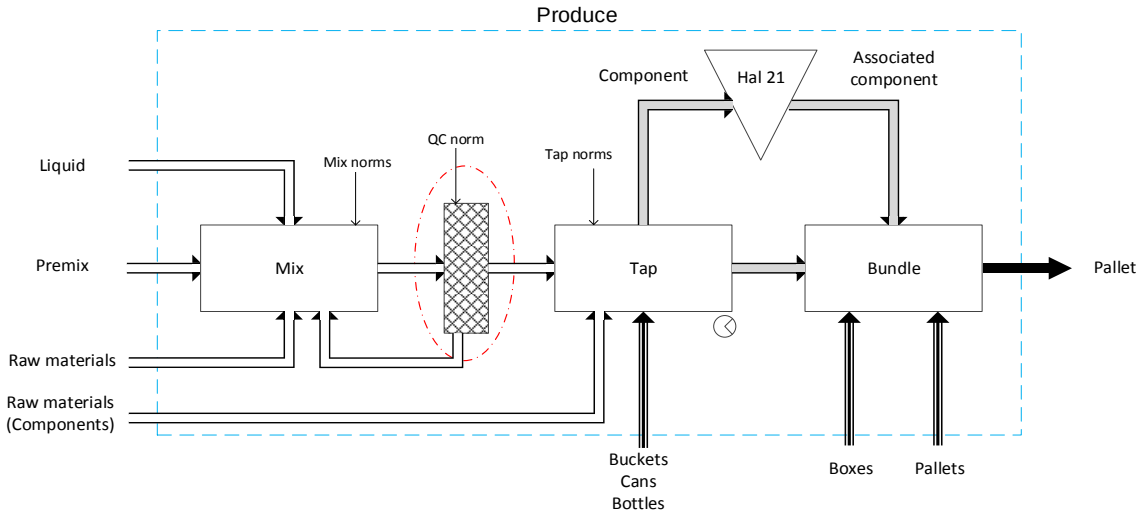


Figure 26: Subfunction "Produce"

After the tapping process, the component will be combined with the associated component which is produced earlier. The components can be combined in two ways:

1. Combining pallets (each pallet contains 1 component)
2. Combining components in one box

In case (2) the operator combines the two components in boxes (with a user manual) and places these boxes on a pallet which will be retrieved by the warehouse assistants.

Dependent on the product, the pallets retrieved may contain one or two components. The batch number of the components and the VP code (combination of the two components consisting of serienr.C1/serienr.C2) are imported in Exact Globe and are automatically blocked, until the QC gives approval and releases it.

One unit of component 1 goes with one unit of component 2 during installation, the same amount of component 1 and 2 are placed on a pallet.

After combining two pallets or retrieving a pallet with combined components in boxes, the pallets will be wrapped in a film. The wrapped pallet will then be labeled containing the name of the product and the batch numbers of both components. The completed pallet is then stored in MIG. Whenever a sufficient amount of pallets are available in MIG, an inter-branch transport will take place to MUG which occurs mostly the same day or the day after the completion of production.

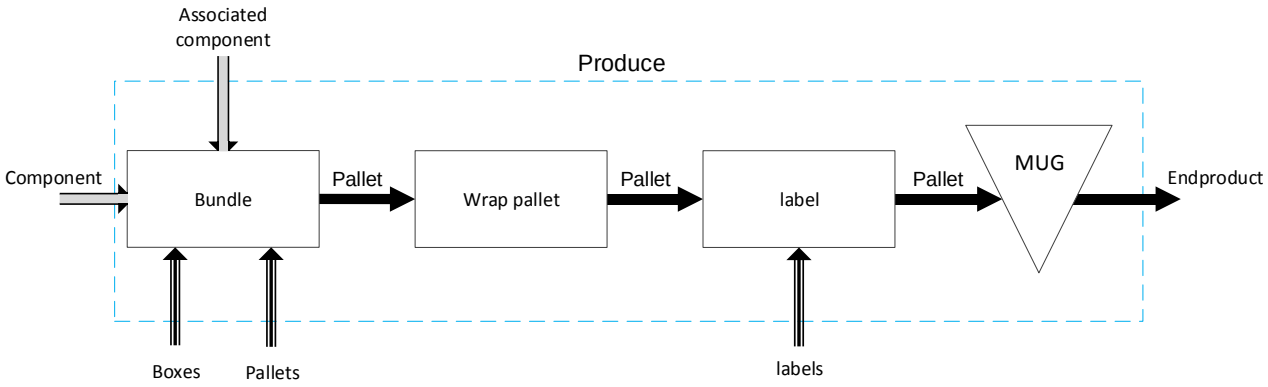


Figure 27: Subfunction "Produce" (bundle and wrapping process)

Table 2: Lead time batch of 'produce'

Subfunctions	Time in hrs
Mixing	0,5 to 15
QC (sample batch during mixing)	0,5
Tap	1 to 16
bundle	0 to 12
wrap+label	1
QC (end inspection)	72 to 240

The times shown in the table are not fixed. This is due to the fact that each product and batch size has its own mixing time. On average, one can assume that a batch can be produced in 1 or 2 days.

Output:
Average 20-30 pallets per day (transported the same day or the next morning to MUG)
Peak periods: 60 pallets

Bottleneck
When the QC cannot complete their quality tests in time, no feedback is given to the planning department. With no feedback to the planning department about the delay, the planning department

cannot intervene. Since a delay of the QC affects the lead time directly, the agreed and planned delivery date cannot be met.
The capacity of the QC department is limited. The throughput time of the QC varies between 72 hours (3 days) and 360 hours (15 days), dependent on the product. Corkelast VA-60, Corkelast TO and the STP take 10 days to test. Other corkelasts, Dex series and the primers need 72 hours for testing.

4. Problem analysis

In the previous chapter the order- and manufacture process is analyzed. Several observations are done with regard to waste.

4.1 Background issues

In this paragraph a few remarks are given about the background issues. These issues contribute to the observed problems.

Unpredictable demand

The unpredictable demand makes the forecast of the expecting incoming orders difficult. The market demand is very dynamic and varies per region. For an inventory-controlled company as EdilonSedra, makes the alignment of the processes with the unpredictable demand problematic.

Diversity of products

Due to the large diversity of products that EdilonSedra can provide, stock is kept in order to react quickly on demand. This makes the production and logistic process complex.

Communication

Each department feels responsible for its own process. There is a lack of communication between departments with the consequence that the joint interest is subordinate to own interest.

4.2 Problem definition

The observations of the previous chapter show that there are different aspects that are directly related to the observed problem.

The initial problem is as follows:

- *How can edilon)(sedra justify the stock levels per product group and reduce inventory in order to reduce working capital without compromising the lead time?*

This problem stems from the fact that there are many items held in stock, which equals to stagnant money plus storage and service costs which cannot be used for other investments. The main reasons of keeping stock are due to the uncertainty of incoming orders, the delivery time of suppliers and the response time.

The finding of the problem is based on the MRP and a formula used by EdilonSedra. This formula determines the allowable stock. Whenever the total stock value exceeds that of the formula, it will be considered as excess. The formula is as follows:

AS = ∑(ROP* 2) + 0.75 * CS + VPO

- *AS = allowable stock*
- *ROP = re-order point in VVP per item* (VVP = Vaste Verreken Prijs, overhead costs included)
- *CS = Cost price Sales next month*
- *VPO = value postponed*

The factor 2, which is multiplied with the ROP, is a theoretical assumption. This represents the maximum minimum stock of the items. The factor 0.75 indicates the delivery time within 3 weeks of the finished goods in the following month. VPO represents the value of postponed items.

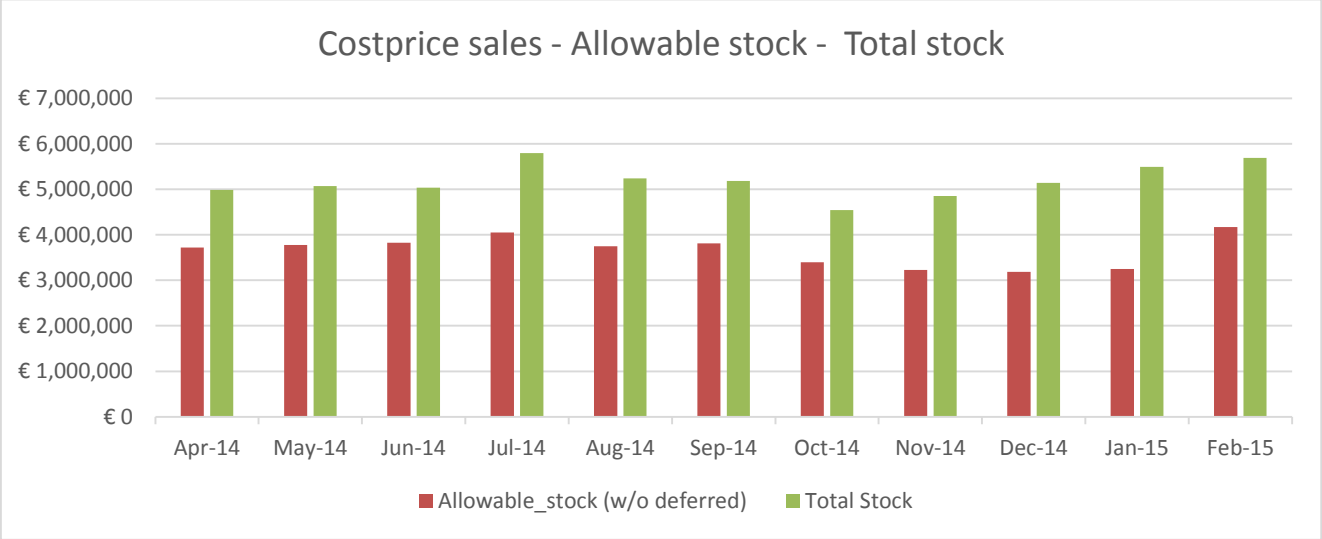


Figure 28: Allowable vs. Total stock

This graph is based on the formula. The postponed orders, which has already been purchased, produced and stored for, are not included in this graph because these have not been tracked. Therefore, the factor *VPO* is not taken into account in the allowable stock. In the graph can be seen that in the year of 2014-2015 the total stock exceeded the allowable stock. The difference can be seen in the figure below and shows that the difference varied between €1200000,- and €2250000,-.

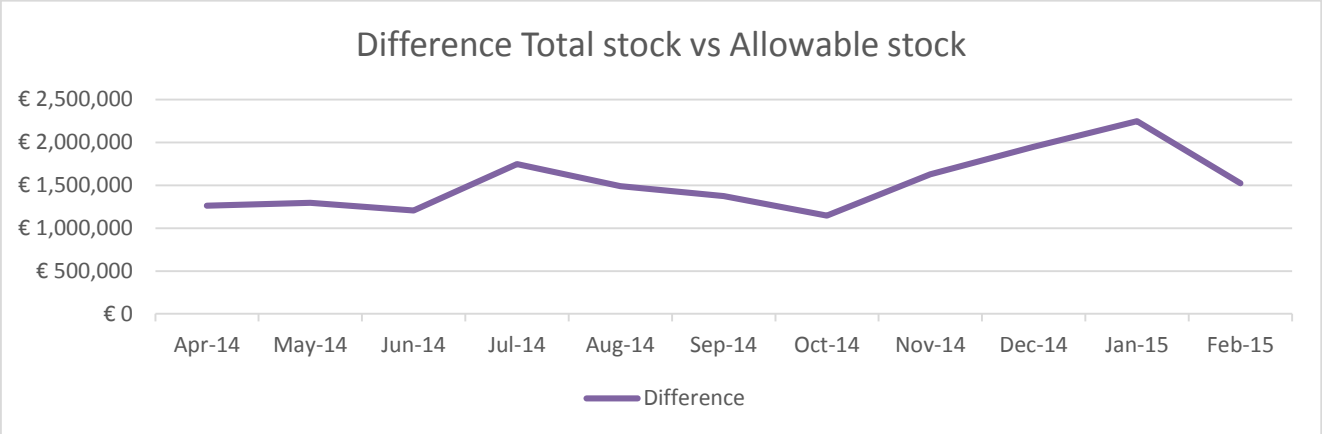


Figure 29: Difference allowable and total stock

The average of the stock values, in the year 2014-2015, of the finished goods, raw materials and packing materials are €2272242,39 and €757905,20 and €221568,74 respectively. The average of the total stock value is €5165401,32. This corresponds to 15% for raw materials, 4% packing materials and 44% finished goods. The remaining 37% is categorized under trade goods. Trade goods are not taken into account in this research and are thus excluded.

Table 3: Mean values of the item groups in the year apr 2014- mar 2015 expressed in terms of cost price

Item group	MUG	MIG	Other	Total mean	Percentage
Finished goods	€1618206,41	€206327,06	€447708,93	€2272242,39	44%
Raw materials	€97221,94	€505276,2	€155407,02	€757905,20	15%
Packing materials	€31256,58	€161685,15	€28627,01	€221568,74	4%
Trade goods (other)	€1531964,78	€113213,72	€268506,50	€1913684,99	37%
Total				€5165401,32	100%

As can be derived from the table, 63% of the total stock value resides in finished goods, raw materials and packing materials. These item groups can be divided in different categories.

The total cost price Sales in the year 2014-2015 equals to €13334296,73. Thus we see that the total average of the stock value of €5165401,32 is equal to 39% of the total cost price Sales. This ratio is not based on the turnover due to the differences in sales margin by type of customer (ICP & third party) which would make the ratio not representative. Hence the cost price Sales is used.

The finished goods and raw materials can be categorized in different types. In appendix you can find the table that shows these types and the corresponding stock values for the year 2014-2015.

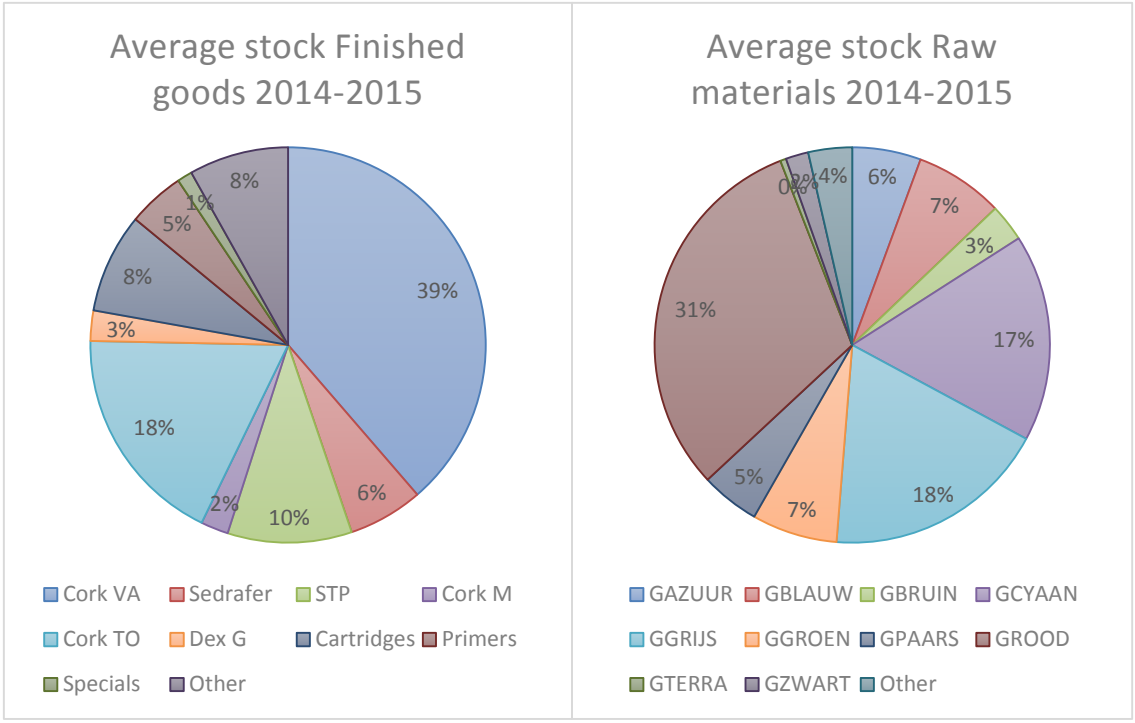


Figure 30: Average stock of finished goods and raw materials in percentages

The two pie diagrams represent the stock value percentages per item type within the item groups finished goods and raw materials. More than 50% of the stored stock values of finished goods reside in the item types Cork VA and Cork TO. This is due to the high demand for these product groups with respect to the other products. 66% of the stored stock values of raw materials reside in the item types GROOD, GCYAAN and GGRIJS which are mainly used in the Corkelasts.

The total number of different raw materials is 105. For packing materials this number amounts to 106. Not all of the items contain a reorder point. The items without a reorder point are purchased on order. 78 types of raw materials and 73 types of packing materials contain a reorder level. Of these numbers of raw materials and packing materials, 71% and 79% know a low purchasing activity (≤ 3 times/year) respectively, which indicates long idle times of these materials (slow movers).

Also, there are no direct KPIs available concerning the (internal) service level of EdilonSedra towards the (internal) customer, idle times of raw materials and finished goods, the postponed orders, the behavior of the incoming materials and the outgoing finished goods, rush orders and inventory turnover ratio.

Two samples (fast movers) are taken, one raw material (GGRIJS0017A) and one finished good (VA-60), to find the average idle times within the inventories of MIG and MUG, respectively. The determination of the average idle times of GGRIJS0017A and VA-60 are therefore done manually as an example. Below, the tables of these two items can be found.

Table 4: WIP of GGRIJS0017A (samples) in year 2014-2015. The time is expressed in days (MIG)

Batch GGRIJS0017A	6425	1414	7428	6404	3420	12429	9303	6325	Mean	St. dev.
Usage time	46	59	27	28	9	24	92	12	34	28
Delivery time	10	10	10	10	10	10	10	10	10	0
Idle time	11	64	19	19	14	33	38	23	26	16
Total time batch in process	57	123	46	47	23	57	130	35	60	40
Batch size in kgs	12k	10k	12k	12k	10k	12k	10k	10k	11k	

Table 5: WIP of VA-60 (samples) in year 2014-2015. The time is expressed in days (MUG)

Batch VA-60	816212/ 04	816218/ 19	816811/ 12	818487/ 88	818546/ 47	819085/ 86	Mean
Idle time in MUG (days)	14 to 25	16	12 to 76	16	16 to 43	27 to 84	19 to 38

The incoming materials and outgoing finished goods go according the FIFO principle. The usage time implies the used time to consume the whole batch of the raw material. The idle time indicates the time between the receipt of the raw material and the moment the raw material is used for a production order. The total time batch in process shows the time the batch of GGRIJS0017A resides in the process (usage time + idle time), which means from receipt of the batch until it is completely consumed. In the table of VA-60 an average of 19 to 38 days is given due to partial deliveries and in some cases postponement of orders.

The process analysis in the previous chapter shows per sub function where the bottlenecks are found. The purchasing order has a direct influence on the stock level of MIG. Whenever the MRP shows that a raw material or packing material falls below the re-order point, the purchaser will place an order to make sure there will be enough for production. The size of the purchase is mainly based on the

replenishment to the indicated maximum whereas other costs are not considered. Adjustments of the re-order points can be made without logging these adjustments. This makes evaluation of past adjustments impossible.

The capacity of the QC department is limited. The throughput time of the QC varies between 72 hours (3 days) and 360 hours (15 days), dependent on the product. Corkelast VA-60, Corkelast TO and the STP take 15 days to test. Other Corkelasts, Dex series and the primers need 3 days for testing.
The lead time is high due to the QC time needed to approve the products which has a direct impact on the inventory.

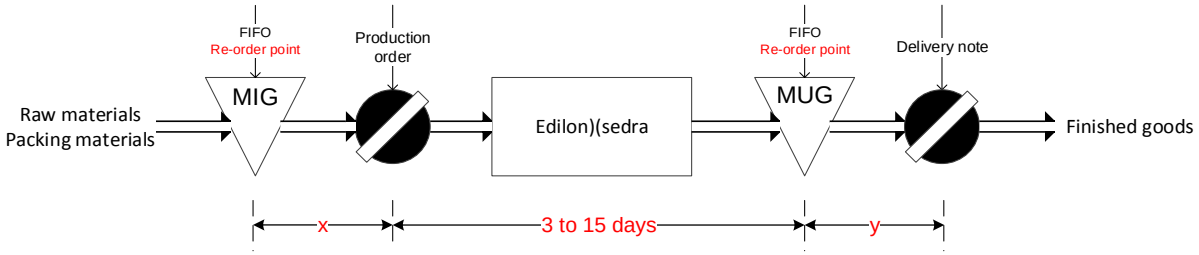


Figure 31: DSA model of the production and the warehouses

Due to lack of KPI's there is no overview of the performance of the inventory control obtainable. The arrival rate and the rate of delivery are not known, including the idle times of the materials in the warehouses MIG and MUG. The re-order levels are not based on theoretical calculations and are based on gut feeling and experience.

Conclusion and research target
The issues to be addressed concern the determination of the KPI's needed in order to be able to evaluate and obtain performance. The safety stock, economic order quantity or lot size of raw materials as well of the finished goods must be determined.

All this leads to the following research target:

Design of inventory control to determine the right order sizes, relevant KPIs and SLA which should lead to a reduction of 10 % of the working capital.

5. Determining Key Performance indicators and Service Level Agreement

As indicated above, there is lack of inventory management. Because KPIs are missing, performance of the inventory control and process cannot be monitored. As a result, it is not possible to evaluate whereby continuous improvement cannot be achieved. KPIs should therefore be considered as vital navigational instruments used by managers to understand whether the company is on course or not. One of the most important aspects of KPIs is that they are a form of communication (Sari, 2015). Below we see the DSA model including the inventory control functions and information flows. This is explained further in chapter 8.

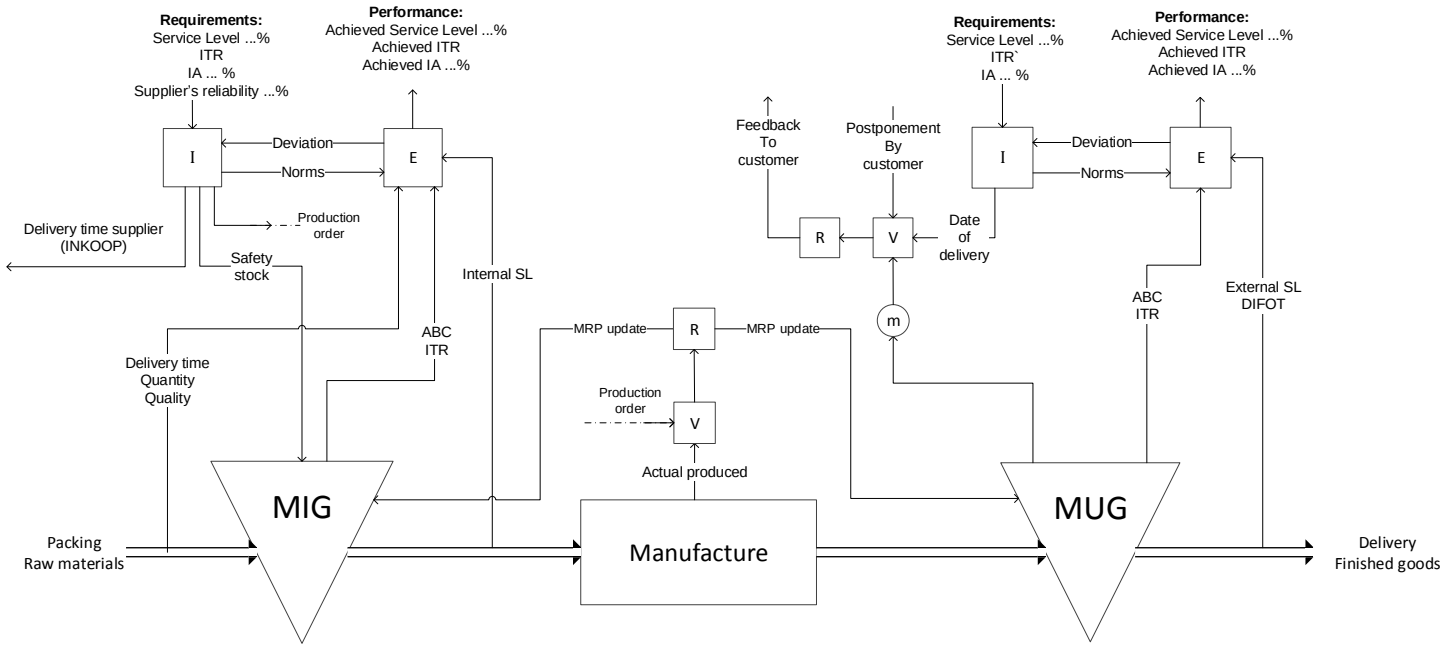


Figure 32: DSA model of the warehouses MIG and MUG and the function Manufacture including the control functions

The KPIs should be (Simon, 2014):

1) Comparative
2) Both snapshot and directional
3) Address both leading and lagging indicators

A quantifiable metric should not only reflect a certain reading or calculation but also some sort of comparison against a goal. Some KPIs are inherently backward looking and some describe how a particular metric is doing, known as lagging and leading indicators respectively. Lagging indicators are measured against a goal but nothing can be done about it and thus only the performance can be seen, while leading indicators can be measured against a target and can be acted upon whenever below target.

By making use of KPIs it is possible to continuously manage and improve the inventory. The following KPIs are described below:

- *Inventory Turnover Ratio (ITR)*
- *Service Level (SL) and Delivery In Full on Time Rate (DIFOT):* how often a stock out relative to production orders, number of times hitting out of stock, registration of number of "no" sale, number of backorders.
- *Supplier's reliability*
- *Inventory accuracy*

In order to determine the right KPIs, the SMART (**S**pecific, **M**easurable, **A**chievable, **R**elevant, **T**ime bound) principle must be adhered to the objectives that we want to achieve. Therefore, the use of KPIs must ensure the improvement of inventory management and thereby achieve the required performance to the customer and organization.

5.1 Inventory Turnover Ratio

This shows how effectively the inventory is managed by comparing cost of goods sold (COGS) with the average inventory for a certain period (usually a year). It measures how many times inventory is turned or sold during the defined period. The total turnover depends on two main components, namely purchasing of stock and sales. If large amounts of stock are purchased, the company will have to sell greater amounts of inventory to improve its turnover. For this purpose, the purchasing, production and sales departments must harmonize.

- Objective: the inventory turnover must increase relative to the ratio of last year.
- Target: an increase of the ratio by 1.
- KPI: COGS divide by AAVI

Low inventory turnover is commonly associated with excess inventory, overstocking and presence of dead inventory. Low inventory turnover leads to increased pressure on working capital. Conversely, high inventory turnover indicates a high selling rate.

One can see whether a business has an excessive inventory investment compared to its sales level. The inventory turnover can be calculated with a simple formula:

$$ITR = \frac{Cost\ of\ goods\ sold\ (COGS)}{Average\ Aggregate\ Value\ Inventory\ (AAVI)}$$

Where

$$AAVI = \sum(avg\ inventory\ for\ product\ i) * (unit\ value\ of\ product\ i)$$

$$COGS\ is\ only\ for\ finished\ goods, valued\ at\ \boldsymbol{cost\ price}\ and\ not\ sales\ price$$

Using the data mentioned before we can fill in the formula for the period 2014-2015:

$$ITR = \frac{€13334296,73}{€5165401,32} = 2{,}58\ turns$$

If the stock turnover can be increased without affecting customer service the costs will decrease. Thus, Inventory turnover is a useful measure of performance (Waters, 1995).

5.2 Service Level

The inventory service level generally can be described as the expected probability not to hit a stock out (Beers, n.d.). It can also be described as the probability to serve client demand to keep customers satisfied. Therefore, the service level at EdilonSedra must be based on the *DIFOT ratio (Delivered In-Full, On-Time)*, the number of *backorders* and the number of *no-sales* versus the total number of incoming orders. Naturally, we want to guarantee a service level of 100%, but is usually not a feasible option. This would mean that (theoretically) an infinite stock must be held.

DIFOT measures whether the demanded product was delivered, with the corresponding documents, in the quantity ordered by the customer at the time which EdilonSedra and the customer agreed upon. This is therefore directly related to the service level.

Service level can be calculated by:

$$Service\ level\ (\%) = \frac{Number\ of\ DIFOT}{Total\ number\ of\ incoming\ orders}$$

Normally, a backorder means that a customer order cannot be fulfilled when presented, for which the customer is prepared to wait for some time. For EdilonSedra this is not the case since most of the time the delivery date is discussed with the planning department. Therefore at EdilonSedra a backorder is defined as an order, which has already been planned for, being postponed due to an internal disturbance.

The service level is only relevant in cases of uncertain demand; otherwise it is a matter of good planning.

- *Objective:* the service level should increase or at least remain equal relative to the service level achieved last year, which can be measured by dividing the number on-time completed orders with the total number of orders. This increase in service level will enhance customer satisfaction and therefore a greater market share can be obtained. This performance must be achieved at the end of the year.
- *Target:* obtaining a service level of at least 90%
- *KPI:* number of on-time completed orders divided by total number of orders

5.3 Supplier's reliability

The supplier's reliability is very important in choosing the most reliable supplier to work with. This rating consists of five parts, namely *On-Time Delivery (OTD)* of packing and raw materials, the supplier's *delivery time*, *Quality*, *Quantity* and *Price.*
Based on this rating a decision must be made whether to (still) do business or to change supplier.

- *Objective:* the supplier's reliability should at least be 98% or higher and must remain consistent in every order delivered.
- *Target:* reliability ratio of at least 0,98
- *KPI:* number of completed purchase orders divided by the total number of purchase orders.

5.4 Inventory Accuracy

The inventory data should correspond to what is physically on stock.

- Objective: The inventory accuracy must increase or at least remain equal with the accuracy achieved last year.
- Target: inventory accuracy of at least 95%
- KPI: difference between data in system and reality expressed as a percentage.

Data of poor quality may result in poor KPI results which in turn may lead to poor decision making (Gendron, 2015). In order to have real-time inventory, automation is necessary. Since this investment is not considered, another method must be used in order to check the accuracy. Cycle counting is a counting procedure where the stock is compared manually with what is in the system (Associates, n.d.). The cycle counting should be done on the basis of the ABC analysis which is discussed in paragraph 7.1.

Cycle counting procedure:

1) Complete data entry on all inventory transactions, so the inventory database is fully updated
2) Print a cycle counting report, which states the locations that are to be counted, and assign it to the warehouse staff
3) The cycle counters compare the locations, descriptions, and quantities stated on the report to what they see on the shelf.
4) Investigate all differences found and discuss them with the manager, and determine whether there is a pattern of errors that may require further action.
5) If further action is required, alter procedures, training, staffing or whatever else is needed to eliminate the error.
6) Adjust the inventory record database to remove the error found by the cycle counter.
7) On a regular basis, audit the inventory and calculate the inventory accuracy percentage.

Another cause for stock discrepancies can be related to the planned production order and the actual manufactured quantity. As long as the quantity produced matches the quantity stated in the production order, there will not be a significant difference between the physical and the virtual inventory. At moments when there are strong deviations, it is important to have these production orders concluded in the system quickly in order to maintain a high inventory accuracy.

5.5 Service Level Agreement

A service level agreement is the type of agreement that sets out arrangements between the provider and consumer of a product. The agreements made in the SLA between the BV and the Group is mainly about the lead time of an order, which is set to a lead time of 6 weeks whereby a delivery is guaranteed and postponement of orders by the customer. This is because the main customer of the BV is EdilonSedra Group. The SLA can be viewed in Appendix G.

6. Postponed orders

Just after the production of a batch of a finished good, it is transported to and stored in MUG until ready for shipment. Since MUG is an external warehouse, space is hired at a price per pallet. The prices can be found in appendix A. Until recently, postponement of orders have never been registered. This implies that EdilonSedra kept stock for the customer without any specified agreements concerning holding stock. The customer is able to postpone any order without compensation for the extra costs (holding cost, interest and re-inspection) that are involved with it, due to lack of specific agreements in contract management concerning postponement of orders. These extra costs that come with the postponement directly reduce the gross profit margin and increase working capital.
Currently (29-9-2015) a total cost price of 1,12 million euros of postponed orders is being held in stock, which exists approximately of €630.000,- of finished goods and €490.000,- of trade goods for six projects. Below we find the table with the project, quantity and value stored of products for which the delivery is postponed (the quantities of trade goods are left out).

Table 6: Postponed projects with the associated finished goods and raw materials

Project	Product	Finished goods		Postponed	Value
		[kg/pcs]	[SKU]	[months]	[€]
Piraeus	Primer 24	1.032 kg	8,6	>6 months	€ 10.036,-
Krakow-Rondo Mogilskie	Editaan70U	2.080 kg	2,7	>4 months	€ 43.760,-
UTE Trancia Ouargla	SEDRAFER PU EXTRA 15' Primer JS Raw materials purchased	3.920 kg 1.265 kg several	8,9 2,6	>9 months	€ 79.633,-
Dockwise	Corklst M-70	854 kg	2	>12 months	€ 4.172,-
Riyadh	Corklst VA-60 Corklst VA-90 Primer U90WB	35.000 kg 20.160 kg 1.964 kg	66,3 42 6,8	>4 months	€ 279.535,-
Al Haramain - KAEC	Corklst VA-60 Primer U90WB Dex-G 20	37.956 kg 651 kg 1.100 kg	72 2,2 3,7	>1 month	€ 212.523,-
Total			**217,8**		**€ 629.659,-**

For the postponement of orders an agreement must be made with the customers. If products are stored longer than 2 weeks after the shipment date, the customer must compensate for these costs in order to reduce working capital. These costs consist of the holding cost, interest rate and (possible) re-inspection costs. The interest rate and holding cost for the postponed orders is determined by the Finance Manager and is set to a value of 0,25% and 0,20% of the selling price per month, respectively. In total this would mean 0,45% of the selling price per month to cover the interest and holding cost.

7. Inventory control

7.1 ABC-analysis

In order to have a good overview of the finished goods, an inventory categorization method is used, known as the ABC-analysis. This analysis divides the finished goods in three categories A, B and C. The ABC-analysis is based on the principle that a limited number of products available allow for a large portion of revenue, and there are a large number of products, which has limited contribution (P. Durlinger & Consultancy, 2013).

The finished goods categorized in A have the highest annual consumption value or revenue. The top 80% of the revenue of the company is achieved by only 14% of the finished goods (total number of 49), which is categorized in A. Category C, on the contrary, represents the goods with the lowest revenue. The vast majority of the goods (69%) are categorized in C with the lowest value of only 5% of the total revenue. The goods categorized in B are considered interclass with a medium revenue value which represents the remaining 15% of the total revenue. This accounts for 16% of the total number of finished goods.

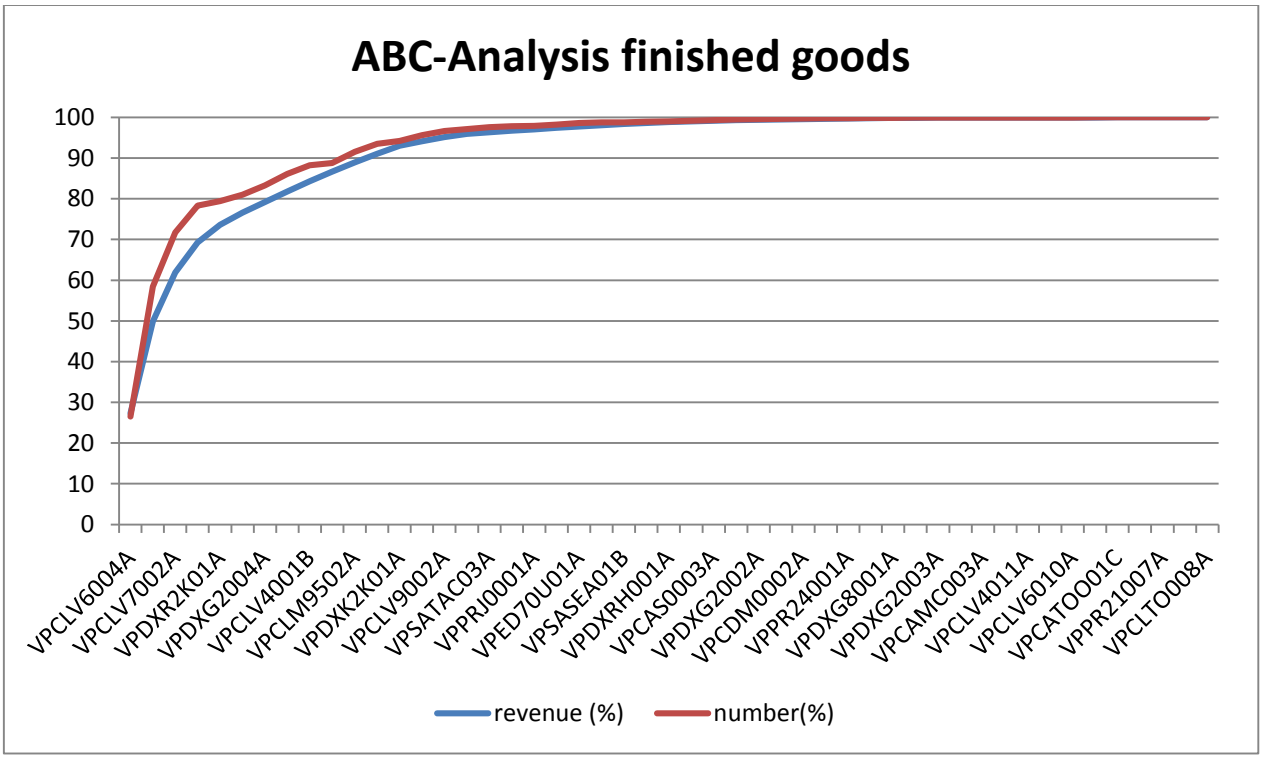


Figure 33: ABC - analysis of finished goods

Based on this analysis we can see what the most profitable products are. The seven products responsible for 80% of the total revenue are:

- Corkelast VA-60 (27%)
- Corkelast TO (23%)
- Corkelast VA-70 (12%)
- STP-25 (7%)
- Dex R2k (4%)

- Primer U90WB (3%)
- Dex G-20 (3%)

On the basis of the determined service level by the MT and demand (forecast), the safety stock can be determined. This is due to the irregular demand for the end products. The safety stock is therefore intended for those products that are of interest. Other products, which provide only 5% of the total turnover, must be re-evaluated to determine whether these products need to be held in stock at all. In addition, on the basis of these data, the lot size and the ROP can be determined per raw material what should lead to an improved and responsible inventory.

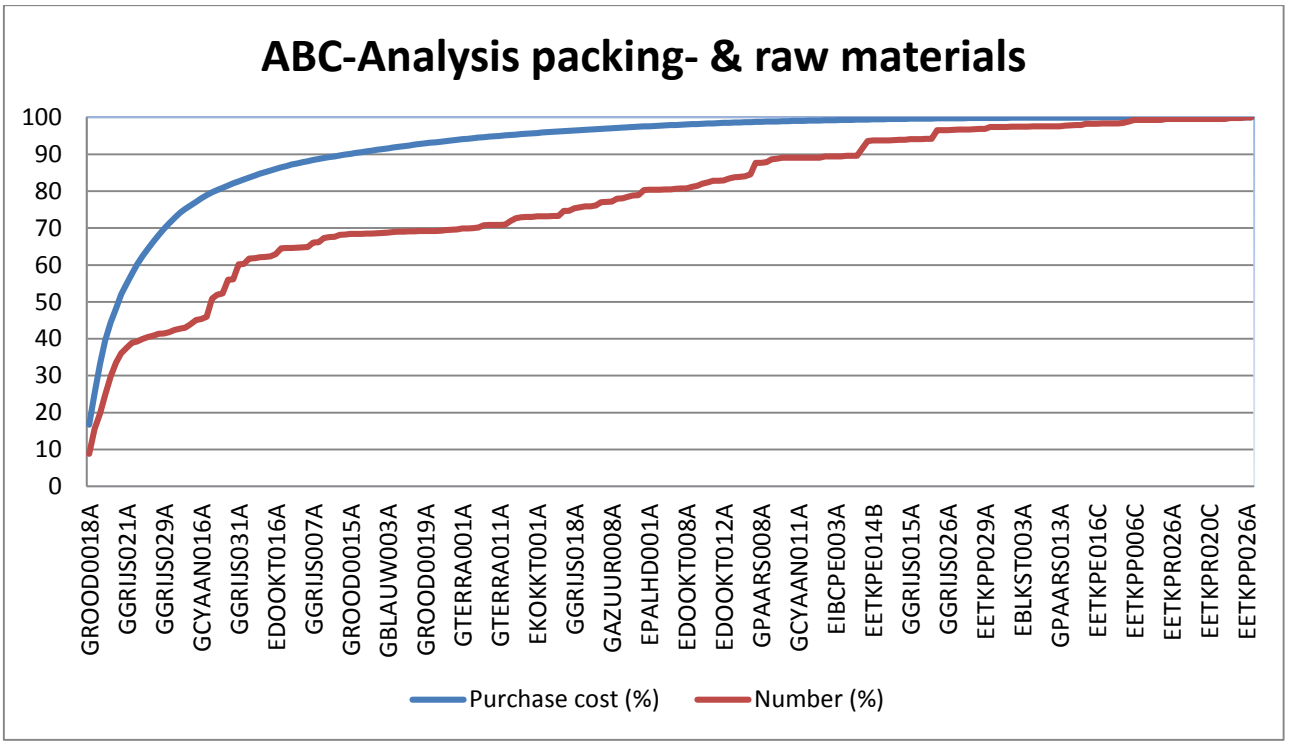


Figure 34: ABC - analysis of packing and raw materials

In the graph above we see the ABC-analysis for packing and raw materials. The blue line represents the purchase costs relative to total purchase cost and the red line the amount used relative to the total number of items. As the graph indicates, 70% of the purchase cost of the packing and raw materials are categorized in A. These A-items are mainly used for production of the A-products which corresponds to the ABC-analysis of finished goods. The B-items represent 25% of the purchase cost and the remaining 5% are the C-items.

The ABC-analysis gives an overview of the items and finished goods which are relevant for production and sales. Based on this analysis, the items and finished goods can be assessed individually. We want to pay most attention to A-products and the associated raw materials, because this category is the most profitable.

7.2 Order methods

As mentioned before, procurement of packing and raw materials is basically done on intuition. Since the purchasing department determines the moment of procurement and the quantity of the order (BS-model), it has a direct impact on the stock level in MIG and thus indirectly on the working capital. For

the determination of lot size and order frequency, the demand downstream and delivery time of the supplier must be considered.

It is evident that products with a regular or predictable demand pattern are easier to control then products with an irregular and unpredictable demand pattern. In the literature can be found when the demand pattern can be judged as regular with the formula of the *variation coefficient* (Silver, Pyke, & Peterson, 1998):

$$VC = \frac{\sigma}{\mu}$$

whereby $\sigma = standarddeviation\ of\ demand$

$\mu = average\ demand$

If the demand is known over a certain period of time, the average and standard deviation can be determined. According to literature a demand may be considered regular if the variation coefficient is smaller than 0,45 which has been demonstrated by means of a simulation.

Knowing this, the demand of every single product should be determined. The sales department is responsible for the delivery of the forecast of demand and the planning department is responsible for entering production orders in the ERP (which translates it to the demand for packing and raw materials in the MRP). Since the sales department does not provide any detailed forecasts for any finished good, the planner must plan production orders based on entered sales orders only. Due to lack of forecast, decisions have to be made on basis of the in the ERP entered sales orders.

Before applying any lot-sizing method, the carrying cost and order cost must be ascertained which are necessary for these lot-sizing methods, since the intention of these methods is to minimize these costs to reduce working capital.

7.2.1 Carrying cost

These are the costs we incur to hold stock in a warehouse. The costs of the external warehouse MUG are used (Appendix A). The fee payed per month to store a pallet is equal to €7,- (for harmless products) and €12,- (for hazardous products). This is calculated from the date of entry until end of the month and then recalculated for the dwelling stock from the first of the following month. For example, if the date of entry is the end of the month and the delivery takes place in the following month then two times the storage fee (€7,- or €12,-) is payed per pallet.

7.2.2 Order cost

The order cost is associated with the costs that incur when an order takes place. The order cost exists of three components:

1) The wage bill of the purchasing department
2) Entry cost
3) Costs of Quality Control for incoming goods

For the wage bill the year salary (€40.000,-) is taken into account of one purchaser since only one purchaser is responsible for ordering packing and raw materials. The order activities per item that have taken place in recent years are known. With that information, the total average of order activities per year is calculated and equals to 590 (221 for packing and 369 for raw materials).

By dividing the year salary by the total average of orders placed per year, the cost per purchase can be determined, which is:

$$purchasing\ cost = \frac{Year\ salary\ purchaser}{Total\ average\ of\ order\ activities} = \frac{€40.000}{590} = €67{,}85/order$$

The entry cost is related to the cost needed to store the incoming goods in MIG. Therefore the cost per hour per involved warehouse employee is taken into account. The time required for stocking incoming goods is assumed to be 0,75 hours. With a total hourly wage of €17,50 the entry cost per order is therefore equal to €13,13.

All incoming raw materials are tested by the QC and therefore this cost must be included in the order cost. The QC takes a sample of every incoming batch and requires 10 minutes to test a batch on average. The hourly wage of the QC equals to €45,- thus the QC cost equals to €7,50 per batch. It is rare for an order to consist of more than one batch, therefore it is assumed that every order consists of one batch. Note: the cost of the QC for packing materials can be left out since these are not tested. Transport costs are left out since the suppliers deliver the materials franco.

By summing up these costs the total order cost equals to €88,48. Now that these data are known, different lot-sizing methods can be applied on historical data. The historical data of five raw materials were used for this analysis. The lot-sizing methods applied are known as the *Economic Order Quantity* ***(EOQ)****, Silver-Meal* ***(SM)****, Least Unit Cost* ***(LUC)*** *and Part Period Balancing* ***(PPB)****.* This single item, discrete, lot-sizing problem determines procurement when the discrete demand over the planning horizon is known (Ir. P. Durlinger, 2012).

7.2.3 EOQ

The choice of a lot-sizing method depends strongly on the demand pattern. The EOQ-method can only be applied when the demand pattern is regular, which means a variation coefficient (VC) below the value of 0,45. The idea of this method, as well as the other heuristic lot-sizing methods, is to minimize the total cost which includes the storage cost and order cost. The formula used for the EOQ is as follows:

$$\mathrm{EOQ} = \sqrt{\frac{2\mathrm{DF}}{\mathrm{Ph}}}$$

Whereby
$Q = Economic\ Order\ Quantity$
$D = yearly\ demand$
$F = Order\ cost$
$P = purchase\ price\ per\ product$
$h = holding\ cost/unit/year\ in\ \%$

According to literature, the formula of the EOQ seems to be insensitive. A deviation of ca. 30% with respect to the EOQ results in a deviation of 5% with respect to the minimal cost (Schwarz, 2008).

Using this method on the historical data of the raw material GGRIJS021A, the yearly demand had to be determined first and the VC. This is obtained by summing up the number of pallets needed for

production per month. This value equals to 135 pallets per year and the value of VC = 0,43. Since the order cost (F) and holding cost (Ph) are known, the value of EOQ can be calculated.

$$\text{EOQ} = \sqrt{\frac{2 * 135 * 88{,}48}{7 * 12}} = 16{,}86\ pallets$$

Dividing the yearly demand by the EOQ gives an order frequency of 8.

Note: If the outcome would not be an integer, this number must then be rounded up or down within the 30% range of the EOQ.

Using these values the EOQ-method resulted in a total cost of **€3.170,48** for GGRIJS021A for the period April 2014 to August 2015.

7.2.4 Silver-Meal (Least Period Cost)

This heuristic lot-sizing method, together with the following methods, is mostly used when the demand is irregular. These methods weigh the order cost and the carrying cost against each other. The method of Silver-Meal tries to minimize these costs per period. The idea of this method is to compare different procurement scenarios. By determining the required number of pallets of GGRIJS021A for the first period (month) the order and carrying cost is established and divided by the number of periods, which is 1. Then the second scenario is assessed where the amount required for the second period is included in the order of the first period. The summation of the incurred order cost and carrying cost is then divided by 2, since the purchaser ordered for two periods. If the value of the second scenario is higher than the first scenario, the SM method would recommend buying only for the first period. If lower, this method has to be repeated until a higher value for the Cost Per Period (CPP) is obtained. And then this is repeated for the next period. Below the values are given from April to September in 2014:

Table 7: application of the Silver Meal for the period April to September 2014

Maand	apr	mei	mei	jun	jun	jul	jul	aug	sep
periode	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**3**
Aantal pallets (SKU)	5,64	14,97	9,33	25,96	16,62	31,45	14,82	22,97	30,44
Bestelkosten	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48
Voorraadkosten	€ 39,46	€ 170,12	€ 65,33	€ 298,08	€ 116,37	€ 323,86	€ 103,74	€ 217,83	€ 374,65
KPP	€ 127,95	€ 129,30	€ 153,81	€ 193,28	€ 204,86	€ 206,17	€ 192,23	€ 153,16	€ 154,38
Minimum cost	**€ 127,95**		**€ 153,81**		**€ 204,86**		**€ 153,16**		

The Silver-Meal method results in a total cost of **€2750,25** for GGRIJS021A for the period April 2014 to August 2015.

7.2.5 Least Unit Cost (LUC)

The Least Unit Cost method has the same principle as the Silver-Meal. In the LUC procedure, the required number of pallets are grouped together to form lots until the total cost reach a minimum level and starts increasing hereafter (Bahl & Bahl, 2009). The cost per unit is calculated by adding the order and carrying cost together and dividing this by the number of stock keeping units (pallets). Below we find the minimum cost from April to September in 2014.

Table 8: application of the Least Unit Cost for the period April to September 2014

Maand	apr	mei	jun	jun	jul	jul	aug	aug	sep	okt
periode	**1**	**2**	**3**	**1**	**2**	**1**	**2**	**1**	**2**	**3**
Aantal pallets (SKU)	5,64	14,97	31,60	16,63	31,45	14,82	22,97	8,15	15,62	24,47
Bestelkosten	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48
Voorraadkosten	€ 39,46	€ 170,12	€ 519,24	€ 116,41	€ 323,90	€ 103,74	€ 217,83	€ 57,04	€ 161,59	€ 347,57
KPU	€ 22,70	€ 17,27	€ 19,23	€ 12,32	€ 13,11	€ 12,97	€ 13,34	€ 17,86	€ 16,01	€ 17,82
Minimum cost	**€ 17,27**			**€ 12,32**		**€ 12,97**		**€ 16,01**		

The LUC method results in a total cost of **€2603,62** for the period April 2014 to August 2015.

7.2.6 Part Period Balancing (PPB)

The principle of the Part Period Balancing method is to aggregate the successive requirements to form lots so that the carrying cost and order cost are (nearly) equal. The difference between these two costs is important for this method since the difference needs to reach zero. The moment the difference increases again, the minimum is found for those periods. Below we see the PPB method applied for the period April to September in 2014.

Table 9: application of the Part Period Balancing for the period April to September 2014

Maand	Apr	mei	mei	jun	jun	jul	jul	aug	aug	sep
productieorder	5,64	14,97	9,33	25,96	€ 16,62	31,45	€ 14,82	22,97	€ 8,15	€ 15,62
Carrying cost	€ 39,46	€ 170,12	€ 65,33	€ 116,37	€ 116,37	€ 323,86	€ 103,74	€ 217,83	€ 57,04	€ 161,59
order cost	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48	€ 88,48
difference	€ 49,02	-€ 81,64	€ 23,15	-€ 27,89	-€ 27,89	-€ 235,38	-€ 15,26	-€ 129,34	€ 31,44	-€ 73,10
difference (ABS)	€ 49,02	€ 81,64	€ 23,15	€ 27,89	€ 27,89	€ 235,38	€ 15,26	€ 129,34	€ 31,44	€ 73,10
Min(ABS)	€ 49,02		€ 23,15		€ 27,89		€ 15,26		€ 31,44	

This results in a total cost of **€2744,55** for the period April 2014 to August 2015.

To have an idea of what the impact is of applying these methods, the total costs found applying these heuristic methods are compared to the total cost incurred by the current method (HM) used by the purchaser for the raw material GGRIJS021A. The table below shows the differences between the current method and the heuristics for this raw material.

Table 10: Savings per year for the RW GGRIJS021A

Comparison	Total cost	Savings/method/yr relative to HM
Huidige methode (HM)	€ 3.794,21	€ 0,00
EOQ methode (EOQ)	€ 3.170,48	€ 467,79
Silver-Meal (SM)	€ 2.750,25	€ 782,97
Least Unit Cost (LUC)	€ 2.603,62	€ 892,94
Part Period Balancing (PPB)	€ 2.744,55	€ 787,24

By applying (one of) these heuristics by the purchase department, we can presume that a saving can be obtained per raw material per year. Some ERP systems, like SAP, have these lot-sizing methods implemented in the software which automatically calculates the optimal lot-size based on the data entered in the system.

Below we see a table with the savings that could have been achieved with the application of the heuristics on the five raw materials relative to the current method.

Table 11: Savings attainable per heuristic method

Raw Material	VC	EOQ	SM	LUC	PPB
Anti Terra	0,45	50%	54%	42%	42%
Vlamroet	0,36	55%	54%	54%	56%
Purmol	0,66	16%	27%	30%	30%
Ethacure	1,00	26%	30%	39%	40%
Desmodur	0,70	9%	10%	10%	11%

According to (Bahl & Bahl, 2009), all the heuristics seem to work well when the coefficient of variation is low or extremely high, but the selection of a heuristic is important in case of variation of demand in an intermediate range. In the literature is found that the heuristic part-period balancing (PPB) gives better results compared to other heuristics and should therefore be implemented in the ERP for the ordering process.

7.3 Purchasing process

When packaging and raw materials are needed, the purchaser has to create a purchase-order to buy from suppliers. The current purchasing process proceeds as follows:

The purchase-order is entered in Exact Globe. After entering the order, a hardcopy is made on a special pre-printed paper with the EdilonSedra logo supplied by a supplier, in color. This hardcopy, which contains the order-information, is then signed by the purchaser and scanned (in black and white). This hardcopy will then be stored and the scanned file will be emailed to the mail of the purchaser. She receives the file with the corresponding information which includes the logo of EdilonSedra and the signature of the purchaser. After this, the purchaser can send the completed order to the supplier and awaits its confirmation.

This is devious and can be done in less steps to increase efficiency of the purchasing process. When the order is entered, instead of printing the order to sign it and scan it again, an automated signature can be implemented in the system to sign the order. By applying this, no paper and thus no backup of hardcopies are needed since all these orders are stored digitally already. Below we see a flowchart of the purchasing process.

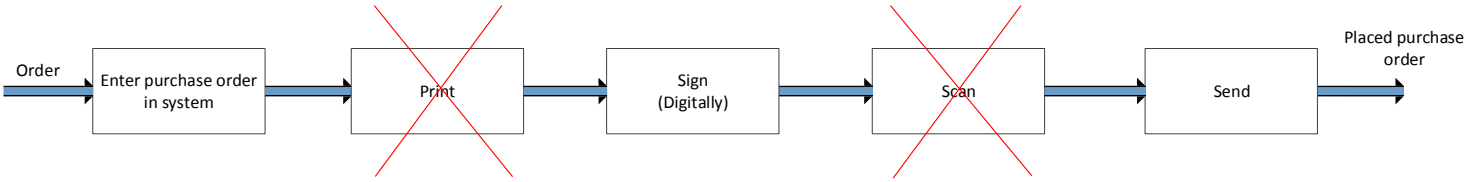


Figure 35: Flow chart purchasing process

The red crosses in this purchasing process indicates activities that do not add value to the end product which the customer is not willing to pay for and thus makes it superfluous. By eliminating these steps, no paper is involved and a purchase can be made more quickly and thus more efficient.

These special designed papers, where the orders are normally printed on, are bought twice a year, one pallet per order. Each order costs the company €3000,-, which makes it a yearly cost of €6000,-.

By eliminating these steps, this value can be saved together with the space where the orders are physically stored and the time the purchaser normally spends on the non-value adding activities.

7.4 Safety Stock raw materials

In order to be able to start production, it is very important to have the required amount of packing and raw materials. A delay is inevitable when the required amount of packing and/or raw materials are not available when production needs to start, which may directly affect customer service. But having too much in stock is as bad as well which is considered waste. Therefore a balance must be found.

As mentioned before, the ABC-analysis indicates which products deserve the most attention. Therefore the A-products are the most important to consider since these provide 80% of the turnover. For the packing and raw materials, the delivery time of the suppliers is relevant in order to decide what to hold on stock and for what product they are used. The raw materials needed for A-products must be immediately available whereas the immediate availability does not account for B or C rated products. In the appendix E, we see a few A-rated products along with the raw materials needed in order to produce the finished good and the delivery time of these materials. These raw materials are automatically A-rated since these are important for the production of A-products.

The Corkelast VA60 and VA70 consist of 14 and 15 raw materials respectively, with the longest delivery time of 60 days for GGRIJS011A. The corkelast TO consists of 11 raw materials with the longest delivery time of 30 days and the STP-25 consists of 10 raw materials with the longest delivery time of 30 days as well. 70% of the raw materials can be delivered in 14 days, 18% in 21 days and 12% takes longer than 21 days. The delivery time for the raw materials can be found in appendix H.

In order to meet the required internal service level which is directly related to the external service level, a safety stock of packing and raw materials must be maintained. The internal service level states the probability that there will be no stockouts within a period time. The safety stock is intended to function as a buffer for uncertainties/irregularities to prevent stockouts. Some factors that causing stockouts are for instance, fluctuating customer demand, forecast inaccuracy and variability in lead times for raw materials. Because there is no detailed forecast, this forecast factor will not play a role in this matter.

The level of the safety stock depends on the defined service level by the MT. The higher the service level, the higher the level of safety stock must be realized, which means a higher inventory. Therefore, a balance must be found between inventory costs and customer service. By using the formula for safety stock found in literature (King, 2011), safety stock levels can be calculated to achieve the desired customer service level.

In order to determine the safety stock, historical data had to be acquired (since no forecasts are available) and some assumptions are made. The demand variability is based on historical data extracted out of the system, where the average demand is determined per month for the A-rated products only. Because only for such products you want to be able to produce in case of irregularities in demand. For the B and C-class, the raw materials (that are used only in these classes) can be bought at the moment an order comes in as the longest delivery time of these raw materials are 21 days (3 weeks) and the throughput for these finished goods is a week by average, thereby remains a margin of 2 weeks. The SLA made by the MT states that a (partial) delivery can be made within 6 weeks (from order to delivery) and therefore it is still possible to deliver in time concerning the B and C class products.

The average demand per week of the A-class products are determined and the lead time is the delivery time of the supplier of raw materials. The lead time demand (*LTD = L*R)* is the average demand (*R)* during the lead time (*L*) of the supplier (in weeks) and is assumed to be normal distributed using the average value *R* and its standard deviation σ_R. The standard deviation of the lead time demand σ_{LTD}, is calculated by multiplying the lead time factor ($\sqrt{L}$) by the standard deviation σ_R.

$$\sigma_{LTD} = \sigma_R * \sqrt{L}$$

For example, If we consider the raw material GGRIJS007A with a lead time *L* of 2 weeks, which is used in Corkelast VA70 with an average weekly demand *R* of 0,55 batches and a σ_R of 0,36, the lead time demand would be *R* times L, which is 1,1 batches (A quantity of 1800 kg GGRIJS007A goes in 1 batch VA70). The corresponding standard deviation of the lead time demand would then be $\sigma_{LTD} = \sigma_R * \sqrt{L}$, which results in a value of 0,51 batches.
In case of an irregular lead time, another formula must be used for the determination of σ_{LTD}, whereby the variability of the lead time σ_L is taken into account in the following formula:

$$\sigma_{LTD} = \sqrt{L * \sigma_R^2 + R^2 * \sigma_L^2}$$

The next step is the determination of the z-score. With the service level, determined by the MT, the z-score can be obtained by using the z-table or the excel function ***NORMSINV(****service level****)***. Below we see in the graph how the service level is related to the z-score.

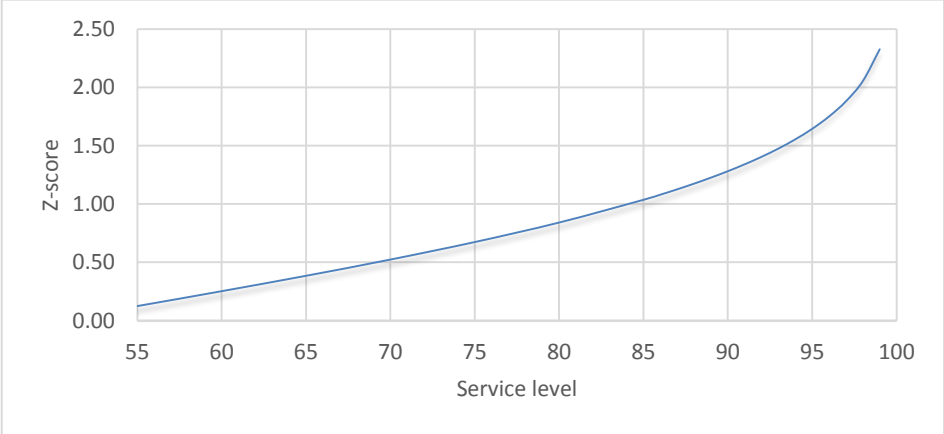


Figure 36: Relation of the Z-score and the Service Level

As illustrated, the relationship is nonlinear. The higher the service level the higher the z-score which does not increase in proportion. Hence there is a non-proportional increase in safety stock when higher service levels are required. In case of no safety stock, the z-score is zero. With a z-value of 0, the probability to hit a stockout is 50%. If the z-score is 1, it means that the safety stock will protect against one standard deviation. Translating z-score with a value of 1 into service level, the excel function ***NORMSDIST(****z-score****)*** can be used and shows a service level of 84%. Statistically, a service level of 100% cannot be reached as it would mean to keep infinite stock, which is not practical. Thus in practice, the inventory manager needs to settle for an imperfect inventory trade off.

The MT of EdilonSedra requires a service level of 90%, which corresponds to a z-value of 1,28, which implies that 90% of the time there will be no stock out.

The safety stock needed is simply the multiplication of the z-score by the standard deviation of the demand variability of the A-rated finished goods.

The formula for the safety stock is as follows:

$$I_s = Z * \sigma_{LTD}$$

Whereby $I_s = Safety\ stock$
$Z = Z - score$
$\sigma_{LTD} = standard\ deviation\ of\ the\ lead\ time\ demand$

After the value of the safety stock is determined, the re-order point can be calculated by summing up the safety stock I_s with the lead time demand *LTD.* In case of the raw material GGRIJS007A, this would result in a total ROP at 3173 kg.

			Mean demand/mth			
Input	---------->	VA60	5,28	0	<----------	vul de hoeveelheid grondstof nodig voor een batch
		TO	17,34	0	<--	
		VA70	2,21	1800	<--	
		STP	1,94	0	<--	
		Dex R2K	3,07	0	<--	
		U90WB	5,5	0	<--	
		Dex-G 20	5,64	0	<--	
		Lead time (weeks)		2	<----------	hier vul je de levertijd in van de leverancier
		Servicelevel (SL)		0,9	<----------	gewenste servicegraad

Lead time supplier	formula	VA60	TO	VA70	STP	Dex R2K	U90WB	Dex-G 20	totaal
R (batches)	demand/wk	0	0	994,5	0	0	0	0	994,5
L (in weeks)	Lead time	2							**2**
LTD	L*R	0,00	0	1989,00	0,00	0,00	0,00	0,00	**1989,00**
σR	std of R	0	0,00	653,11	0,00	0,00	0,00	0,00	**653,11**
L factor	sqrt(L)	1,41							**1,41**
σLTD	σR*L factor	0,00	0,00	923,63	0,00	0,00	0,00	0,00	**923,63**
z	normsinv(SL)	1,28							**1,28**
SL	service level	0,90							**0,90**
Is (safety Stock)	z*σLTD	0,00	0,00	1183,68	0,00	0,00	0,00	0,00	**1183,68**
ROP	LTD+Is	0,00	0,00	3172,68	0,00	0,00	0,00	0,00	3172,684
MIG	Factor MIG	1,00							3172,684
WIN	Factor WIN	0,00							0

Output	---------->	ROP MIG	3172,68	kg
	---------->	ROP WIN	0,00	kg
		Total ROP	3172,68	kg

Figure 37: Excel file for the determination of the Safety stock (and ROP) per warehouse

The figure above shows the excel file whereby the safety stock per raw material can be calculated. The values shown in the figure are of the raw material GGRIJS007A. By entering the required quantity of raw material per batch per A-product, the supplier's lead time and the required service level, the value for the safety stock can be determined per warehouse. In appendix H we find an overview with the

required quantities of raw materials for producing a batch, as well as the lead time of the suppliers, the minimum order quantity and the throughput time of the finished goods.

7.5 Safety stock of finished goods

As the ABC-analysis of finished goods showed, only 14% of the total number of end-products is responsible for 80% of the total revenue.

In the MRP can be found that 21 end products (43%) have a safety stock, while only 14% of the end products provide a turnover of 80%. Below we see the table with the 21 finished goods that contain safety stock, cost price and investment. The column investment shows the value of the cost price times the quantity of the safety stock.

Table 12: Current Safety stock levels of finished goods

Finished goods	Safety stock	SKU	Cost price	investment	Class
Corkelast VA 60 12 kg	30000 kg	56,8	€4,444	€133320,-	A
Corkelast TO 10kg	30000 kg	54,6	€2,938	€88140,-	A
Corkelast VA 70 10kg	2000 kg	4,2	€5,117	€10234,-	A
STP 25	geen	0	€6,049	€0	A
Dex R2k	1200 pcs	2	€23,939	€28726,8	A
Primer U90WB	1600 kg	5,6	€10,508	€16812,8	A
Dex G20 10kg	1500 kg	2,5	€6,37	€9555,-	A
Edilon release agent 10kg	100 kg	1	€21,907	€2190,7	C
Edilon cleaner S 5kg	100 kg	1	€7,93	€793,-	C
Corkelast VA 40 9kg	7500 kg	17,4	€5,951	€44632,5	B
Corkelast VA 60 DB EBA	8000 kg	16,7	€4,963	€39704,-	B
Dex G20 2,5kg	300 kg	1	€9,07	€2721,-	C
Dex G 40 15kg	990 kg	2	€4,556	€4510,44	B
Dex G 80 20kg	500 kg	1,7	€3,994	€1997,-	C
Dex K2K 600ml	1500 pcs	2,3	€17,281	€25921,5	B
Dex L2K Tix 600ml	1200 pcs	2	€23,386	€28063,2	B
Dex RH	396 kg	1	€13,467	€5332,93	C
Dex WR	396 kg	1	€15,378	€6089,69	C
Primer 21 3kg	1600 kg	2,1	€6,656	€10649,6	C
primer 21 2K	800 kg	1,7	€11,761	€9408,8	C
Ediseal 600 mil	200 pcs	0,4	€38,446	€7689,2	C
Editack n Black	100 kg	0,2	€5,18	€518,-	C
Total		**177,2**		**€477010,16**	

Adding up the investment values of all the safety stock levels gives a value of €477010,16 and the corresponding carrying cost of at least €14.885,- .

7.5.1 Little's law

The throughput time varies per finished good. In appendix H we find the time needed to produce finished goods from moment of production to the approval of the Quality Control and thus ready for shipment in MUG. The longest throughput time is that of Corkelast VA60 and STP-25 with a throughput time of 9 days and 14 days respectively. This is due to the QC time needed to approve this product. The throughput time consists of the time to prepare raw materials, production, quality control and shipment from MIG/WIN to MUG. The time needed to prepare raw materials is maximum 2 days. For the VA60 and the STP, two days are needed to produce a batch, while the production time for U90WB is 1 day. The QC time is on average 3 days for the most finished goods except for the VA60, STP-25 and TO. For the VA60 and the TO a QC time of 5 days is required and for the STP-25 a QC time of 10 days is required. Below we see the throughput of the STP-25 of 2 weeks in the flowchart.

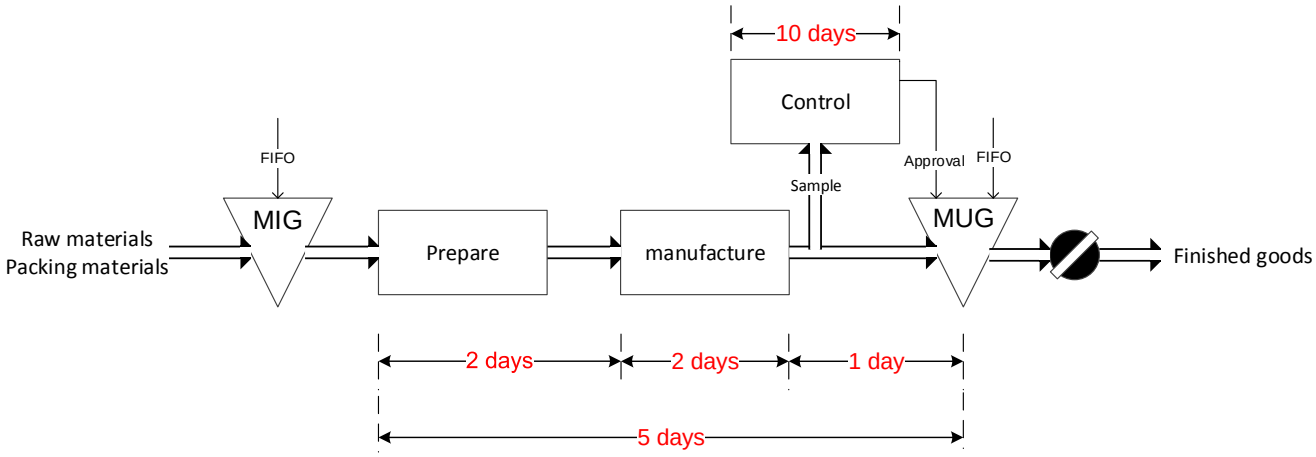


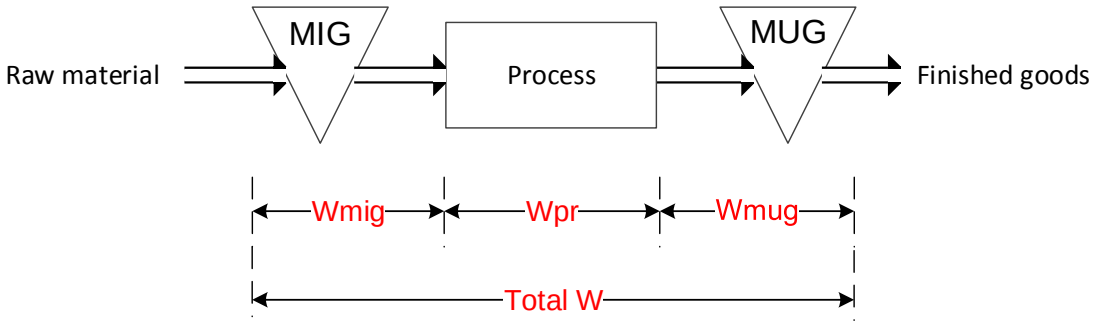
Figure 38: lead time of STP-25

Above we see the time needed per activity in order to have a batch ready for shipment in MUG. Since STP-25 is an A-rated product, it is required to be able to produce at the moment an order enters the system. The Service Level Agreement guarantees a partial delivery within 6 weeks. This means in case of the STP-25, which has the longest throughput time, a delivery can even take place after 2 weeks. Dependent on the moment an order has been placed relative to the required delivery date and the quantity ordered of a finished product.

By using little's law $L = \lambda * W$, the average time a raw material spends in the system can be calculated. The formula for little's law states that the average number of units L in the system is equal to the multiplication of the average delivery rate λ (or arrival rate) with the average time W the unit spends in the system (Little & Graves, 2008). Since every raw material is treated differently and used for different finished goods, a few examples are taken for the sake of the calculation.

GGRIJS021A

This raw material is used in the three A-class finished goods, namely Corkelast VA60, VA70 and the TO. To calculate the total average time of GGRIJS021A in the system, the average quantity in MIG, L_{MIG}, must be determined first. This is retrieved from the historical data extracted from the MRP. The total time W_{tot} consists of the time the material dwells in MIG, in the process and in MUG (in the form of finished good).



First the idle time W_{MIG} in MIG is calculated:

- L_{MIG} = 4500 kg
- Batches per week:
  - Corkelast VA60: 1,32 batches
  - Corkelast TO: 4,34 batches
  - Corkelast VA70: 0,56 batches

  The quantity required of GGRIJS021A to produce these batches per week is thus:
  - λ_{VA60} = 1,32 * 345 = 455,4 kg/wk
  - λ_{TO} = 4,34 * 109 = 473,1 kg/wk
  - λ_{VA70} = 0,56 * 80 = 44,8 kg/wk

  In total: λ_{tot} = 973,3 kg/wk. This will result in a W_{MIG} of:

- $\boldsymbol{W_{MIG}} = L_{MIG} / \lambda_{tot}$ = 4500 / 973,3 = 4,6 wks.

The time GGRIJS021A dwells in MUG (in form of finished good):

- $L_{MUG} = L_{VA60} + L_{VA70} + L_{TO}$
  - *whereby* $L_{finished\ good} = (ROP_{current} / Q_{Batch}) * Q_{Raw\ material\ in\ batch}$ and Q is the quantity in kgs.

Filling in the values for L_{VA60}, L_{VA70} and L_{TO}, the following is calculated:

- L_{MUG} = (155.699/9036) * 345 + (32.979/8850) * 80 + (88549/3040) * 109
  = 9417,75 kg

- $\boldsymbol{W_{MUG}} = L_{MUG} / \lambda_{tot}$ = 9417,75 / 973,3 = 9,7 wks

Note: Since in MUG only finished goods are stored, the unit flow changes after the processing part. The unit flow, which is in the beginning raw material, transforms into a finished good after processing. Therefore W_{MUG} for raw material does not represent the idle time of the finished good but of the raw material itself which is processed in different end products.

Now that the idle time in MIG and MUG is calculated, the remaining time to be calculated is that of the processing part. But the processing time of the three finished goods differ. The VA60, VA70 and the TO require 12, 5 and 7 working days respectively. By calculating the average a process of 8 days is found. This means that the average quantity that is being processed is L_{Pr} = (8 / 5) * 973,3 = 1500 kg. The total average time GGRIJS021A spends in the system is then:

$\boldsymbol{W_{tot} = W_{MIG} + W_{pr} + W_{MUG}}$ = 4,6 + 1,6 + 9,7 = 15,9 wks.

Below a table is shown with other raw materials as examples.

Table 13: Little's law applied on few raw materials

$L = \lambda * W$	MIG			PROCESS			MUG			Total		
raw material	*L (kgs)*	*λ (kgs/wk)*	*W (wks)*	*L (kgs)*	*λ (kgs/wk)*	*W (wks)*	*L (kgs)*	*λ (kgs/wk)*	*W (wks)*	*L (kgs)*	*λ (kgs/wk)*	*W (wks)*
GGRIJS021A	4500	973,3	4,6	1500	973,3	1,6	2239,2	973,3	2,30	8239,20	973,30	8,50
GROOD0012A	4900	125,49	39,05	150,59	125,49	1,2	222,25	125,49	1,77	5272,84	125,49	42,02
GROOD0008A	119	4,6	25,87	5,52	4,6	1,2	10,33	4,6	2,25	134,85	4,60	29,32
GGRIJS004A	16300	3100	5,26	4340	3100	1,4	7057,05	3100	2,28	27697,05	3100,00	8,93
GBLAUW005A	441	16,16	27,29	19,39	16,16	1,2	28,65	16,16	1,77	489,04	16,16	30,27
GROOD0004A	1900	246,13	7,72	246,13	246,13	1	497,22	246,13	2,02	2643,35	246,13	10,74

The same can be done for finished goods containing a safety stock. But we only apply it to the A-rated products since the arrival times of these products are determined only. The values for *L*, extracted from the MRP, and the delivery rate *λ* were used to calculate the average time the finished goods dwell in MUG. The table below shows the values.

Table 14: Little's law applied on A-rated finished goods

$L = \lambda * W$	MUG			MUG (no SS)		
Finished good	*L (kgs)*	*λ (kgs/wk)*	*W (wks)*	*L (kgs)*	*λ (kgs/wk)*	*W (wks)*
Corkelast VA60	155699	11928	13,1	125699	11928	10,5
Corkelast TO	88549	13178	6,7	58549	13178	4,4
Corkelast VA70	32979	3227	10,2	30979	3227	9,6
STP-25	26019	2061	12,6	26019	2061	12,6
Dex R2K	2792	530	5,3	1592	530	3,0
Primer U90WB	5527	792	7	3927	792	5
Dex-G 20 10kg	3730	846	4,4	2230	846	2,6

These quantities stored in MUG include the quantities of the safety stock. By reducing the safety stock of these finished products, the average quantity stored will decrease by the same amount.
For example, L_{VA60} becomes 125.699 kg instead of 155.699 kg. By calculating with this value, we find $W_{VA60} = L_{VA60} / \lambda_{VA60}$ = 125.699 / 11.928 = 10,5 wks. This reduces the dwell time in MUG with 2,5 wks.

7.6 Production capacity

The production capacity is important to know how much the production facility can manufacture within a certain period of time. This analysis is already done by the people of EdilonSedra who have created a spreadsheet where the capacity is visible. The spreadsheet can be found in Appendix I. The goal of this analysis was the identification of the bottlenecks when the amount of the total demand and thus production quantities increases. Below we can see the quantities produced per year so far since 2010.

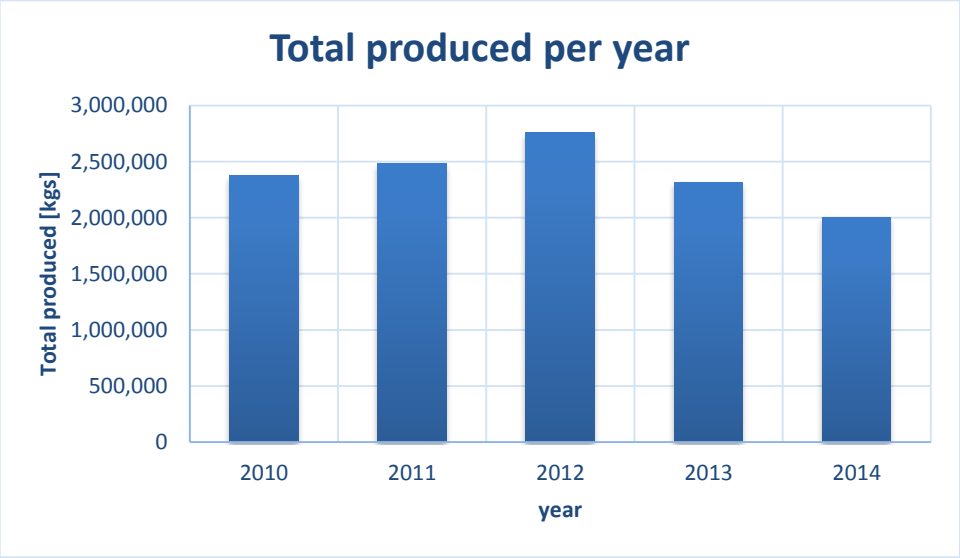


Figure 39: Produced quantities from the year 2010 to 2014

The spreadsheet is based on a yearly total demand of 3.972.500 kgs, divided over different product groups, which must be realized in 8 months. This amount far exceeds the amount produced in previous years. Experience tells that the busiest months are in the months March to October. Hence 8 months is chosen instead of 12 months. The quantities determined per product group are then again divided in finished goods. The corresponding quantities are based on the average ratio among the finished goods within a product group, determined from the period 2012 - 2013. In appendix I can be seen that the amount of kgs per finished good are converted into the amount of batches which must be produced per month in order to satisfy this demand. Thereby an average of 21 working days per month is considered with one shift (from 08:00 to 17:00). The required production quantities are scheduled in a month of 21 working days as can be seen in the table of the appendix I. This problem is already being tackled by the production manager and thus can be concluded that the production capacity is sufficient for the production of these quantities.
From this schedule, the current capacity of the production per month is derived:

Table 15: Current max capacity with one shift of production in one month

Finished good	Capacity [batch/month]	Finished good	capacity [batch/month]
VA60	21	**Sedrafer**	3
VA40	2	**STP-25 C1**	1
VA70	2	**Dex-G**	18
TO	57,2	**Dex-L2k Tix + K2k**	7
VA90	3	**Dex-R 2K**	4
M95	3	**P21**	8
WR / RH	4	**P21 2k**	9
va40/60 N	5	**U90WB**	7
		STP-15	7

Compared to the average delivery per month (which can be seen in figure 37), the production capacity is more than sufficient to satisfy the demand below this amount. This conclusion is made with the assumption that the ratios among finished goods in product groups are as determined for the analysis.

8. Implementation

The solutions for the identified problems were elaborated in the chapters 5, 6 and 7. These solutions have to be applied in the current process in order to reduce working capital on basis of inventory.

8.1 Introduction of the Key Performance Indicators

As was identified, there is a lack of KPIs which did not make it possible to evaluate any process. The model below shows how the KPIs are applied as requirements for the process.

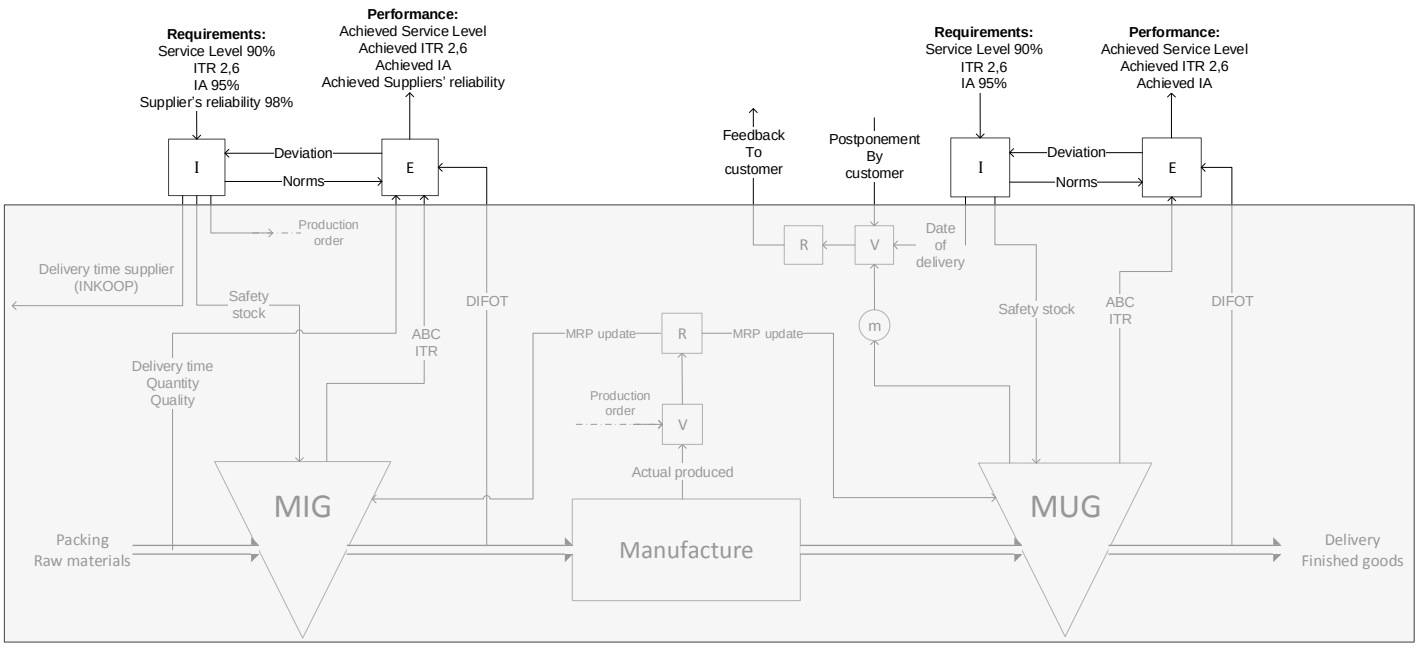


Figure 40: DSA model of the control functions of the warehouses MIG and MUG with the specified requirements & performances.

The requirements given in the DSA model for inventory management are equal to the defined KPIs. The norms that come out of the *Initiator function* (I) are based on these specified requirements. The *Evaluation function (E)* evaluates the incoming data (the input arrows of *E*) of the concerning process and compares these with the determined norms. In case of a major deviation (output arrow of *E)* between the stated norm by the initiator and the actual achieved value, the *Initiator function* (I) adjusts the norms in order to control the process and to lead it in the desired direction which enables continuous improvement.

8.1.1 Service Level (SL)

The first requirement the management team has to determine is the service level. This is a target that EdilonSedra must achieve at the end of the year in order to keep (internal) customers satisfied to preserve or increase market share. To keep track of the service level, some data must be registered in the system such as:

- Number of incoming orders
- Number of DIFOT orders

- Number of no-sales
- Number of backorders

The Service Level and DIFOT can be calculated with these data. This shows whether the stated goal is achieved or not. If not, an evaluation must take place by the management team to find the root cause of the problems occurred that belonged to certain customer's orders. The root cause of the deviation must then be solved to eventually achieve the specified goal. For the start of the implementation, a service level of 90% has been chosen by the management team.

8.1.2 Inventory Turnover Ratio (ITR)

A dashboard is needed to keep track of the ITR as well to determine how effective the inventory is managed. Therefore the Cost of Goods Sold and the average inventory over the defined period must be registered in the system. These data must then be used to calculate the ITR of the defined period. Every 3 months the ITR must be checked whether this is close to the required target. As well for the ITR an evaluation has to take place in case of underperformance to solve the cause of the problem so that the norms can be improved. For the start of the implementation an ITR of 2,58 is determined since this is a value achieved in the year 2014-2015 and which is chosen as a benchmark for the following year. Below an example of a dashboard is illustrated.

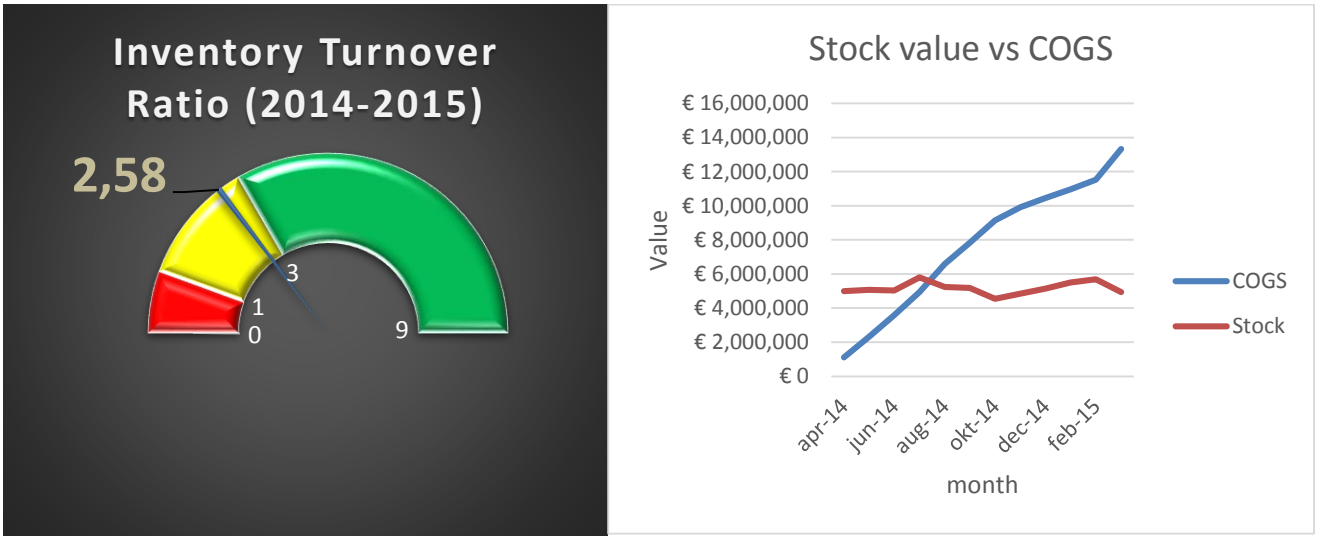


Figure 41: Dashboard ITR

The left figure shows a speedometer with values from zero to nine. This speedometer consists of three parts and a pointer which indicates the value of the ITR. The red, yellow and the green part displays the status of the Inventory Turnover Ratio. The red and the yellow part indicate that EdilonSedra performance under and thus improvement is necessary in order to get over to the green safe zone, which means higher performance. With this dashboard one can see in one glance how well the inventory is managed. Therefore the performance is made visible. The graph on the right shows the relation between the stock values with the COGS, which are necessary for the calculation of the ITR.

8.1.3 Inventory Accuracy (IA)

The inventory accuracy states how many items in the inventory correspond in quantity with the number of items in the ERP. Thus, an accuracy of 95% implies that 95% of the items in the system corresponds in quantity with the items physically stored. The major cause of discrepancies in the inventory is due to the procrastination of the conclusion of a production-order when the production-order requirements are not met. If the materials have been consumed in the given amounts, no major

deviation between virtual inventory and physical inventory will occur. This can be seen in figure 42. The production-order is a norm for the function “manufacture” whereby this norm is compared with the actual consumption of the production process. In case of a strong deviation, the conclusion of the production order must be immediately entered in the ERP in order to update the MRP for a higher IA.

The cycle counting process, described in paragraph 5.4 must be done on the basis of the ranking of the ABC analysis. The A – ranked raw materials should be counted more often than C – ranked products due to the high value and the use for A – ranked finished goods. The physical counting process must be done to find the errors and to eventually eliminate the root cause of the error, thereby maintaining a high accuracy. The ABC cycle counting process requires the A – ranked materials to be counted 4 to 6 times a year. The B – ranked materials must be counted 3 times a year and the C – ranked materials 1 to 2 times a year.

Table 16: Example of the ABC Cycle counting schedule

Month	ABC	Month	ABC
January	A	July	A
February	B	August	C
March	A	September	B
April	B	October	A
May	A	November	
June		December	A

8.1.4 Supplier’s reliability

This KPI is very important in selecting the most appropriate supplier for a certain raw material. The purchasers have to assess the suppliers based on the OTD, delivery time, quality, quantity and price. Every purchase order must therefore be assessed. The supplier is then selected based on the highest performance. This can be implemented in Exact Synergy. The supplier must at least achieve a reliability level of 98%. If not the case, EdilonSedra must communicate with the corresponding supplier in order to increase reliability level or select a more reliable supplier.

8.2 Introduction of the Service Level Agreement

This document can be found in Appendix G. The agreements that can be found herein shall be complied with. Important is that the postponed orders (by the customer), which is already produced for and held in stock, must be compensated if extra costs occur. This compensation equals to 0,45% of the sales price. The BV produces also only on order and guarantees a (partial) delivery within six weeks, unless otherwise agreed. Furthermore, the BV will keep stock of specified products and quantities, if Group requires BV to do so (based on an agreement with their customer). Group is obligated to sell this product/volume within 6 months.

8.3 ABC-analysis

The ABC-analysis is very important for inventory management and must therefore be done once every 3 months, so that A-rated products are continuously focused on. This can be done by using the function ABC-analysis in Exact Globe which gives an overview of the finished goods that attain the highest profits or highest purchase cost in case of packing and raw materials. This categorization method will therefore show the finished goods and the corresponding raw materials which should be focused on. As illustrated in the DSA model (figure 42) the ABC items/finished goods must be evaluated and adjusted if necessary.

8.4 Order method

Currently the purchase department purchases items whenever these items fall below the minimum value in the MRP. These items are then topped up to the specified maximum. This process can be done in a more efficient way by applying the Part Period Balancing method. This heuristic method has to be implemented in the purchasing process of Exact Globe in order to reduce the costs as is analyzed in paragraph 7.2.

8.5 Safety stock

The safety stock currently used is not based on data and therefore paragraph 7.4 and 7.5 is dedicated to that subject. In case of finished goods, the safety stock can be reduced to zero since there are no agreements made between the BV and the (internal) customers. In case of raw materials, the safety stock of A-rated materials have to be calculated which is based on the pre-defined service level, delivery time of the supplier and the average demand during lead time (of the supplier). This calculation can be done with the excel file shown in figure 37. The B and C rated materials must be bought at the moment an order has taken place whereby these raw and packing materials are required. The safety stock for A-rated products makes it possible to cover for variability in demand which is not necessary for B and especially C products since these only provide 15% and 5% of the profit in total, respectively.

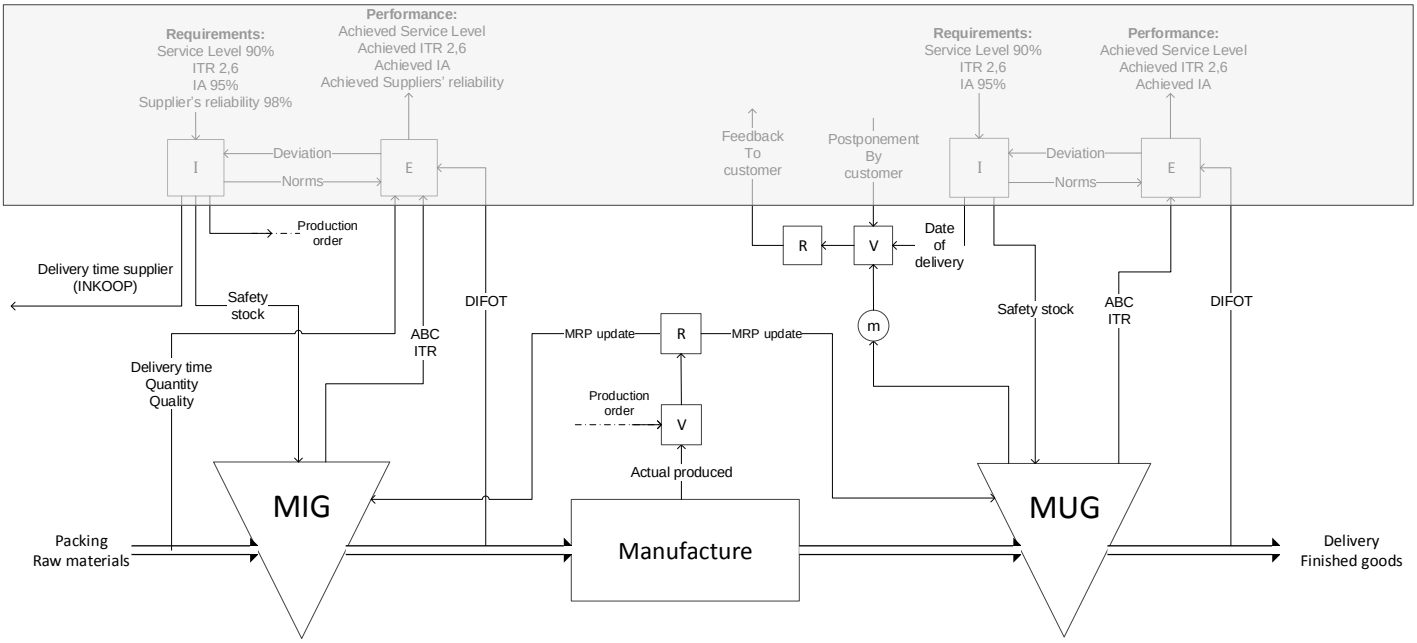


Figure 42: DSA model of the warehouses MIG and MUG and the function "Manufacture"

9. Conclusion and recommendations

9.1 Conclusion

The management of EdilonSedra requires the reduction of working capital in order to increase profit. A good system of inventory control is of importance to this theme, yet lacks at the company. This is reflected in several aspects of the management of inventory. The performance of the inventory management is not evaluated due to lack of KPIs. Safety stocks of raw materials as well as finished goods are based on intuition rather than calculations based on data. The company is push and pull oriented, meaning they produce on stock as well as on order, while no detailed forecasts are available. Purchasing and the determination of lot size (order quantity) is not based on the quantity of demand but is replenished up to the determined maximum value.

This problem has resulted in the following research objective:
Design of inventory control to determine relevant KPIs, optimal order sizes and safety stocks, and SLA which should lead to a reduction of 10% of the working capital.

The research objective is related to the following:

- Key Performance Indicators
- Service Level Agreement
- Product rating
- Order methods
- Safety stock for packing & raw materials
- Reduction of safety stocks of finished goods
- Postponements

9.1.1 Determination of KPIs and SLA

There are no key performance indicators that allow the evaluation of inventory. Hence no continuous improvement can be realized. In order to have a certain indication of the performance, KPIs are necessary. Therefore these KPIs are introduced:

- *Inventory Turnover Ratio*: this measures how many times inventory is turned or sold during a defined period. By defining a target, the performance can be measured. When the performance is below the expected target, the MT is able to evaluate in order to find the cause to eventually alter norms or intervene wherever necessary.
- *Service level*: service level can be defined as the expected probability not to hit a stock out. Also can it be described as the probability to serve client demand to keep customers satisfied. For the internal service level (towards the production), the first definition is meant. At the external service level (towards the customer), the second definition is meant. The internal service level is necessary for the calculation of the safety stock. The external service level is determined by the performance indicator dividing the on-time completed orders by the total number of orders (including no-sales).
- *Supplier's reliability (Already in use):* this is very important for the evaluation of the suppliers. The assessment is necessary to select the most reliable supplier and consists of five parts, which are:
    - *OTD* (On-Time-Delivery)
    - *Delivery time*
    - *Quality*
    - *Quantity*
    - *Price*

- *Inventory accuracy:* this indicator is necessary in order to measure the resemblance between the physical inventory and the virtual inventory.

The Service Level Agreement is a document in which agreements are stated between supplier (BV) and customer (Group).

9.1.2 Product rating

Finished goods can be ranked according to the principle of the ABC-analysis. By carrying out this analysis, a distinction can be made between the important end products and the minor products. This analysis shows therefore which items deserve the most attention. The few A-rated products deserve the most attention since they provide a turnover of 80%, while the many C-rated products, which only provides 5% of the turnover, deserve a little or no attention at all. The grey "B" area should be examined but must not take too much time. For this reason, the ABC-analysis should be carried out from time to time (e.g. every 4 months), so that the organization perceives what products requires most attention.

9.1.3 Order methods

The stock levels of packing and raw materials in MIG are directly influenced by the purchasing behavior of the purchaser, since the purchaser determines the moment and quantity of a purchase-order. This purchasing process is done intuitively. In order to purchase cost-efficiently, different lot sizing methods are applicable, all of them with the intention to minimize the carrying and order cost. These (heuristic) methods are:

- *EOQ:* applicable when the demand is regular (variation coefficient <0,45)
- *Silver-Meal*: applicable when the demand is irregular (variation coefficient >0,45)
- *Least Unit Cost:* applicable when the demand is irregular (variation coefficient >0,45)
- *Part Period Balancing:* applicable when the demand is irregular (variation coefficient >0,45)

The savings became visible, as a result of applying these methods on historical data of a raw material. These heuristic methods are implemented in some ERP systems (like SAP) which calculates the optimal order quantities as well as the moment of purchasing, based on the data entered in the system. From these methods it is found that the part-period balancing method is the best method to apply.

9.1.4 Safety stock for packing & raw materials

In order to determine safety stock for the raw materials, the service level must be determined by the MT. With the determined service level and the variability of the lead time demand, the safety stock per packing and raw material can be calculated. The safety stock is necessary in order to prevent stock outs and functions as a buffer for irregularities. Only the packing and raw materials, required for the production of A-ranked finished goods, need a safety stock to be able to produce when an order enters the system so that a sufficient amount of raw material is available during the lead time of the supplier.

Safety stock should be dynamic and change with the demand. In case of seasonal demand, the safety stock must adapt accordingly so that no excess inventory is held in low seasons. In order to do this efficiently, forecasts are necessary.

9.1.5 Reduction of safety stocks of finished goods

Due to the SLA which states that a delivery is guaranteed within 6 weeks, the safety stocks for finished goods can be reduced to zero since there is enough production capacity, as can be seen in chapter 7. This reduction will reduce the time W_{MUG} and thus the time the materials remain in the system. As a consequence, the inventory turnover increases since the units in the system decreases and therefore a higher performance is attained. This means that the company must convert from a push/pull system to a complete pull system. Thus production will only take place at the moment an order is entered in the system.

The aggregate value of the safety stocks of finished goods is equal to €477010,16. This total amount of 177,2 pallets is constantly in stock in MUG. By reducing the safety stock to zero a yearly savings of €14.885,-can be realized, which is the holding cost of the safety stock (excluding interest cost and risks). Furthermore, the investment in safety stock of €477010,16, which is normally dead inventory, can then be used for other investments.

9.1.6 Postponements

There should be agreements concerning postponement of orders by the customers. Contracting management must be responsible for the inclusion of these agreements. Customers could postpone orders indefinitely. The consequence is that customers postpone orders continuously and therefore the desired profit could not be attained for these projects. To tackle this problem, an agreement is made in the SLA stating that whenever a delay of the sales order exceeds 2 weeks, BV will charge 0,45% of the sales price per month (aggregate value of the additional costs).
By adding up the costs of holding stock and working capital of the current postponed projects, a loss of €50.872,- per year is found and thus can be recovered due to this agreement.

9.1.7 Results

In conclusion we can say that using KPIs will give an indication of the company's performance, which are necessary for the management of inventory. On the basis of the ABC-analysis and the pre-determined service level, justifiable stocks can be held for packing and raw materials. The purchasing of raw materials should be based on one of the heuristic lot-sizing methods in order to minimize carrying and order costs. Further, the safety stocks for finished goods are redundant and can thus be eliminated due to the 6 weeks lead time after order confirmation which is stated in the SLA. The extra holding cost and working capital, due to postponement, must be recovered from the customer as it should be clearly defined in the contract.
All this results in an average yearly capital savings of €14.885,- due to the reduction of safety stocks. The investment of €477.010,16 can be used for other investments and €50.872,- can be saved per year due to postponement (dependent on the number and size of the postponed project(s)).
In conclusion it can be said that the research objective has been achieved. The developed control model leads to a better inventory control and eventually customer satisfaction.

9.2 Recommendations

In this research several issues remain, which can be further investigated.

Throughput quality control

The throughput time of the quality control is significant. The reduction of the throughput time of the quality control will have a tremendous effect on the dwell time of finished goods in MUG. Therefore a research on test alternatives is necessary to increase efficiency of the Quality Control.

Standardization of products

There are many different products within a product group. Different products are available while maybe only one standard product may be sufficient for different applications. For example, the Corkelast VA60 might be applicable in situations where normally the Corkelast VA70 or VA40 is applied. By standardizing products, a reduction of finished goods will be attained. This, in effect, will have a positive influence on the production process and the inventory levels.

Barcode systems

The introduction of a barcode system would increase inventory accuracy due to the reduction of human error and workload for the warehouse assistants. Thereby making the entering process more efficient and easier.

Automation of production

The production process consists of the preparation of packing and raw materials, mixing and tapping. By implementing an automated system which controls the supply from the warehouse to the mixer, no preparation of raw materials would be needed. By implementing such a system a reduction of the production throughput can be realized. If the tapping can be done automatically as well, a few operators are necessary in order to control the process and the tapping accuracy would increase.

Fusion of the QC and production

If the production is automated, a fusion of the QC and production can be done. The employees can be educated to multi skilled operators, whereby these operators fulfill QC and production activities (Laborator). This will lead to an increase of the QC capacity and an upgrade of knowledge and involvement of the operators.

Make-or-buy

A make-or-buy may also be considered. Just as the trade goods, it might be possible to hire a toll manufacturer for the production of finished goods. This would mean that the storage of packing and raw material can be eliminated and the production facility can be converted to a warehouse for the storage of finished goods only. A cost-benefit and risk analysis is necessary in order to determine whether this would be a reliable and profitable system for EdilonSedra.

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Appendices

Appendix A: Research paper

Design of inventory control structure for the justification and reduction of working capital on the basis of inventory

K. Aberkan BSc; T.C. van Doorn; Dr. Ir. H.P.M. Veeke; Prof. Dr. Ir. G. Lodewijks[1]

***Abstract* – Since the start of the economic recession, manufacturing companies of railsystems are forced to reduce working capital in order to compete in the market. The internal logistic processes of EdilonSedra are analyzed with the Delft Systems Approach. Several problems are determined related to inventory control and management. The analysis of the processes shows that there is a lack of detailed forecasts and process performance measurements. No service level agreement is implemented for having clear agreements between supplier and customer and no actual data is used for the determination of safety stocks.**

The control structure is revised to improve the control and management of inventory. Due to this improvement a reduction of 10,5% of the working capital can be attained on the basis of inventory whereby the quantities of raw materials and finished goods stored can be justified.

Introduction

The international supplier of rail-isolation systems has two production facilities in the Netherlands. Packaging and raw materials are stored in these facilities for producing the finished goods which forms the components of these systems. According to internal data, the total amount produced in 2012 is 2,75 million kgs and is decreasing ever since, whereby the turnover and profit margin are under pressure. This combination is an important motivation to study the logistic processes of the inventories for improvement.

The packing and raw materials are bought by the purchase department which are stored in the warehouses of the production facilities. The finished goods are transported to an external warehouse where space and service is hired. From this external warehouse, the finished goods are transported to the desired location.

The transport of the finished goods from the external warehouse in Amsterdam to the desired location and the installation process are not considered in this study, as well as the process of trade goods.

EdilonSedra wants to justify the quantities stored and reduce working capital on the basis of inventory.

[1] This study concerns a graduation project of the Delft University of Technology, the Netherlands. From this University: graduate (K Aberkan BSc), initiator (Prof. dr. ir G. Lodewijks), supervisor (dr. ir H.P.M. Veeke). From EdilonSedra, supervisor (T.C. van Doorn).

Method

For the description and modelling of the current process flow the Delft Systems Approach was used. Thereby making use of the PROPER (PROcess PERformance) model *(Fig. 1)* for the depiction of the multi-aspect system. By zooming into this model, the so called steady state model can be depicted. This model contains an input, an output and an execution function to transform input to output. These processes need to be controlled by control mechanisms, called the process- and function control. The function control sets standards for the system based on the requirements of the environment. The process control compares the process-information with the standards that are set by the function control. In case of disturbances, the process control intervenes in the process. The function control evaluates the results by comparing it with the norms and adjust these if necessary (Veeke et al.,2008).

The Delft System Approach is used in order to pinpoint the exact problem within the system.

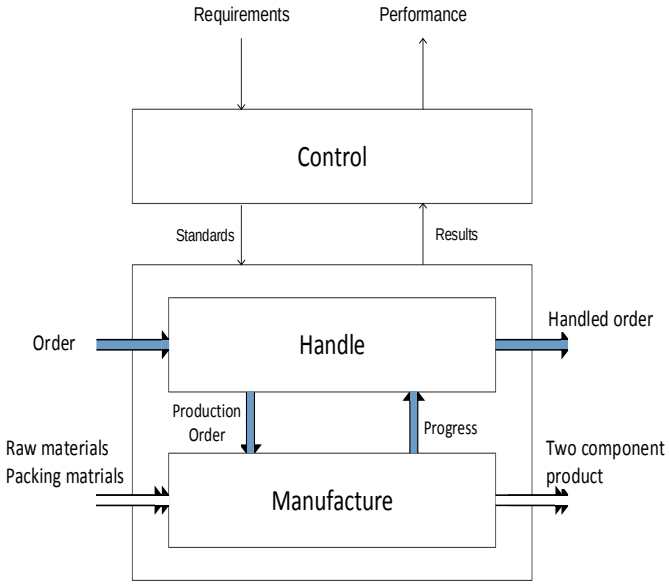

Figure 1: PROPER model of the current process

The system boundary is defined at the input side by the moment the orders and materials are received by the company. The boundary at the output side is at the warehouse where the two component products are transported to the desired destination.

As can be seen in the PROPER model in figure 1, two aspect flows are considered; the order flow and the flow of materials. The coupling between the two functions is the production order and the progress. This article is primarily concerned with the process in which materials are stored in the warehouses. Therefore the subfunctions 'Handle' and 'Manufacture' are examined further, together with the overall control function.

Results

To control and manage inventory, different aspects have to be considered.

ABC – analysis for product categorization

This analysis divides the products in three categories in which the A products are of the highest value and C of the lowest. As for finished goods, this means that A products have the highest annual consumption value or revenue. In figure 2 can be seen that the top 80% of the revenue of the company is achieved by only 14% of the finished goods (A – ranked), while 69% of the goods only provide 5% of the revenue (C – ranked). The goods categorized in B are considered interclass with a medium revenue value which represents the remaining 15% of the total revenue. This accounts for 16% of the total number of finished goods. The incoming goods, packaging and raw materials, are also categorized based on the purchase cost and in what finished goods the materials are processed. Due to this categorization method an assessment on the products can be done in order to determine how to manage the assessed product. Therefore the A – ranked products require most attention, while C – ranked products do not need that same effort.

Safety stock is therefore intended only for the A – ranked products.

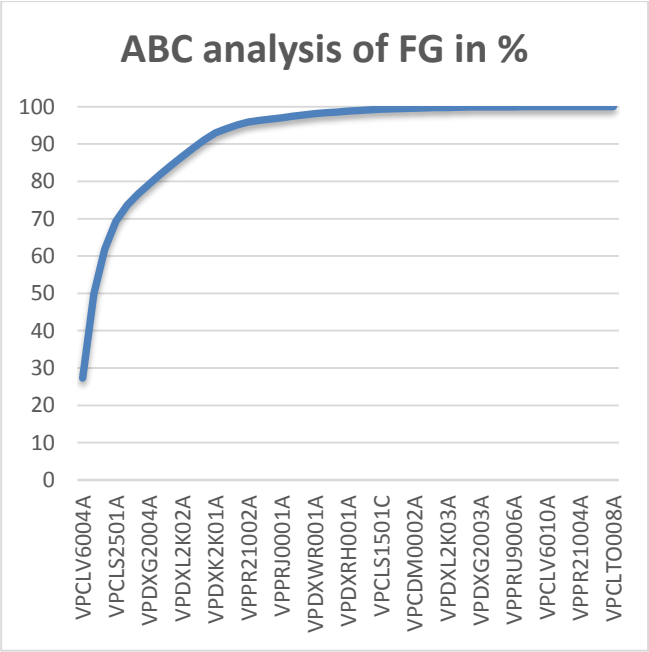

Figure 2: ABC analysis of finished goods (FG) in % of the total revenue.

Key Performance Indicators

Key Performance Indicators are necessary for the improvement of the inventory control. Without the indicators no measurements are made and the company cannot know how it performs. The indicators that are necessary for the management of inventory are *Inventory Turnover Ratio (ITR), Service level (SL), supplier's reliability* and *Inventory accuracy.*

The *ITR* shows how effectively the inventory is managed by comparing cost of goods sold (COGS) with the average inventory for a defined period (usually a year). It measures how many times inventory is turned or sold in that period and was calculated by

$$ITR = \frac{Cost\ of\ goods\ sold\ (COGS)}{Average\ Aggregate\ Value\ Inventory\ (AAVI)}$$

The ratio gives an indication of how well the control of inventory has performed.

The *service level* generally can be described as the expected probability not to hit a stock out and also as the probability to serve client demand to keep customers satisfied. Determining a service level is necessary in case of uncertain demand, otherwise it is a case of good planning. The achieved service level can be calculated by

$$SL = \frac{Number\ of\ DIFOT}{Total\ number\ of\ incoming\ orders}$$

Here the DIFOT denotes the number of orders that are Delivered-In-Full-On-Time. This value will be evaluated with the desired target of 90%. This desired service level is used for the determination of the safety stock.

The performances of the suppliers are monitored as well in order to keep track whether the supplier supplies according the agreements. The performance indicator *supplier's reliability* is being measured by keeping track of the supplier's On-Time Delivery (OTD), the delivery time, Quality, Quantity and Price. Based on these factors a ratio can be found by dividing the on-time completed purchase orders by the total purchase orders per supplier. The performance target is set at a ratio of 0,98 by the management team (MT). Based on the achieved performance of the suppliers, the MT of the logistics department decides whether to continue doing business or change supplier.

In order to determine to what extent the inventory in the system corresponds to the physical stock, the KPI *Inventory Accuracy* is applied. Therefore a cycle counting process can be applied for the determination of the accuracy per product. The products are counted in this process and compared to the values in the software. The ABC analysis shows that the A – ranked products deserve the most attention and thus must be counted more often in order to control the A – ranked products more efficient.

Service Level Agreement

The Service level agreement is a document in which agreements are stated between the supplier and customer. The agreements made in the SLA between the manufacturing department and the internal customer (sales department), which are relevant for the control of inventory, is mainly about the lead time of an order, which is set to a lead time of 6 weeks whereby a delivery is guaranteed. As well as the postponement of orders made by the customer. The customers that postpone orders are charged with 0,45% of the selling price per month that the orders are postponed in order to reduce working capital and to cover extra costs for keeping stock during that deferred period.

Order methods

The purchasing department determines the moment of procurement and the quantity of the order and has therefore a direct impact on the inventory level and thus working capital. To determine lot size and order frequency, the demand downstream and delivery time of the suppliers must be considered. According to (Silver et al., 1998) the demand pattern can be judged as regular with the formula of the *variation coefficient:*

$$VC = \frac{\sigma}{\mu}$$

The μ denotes the average demand and σ the corresponding standard deviation of the demand. A VC value below 0,45 indicates a regular demand where as a value above 0,45 indicates irregularity. Based on historical data, concerning the demand, a VC value can be defined per finished good which can be translated to the demand of the required raw materials. For every raw material, the VC can be determined in order to choose the order methods most suitable. The heuristic methods that can be used for the order process are known as the *Economic Order Quantity (EOQ), Silver-Meal (SM), Least Unit Cost (LUC)* and *Part Period Balancing (PPB).* The principle of the order methods is to reduce the holding- and order costs. The *EOQ* is best applied for a VC value below 0,45 as where the others are more suitable for a higher VC value.

Table 1: Savings attainable per heuristic method

Raw mat.	VC	EOQ	SM	LUC	PPB
Anti Terra	0,45	50%	54%	42%	42%
Vlamroet	0,36	55%	54%	54%	56%
Purmol	0,66	16%	27%	30%	30%
Ethacure	1,00	26%	30%	39%	40%
Desmodur	0,70	9%	10%	10%	11%

By applying the heuristic methods savings can be attained compared to the current ordering method. All the heuristics seem to work well when the coefficient of variation is low or extremely high, but the selection of a heuristic is important in case of variation of demand in an intermediate range. It is found that the heuristic part-period balancing (PPB) gives better results compared to other heuristics (Bahl & Bahl, 2009).

Safety stock

The safety stock is intended to function as a buffer for uncertainties and irregularities in demand to prevent stockouts for the A – ranked materials. The level of the safety stock depends on the defined service level by the MT, which is 90%. The higher the service level, the higher the level of safety stock to be realized, which means more inventory. Therefore a balance must be found between inventory costs and customer service. By using the formula for safety stock (King, 2011), safety stock levels can be calculated to achieve the desired customer service level.

$$I_s = Z * \sigma_{LTD}$$

The average customer demand of the A – ranked products are determined based on historical data. The lead time demand *(LTD =*

*R*L)* is the average customer demand *(R)* during the lead time (*L*) of the supplier (in weeks). The factor σ_{LTD} is the standard deviation of the Lead Time Demand and can be calculated by the following formulas:

$$\sigma_{LTD} = \sigma_R * \sqrt{L} \qquad (1)$$

$$\sigma_{LTD} = \sqrt{L * \sigma_R^2 + R^2 * \sigma_L^2} \qquad (2)$$

In case the supplier has a constant lead time, formula (1) should be applied, otherwise formula (2). The Z-score can be obtained by using the z-table based on the desired service level.

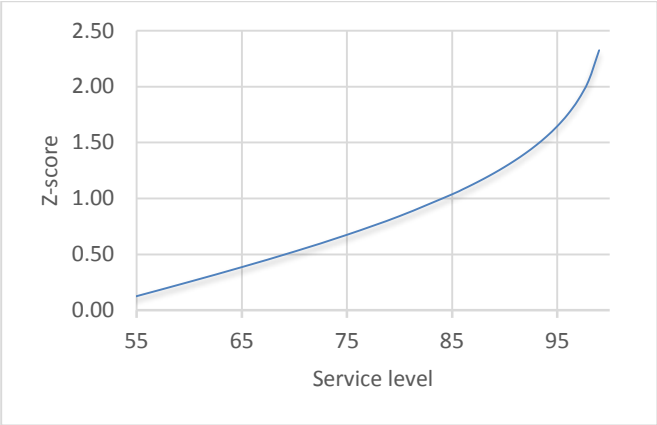

Figure 3: Relation of Z-score and SL

At a service level of 90% a Z-score of 1,28 is found. With these obtained data the safety stock per raw material is calculated.

As for the finished goods, the ABC – analysis showed that 14% of the products is responsible for 80% of the total revenue.
In the MRP is found that 43% of the end products have a buffer stock in the external warehouse, which is a combination of A, B and C – ranked products, while only 14% of the end products provide a turnover of 80%.

Due to the SLA which states that a delivery is guaranteed within 6 weeks, this buffer for finished goods can be reduced to zero since there is enough production capacity. This reduction will reduce the time the products remain in the external warehouse. As a consequence, the inventory turnover increases since the units in the system decreases and therefore a higher performance is attained. This means that the company must convert from a make-to-stock/make-to-order system to a make-to-order system whereby the customer order decoupling point transfers from the external warehouse to the internal warehouse.

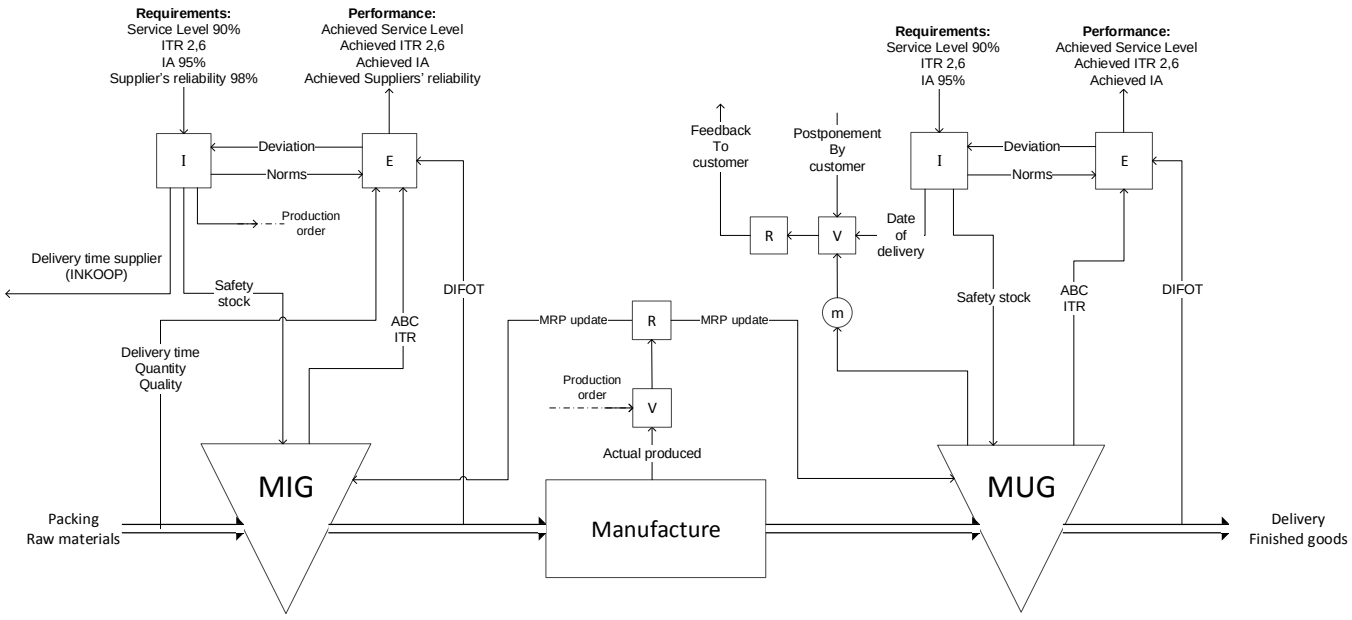

Figure 4: Design of the Inventory control model

Discussion

The current process lacks inventory control and management. The quantities purchased and stored can therefore not be justified. Also no continuous improvement is made possible. The data analysis showed that a certain amount of inventory of finished goods is kept without an order, while the lead time of the production is sufficient to produce on order. Also no detailed forecasts are available and customers can postpone orders indefinitely. This led to the design of the inventory control, which can be seen in figure 4, in order to enable evaluation and continuous improvement of the internal process to reduce working capital. As is the SLA introduced for clear agreements between customer and supplier.

On the basis of the ABC-analysis and the pre-determined service level, justifiable stocks can be held for the A – ranked products.

Using KPIs will give an indication of the performances, which are necessary for the management of inventory and continuous improvement. The desired goals of the KPIs form the requirements on the system and the measured values the performance.

The ordering of raw materials should be based on one of the heuristic lot-sizing methods to reduce the costs between 10% and 50% yearly per material relative to the current ordering process. Furthermore, the safety stocks for finished goods are redundant and can thus be eliminated due to the 6 weeks lead time which is stated in the SLA. This, including the savings that come with it reduces the working capital by 10,5% based on the inventory. The longest lead time for a finished good is 2 weeks, of which 10 days is needed for the Quality Control. Reducing the lead time of the QC will have a great influence on the inventory and flexibility of the process. The extra costs, due to postponement, must be recovered from the customer which should be clearly defined in the contract.

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Appendix B: Price list of CJ Hendriks Group

DIERGAARDE CHEMICAL STORAGE B.V.

ADRES:
Latexweg 10
1047 BJ Amsterdam
Port no. Westpoort 7861
The Netherlands
PHONE:
+ 31(0)20 497 30 11
FAX:
+ 31(0)20 497 79 67
E-MAIL:
info@diergaarde.xs4all.nl
WEBSITE:
www.cjhendriksgroup.com

RABOBANK:
12.68.56.842
IBAN:
NL92 RABO 0126 8568 42
SWIFT:
RABONL2U
K.v.K.:
33276823
BTW:
NL 80.45.20.902.B01

Edilon Sedra

Dienst	*Per*	*Tarief*
1) Transport		
Haarlem – loods Amsterdam	Volle trailer	€ 130,- 115 / 131
Haarlem – loods Amsterdam	Halve trailer	€ 90,- 97
2) inslag		
Inslag per pallet gevaarlijke stoffen, inclusief controle op aantallen en uiterlijke staat (van dozen/emmers) en voorraadadministratie	Pallet	€ 4,25 4,55
Inslag per pallet, inclusief controle op aantallen en uiterlijke staat (van dozen/emmers) en voorraadadministratie *Minimum per inslag is het tarief voor 1 pallet, dit geldt tevens voor 1 of meerdere dozen / losse artikelen*	Pallet	€ 2,50 2,68
3) Bewaarloon per maand		
Gevaarlijke stoffen	Europallet	€ 11,- 11,79
Gevaarlijke stoffen	Blokpallet	€ 13,- 13,93
Berekend vanaf datum inslag tot einde maand, vervolgens liggende voorraad per 1e van de maand		
Ongevaarlijke producten	Europallet	€ 5,- 5,36
Ongevaarlijke producten	Blokpallet	€ 6,- 6,43
Ongevaarlijke producten	2 x 1 meter	€ 7,50 8,04
Berekend vanaf datum inslag tot einde maand, vervolgens liggende voorraad per 1e van de maand		
Bewaarloon per m2	Maand	€ 5,- 5,36
4) Orderpicken		
Orderpicken verschillende artikelen	Artikelregel	€ 4,- 4,29
5) Uitslag		
Per pallet gevaarlijke stoffen	Pallet	€ 4,25 4,55
Per pallet ongevaarlijke stoffen	Pallet	€ 2,50 2,68
Buiten kantoortijden (16:00 – 07:30)	Uur	€ 75,-
6) Administratie		
Opmaken vrachtbrief en administratieve afhandeling voorraadadministratie	Uitgaande zending	€ 5,- 5,36
7) Distributie		
Distributie per pallet door Nederland		Zie bijlage
Distributie pakketjes door Nederland		Zie bijlage
8) Overige		
Op aanvraag natellen van inhoud in dozen / emmers, assemblage werkzaamheden of overige value added logistics	Uur	€ 32,50
Voor grotere projecten kan in overleg een tarief vastgesteld worden		
Tussentijdse telling 1 x per jaar		In tarief

Tarieven exclusief:
* Assurantie
* BTW ad 19%
* Diesel olie toeslag

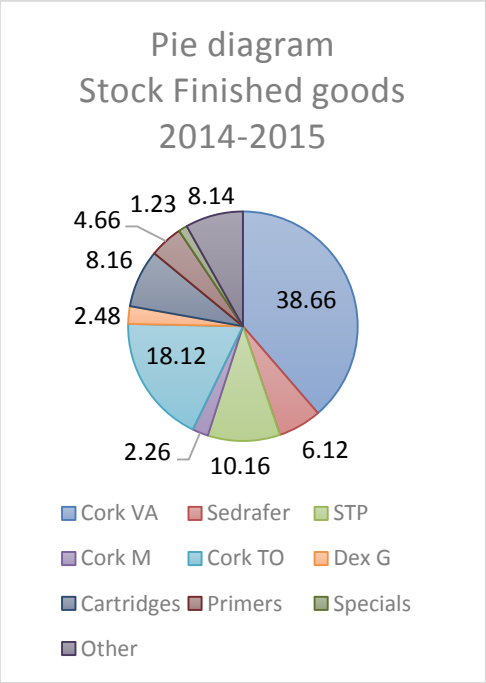
Condities
Opslag: Veemcondities Amsterdam en Rotterdam (meest recente versie)
Transport: AVC dan wel CMR condities (meest recente versie)

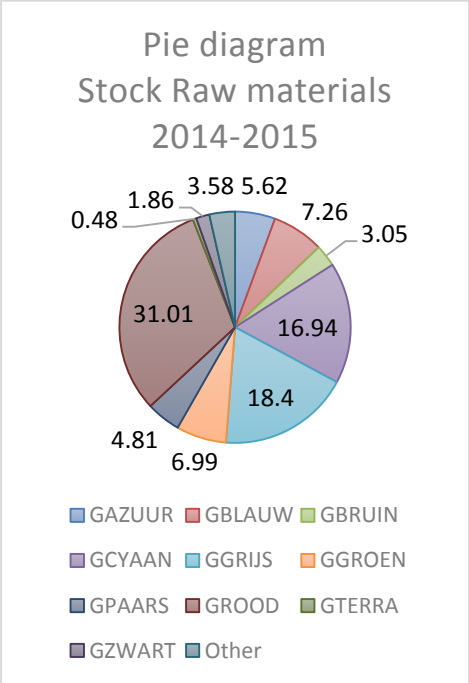
TC 6

CJ Hendriks group

Appendix C: Table stock values of item groups in 2014-2015

Item group	Stock value 2014-2015 (mean)	Percentage %
Finished goods		
Cork VA	€878548,53	38,66
Sedrafer	€139114,82	6,12
STP	€230959,83	10,16
Cork M	€51336,79	2,26
Cork TO	€411693,61	18,12
Dex G	€56258,12	2,48
Cartridges	€185492,18	8,16
Primers	€105953,24	4,66
Specials	€27968,18	1,23
Other	€184917,10	8,14
Total	€2272242,39	100
Raw materials		
GAZUUR	€42621,50	5,62
GBLAUW	€55024,93	7,26
GBRUIN	€23119,90	3,05
GCYAAN	€128382,85	16,94
GGRIJS	€139448,12	18,40
GGROEN	€52987,27	6,99
GPAARS	€36424,56	4,81
GROOD	€235011,93	31,01
GTERRA	€3643,27	0,48
GZWART	€14096,89	1,86
Other	€27143,99	3,58
Total	€757905,20	100





Appendix D: ABC-analysis Finished Goods

Item	Description	ABC	turnover	%	turnover (%)	Number	%	number(%)
VPCLV6004A	EDILON Corkelast VA-60, 12kg	A	3.377.451,520	27,326	27,326	658.720,000	26,514	26,514
VPCLTO008B	EDILON Corkelast TO, 10kg	A	2.783.559,500	22,521	49,848	792.390,000	31,894	58,408
VPCLV7002A	EDILON Corkelast VA-70, 10kg	A	1.489.722,200	12,053	61,901	330.080,000	13,286	71,694
VPCLS2501A	edilon)(sedra STP-25 10kg (2011-1104REC2)	A	914.578,000	7,400	69,301	165.200,000	6,649	78,344
VPDXR2K01A	EDILON Dex-R 2K, 600ml	A	536.391,900	4,340	73,640	28.001,000	1,127	79,471
VPPRU9002B	EDILON Primer U90WB, 3kg	A	368.548,020	2,982	76,622	38.731,000	1,559	81,030
VPDXG2004A	EDILON Dex-G 20 10kg	A	322.413,780	2,609	79,231	56.870,000	2,289	83,319
VPCLV6009A	EDILON Corkelast VA-60, 10kg DB-EBA	B	318.495,440	2,577	81,808	69.930,000	2,815	86,134
VPCLV4001B	EDILON Corkelast VA-40, 9kg	B	312.047,400	2,525	84,333	52.641,000	2,119	88,253
VPDXL2K02A	EDILON Dex-L 2K Tix, 600 ml	B	288.901,490	2,337	86,670	13.432,000	0,541	88,793
VPCLM9502A	EDILON Corkelast M-95, 12kg	B	278.909,930	2,257	88,927	67.452,000	2,715	91,508
VPCLV1507A	SEDRAFER PU EXTRA 15, 10kg	B	265.825,800	2,151	91,077	50.660,000	2,039	93,547
VPDXK2K01A	EDILON Dex-K 2K, 600ml	B	241.396,230	1,953	93,030	17.083,000	0,688	94,235
VPDXG4001B	EDILON Dex-G 40, 15kg	B	133.389,900	1,079	94,110	34.105,000	1,373	95,608
VPCLV9002A	EDILON Corkelast VA-90, 10kg	B	126.673,070	1,025	95,135	25.110,000	1,011	96,633
VPPR21002A	EDILON Primer 21, 3kg	C	96.342,720	0,779	95,914	13.481,000	0,543	97,161
VPSATAC03A	EDILON Editack N BLACK, 20kg	C	52.689,200	0,426	96,340	10.620,000	0,427	97,588
VPPR21003A	EDILON Primer 21 2K, 2kg	C	44.704,600	0,362	96,702	5.287,000	0,213	97,801
VPPRJ0001A	EDILON Primer JS, 2,5kg	C	43.920,000	0,355	97,057	2.930,000	0,118	97,919
VPCLV6008A	EDILON Corkelast VA-60 N, 10kg	C	43.720,000	0,354	97,411	7.000,000	0,282	98,201
VPED70U01A	EDILON Editaan 70U, 16kg	C	42.761,600	0,346	97,757	10.432,000	0,420	98,621
VPDXWR001A	EDILON Dex-WR, 3kg	C	42.096,750	0,341	98,098	3.075,000	0,124	98,745
VPSASEA01B	EDILON Ediseal, 600ml	C	31.458,010	0,255	98,352	1.123,000	0,045	98,790
VPDXL2K04A	EDILON Dex-L 2K Tix, in 200 l vaten	C	31.099,200	0,252	98,604	2.945,000	0,119	98,908
VPDXRH001A	EDILON Dex-RH, 3kg	C	30.134,250	0,244	98,848	2.925,000	0,118	99,026
VPSATAC04A	EDILON Editack N WHITE, 20kg	C	22.410,000	0,181	99,029	4.500,000	0,181	99,207
VPCAS0003A	EDILON Cleaner S, 5kg	C	19.427,390	0,157	99,186	2.555,000	0,103	99,310
VPCLS1501C	edilon)(sedra STP-15 10kg (2011-0602REC51)	C	19.320,000	0,156	99,342	4.020,000	0,162	99,472
VPDXG2002A	EDILON Dex-G 20, 2,5kg	C	11.417,800	0,092	99,435	1.372,500	0,055	99,527
VPCLM7001A	edilon)(sedra Corkelast M-70, 14kg (2013-1001/5)	C	10.373,160	0,084	99,519	2.226,000	0,090	99,617
VPCDM0002A	CDM Last, 10kg	C	9.372,600	0,076	99,595	2.540,000	0,102	99,719
VPDXG2005A	EDILON Dex-G 20 ELV, 10,28kg	C	9.252,770	0,075	99,669	1.573,600	0,063	99,782
VPPR24001A	EDILON Primer 24, 2kg	C	8.637,600	0,070	99,739	934,000	0,038	99,820
VPDXL2K03A	EDILON Dex-L 2K Tix, 60kg	C	7.548,000	0,061	99,800	600,000	0,024	99,844
VPDXG8001A	EDILON Dex-G 80, 20kg	C	6.271,730	0,051	99,851	1.780,000	0,072	99,916
VPPR21001A	EDILON Primer 21, 0,5kg	C	5.641,300	0,046	99,897	203,000	0,008	99,924
VPDXG2003A	EDILON Dex-G 20 USA, 22 lb (10kg)	C	4.410,000	0,036	99,932	750,000	0,030	99,954
VPCARA001A	EDILON Release agent, 10kg	C	2.984,000	0,024	99,957	140,000	0,006	99,960
VPCAMC003A	edilon)(sedra Machine rinsing agent, 10kg	C	1.450,000	0,012	99,968	500,000	0,020	99,980
VPPRU9006A	EDILON Primer U90WB USA, 6,6 lb (3kg)	C	885,600	0,007	99,976	90,000	0,004	99,983
VPCLV4011A	EDILON Corkelast VA-40 USA, 19 lb (9kg)	C	729,000	0,006	99,981	135,000	0,005	99,989
VPDXGF003A	EDILON Dex-GF, 12kg	C	708,000	0,006	99,987	60,000	0,002	99,991
VPCLV6010A	EDILON Corkelast VA-60 USA, 26,5lb (12kg)	C	562,320	0,005	99,992	132,000	0,005	99,997
VPCAS0004A	CDM Cleaner, 5kg	C	453,500	0,004	99,995	50,000	0,002	99,999
VPCATOO01C	edilon)(sedra Tool cleaner, 10kg	C	415,000	0,003	99,999	10,000	0,000	99,999
VPPR21004A	CDM-1K Primer, 3kg	C	120,060	0,001	100,000	18,000	0,001	100,000
VPPR21007A	EDILON Primer 21 USA, 6,6lb (3kg)	C	36,420	0,000	100,000	6,000	0,000	100,000
VPCARA002A	EDILON Release agent, 250ml	C	0,000	0,000	100,000	2,000	0,000	100,000
VPCLTO008A	EDILON Corkelast TO, 10kg	C	0,000	0,000	100,000	0,000	0,000	100,000
TOTAL			12.359.657	100		2.484.420		

Appendix E: ABC-Analysis packing- & raw materials

Item	Description	ABC	Purchase costs	%	Purchase cost (%)	Aantal	%	Number (%)
GROOD0018A	**DESMODUR E15 of Vorastar HB6624**	A	1.217.917,800	16,769	16,769	454.110,000	8,864	8,864
GCYAAN008A	**CARADOL SP30-15, tank 1**	A	616.834,000	8,493	25,262	344.600,000	6,726	15,590
GROOD0017A	**Desmodur E14 of Vorastar HB6668, IBC 1000kg**	A	577.498,000	7,951	33,214	213.825,000	4,174	19,763
GCYAAN003A	**DESMOPHEN 2061BD of Voranol 2000L, tank 3**	A	457.518,000	6,299	39,513	259.620,000	5,067	24,831
EEMMPP003A	**Emmer 14 liter, wit**	A	354.886,400	4,886	44,399	249.920,000	4,878	29,709
GBLAUW002A	**JAYFLEX DINP, tank 5**	A	279.756,300	3,852	48,251	198.570,000	3,876	33,584
EBLKST018A	**Blik 5 liter, consafe**	A	276.441,000	3,806	52,058	125.655,000	2,453	36,037
GGRIJS021A	**Purmol 3ST / Baylith-L poeder**	A	205.920,000	2,835	54,893	78.700,000	1,536	37,573
GROOD0016A	**SUPRASEC 2030**	A	199.500,000	2,747	57,640	70.000,000	1,366	38,939
GROOD0006A	**ETHACURE 300**	A	184.800,000	2,544	60,184	16.800,000	0,328	39,267
GROOD0005A	**Ethacure 100**	A	164.900,000	2,270	62,455	34.000,000	0,664	39,931
GAZUUR001A	**Kaneka Silyl SAX510**	A	143.250,000	1,972	64,427	29.000,000	0,566	40,497
GROOD0004A	**EPILINK 701 Verharder**	A	133.740,000	1,841	66,268	18.000,000	0,351	40,848
GAZUUR002A	**Kaneka Silyl SAX260**	A	133.000,000	1,831	68,100	28.000,000	0,547	41,395
GGRIJS029A	**EXPANCEL 461 DET 80d25**	A	126.918,000	1,747	69,847	4.752,000	0,093	41,488
GGROEN004A	**ECOCRYL Resin 05345**	B	105.820,000	1,457	71,304	16.000,000	0,312	41,800
GGROEN002A	**EPIKOTE Resin 238 / EPILOX AF 18-30, tank 4**	B	104.412,000	1,438	72,742	31.640,000	0,618	42,417
GROOD0012A	**CARDOLITE NC 566**	B	101.758,160	1,401	74,143	18.776,160	0,366	42,784
GGROEN003A	**EPIKOTE Resin 169 / Epilox AF 16-50**	B	73.000,000	1,005	75,148	10.000,000	0,195	42,979
GGRIJS011A	**Kurk AP 649 (1-2mm)**	B	71.675,370	0,987	76,135	50.618,200	0,988	43,967
GGRIJS025A	**WINNOFIL SPT**	B	69.187,500	0,953	77,087	56.250,000	1,098	45,065
GCYAAN016A	**Daltoped AF 55905**	B	67.680,000	0,932	78,019	14.400,000	0,281	45,346
GCYAAN004A	**DESMOPHEN 5034 BT of DOW Voranol CP 4755 of Voramer MM-2515**	B	65.800,000	0,906	78,925	30.000,000	0,586	45,932
GGRIJS017A	**MICRODOL A1, 500kg**	B	53.065,800	0,731	79,656	256.000,000	4,997	50,928
EKOKPP001A	**Koker 2x300 ml, PP, oranje, Sulzer**	B	48.735,000	0,671	80,327	51.300,000	1,001	51,930
EBLKST007A	**Blik 10 liter, chroom**	B	44.467,500	0,612	80,939	18.150,000	0,354	52,284
GGRIJS004A	**Rubbergranulaat 0,5-2 mm**	B	42.172,020	0,581	81,520	191.691,000	3,742	56,026
GBRUIN006A	**Anti-Terra-204**	B	41.995,800	0,578	82,098	5.940,000	0,116	56,141
GGRIJS031A	**MICRODOL 1KN, zak**	B	39.823,200	0,548	82,646	207.600,000	4,052	60,194
GROOD0007A	**EPIKURE Curing Agent 105**	B	38.400,000	0,529	83,175	5.000,000	0,098	60,291
GGRIJS032A	**Carbital C110S**	B	38.250,000	0,527	83,702	75.000,000	1,464	61,755
GBLAUW006A	**HELOXY Modifier HD**	B	37.380,000	0,515	84,216	6.000,000	0,117	61,872
GZWART001A	**Vlamroet 101**	B	34.782,000	0,479	84,695	10.200,000	0,199	62,071
EPALHT003A	**Pallet 800x1200 mm (CP2), gegast hout**	B	34.521,000	0,475	85,171	6.584,000	0,129	62,200
GTERRA004A	**NOXYDE 50 Black**	B	33.672,000	0,464	85,634	7.320,000	0,143	62,343
EDOOKT016A	**Doos 2x14 liter**	B	28.940,560	0,398	86,033	31.441,000	0,614	62,956
EFLSPE003A	**Fles 1 liter, PE, transparant, UN keur, inclusief seal dop**	B	28.560,000	0,393	86,426	81.600,000	1,593	64,549
GPAARS004A	**DABCO B-16**	B	28.434,480	0,392	86,818	2.766,000	0,054	64,603
GBRUIN008A	**BYK-E 410**	B	27.936,000	0,385	87,202	1.600,000	0,031	64,634
GROOD0001A	**EPIKURE Curent Agent 114**	B	24.576,000	0,338	87,541	3.200,000	0,062	64,697
GGRIJS002A	**GARAMITE 1958**	B	22.869,000	0,315	87,855	2.100,000	0,041	64,738
EFOLPE004A	**Krimpfolie 1250/2x425x2360 mm, 175mu, PE**	B	21.193,460	0,292	88,147	5.690,000	0,111	64,849
GGRIJS007A	**Portaryte D50, 1000kg**	B	20.487,000	0,282	88,429	65.000,000	1,269	66,117
GTERRA008A	**NOXYDE WHITE**	B	18.952,000	0,261	88,690	4.120,000	0,080	66,198
EQUAPP002A	**EDILON Static Mixer, PP, orange**	B	18.512,800	0,255	88,945	58.400,000	1,140	67,338
GCYAAN007A	**RICINUSOLIE**	B	18.392,000	0,253	89,198	10.450,000	0,204	67,542
GCYAAN019A	**Specflex NC 700**	B	17.808,000	0,245	89,444	6.720,000	0,131	67,673
EEMMPP005A	**Emmer 3,4 liter, wit**	B	17.286,000	0,238	89,682	25.800,000	0,504	68,176
GBLAUW004A	**Protectol PP**	B	17.078,000	0,235	89,917	5.840,000	0,114	68,290
GROOD0015A	**SUPRASEC 5025**	B	16.625,000	0,229	90,146	6.250,000	0,122	68,412
GPAARS005A	**Borchi Kat 24**	B	15.876,500	0,219	90,364	1.130,000	0,022	68,434
GGRIJS006A	**AEROSIL R 202**	B	15.860,000	0,218	90,583	1.000,000	0,020	68,454
GPAARS007A	**ACCELERATOR 399**	B	15.513,180	0,214	90,796	2.724,000	0,053	68,507
GBRUIN011A	**Dynasylan AMMO / Syntreco Silane 565**	B	15.420,000	0,212	91,009	1.200,000	0,023	68,531
GCYAAN001A	**DESMOPHEN 1400 BT**	B	14.960,000	0,206	91,214	4.400,000	0,086	68,616
GROOD0023A	**SUPRASEC 2433**	B	14.850,000	0,204	91,419	5.400,000	0,105	68,722
GBLAUW003A	**Novares LA 300**	B	14.720,000	0,203	91,622	3.200,000	0,062	68,784
GBLAUW008A	**JEFFSOL PC**	B	14.040,000	0,193	91,815	6.000,000	0,117	68,901
EFLSPE004A	**Fles 500 ml, PE, transparant, UN keur**	B	14.021,640	0,193	92,008	5.458,000	0,107	69,008

GTERRA003A	Safe Clean reinigingmiddel	B	13.995,600	0,193	92,201	3.210,000	0,063	69,071
GROOD0014A	PEROXAN BP-40 LS	B	13.860,000	0,191	92,392	2.100,000	0,041	69,112
GZWART006A	Repiplast White 11103	B	13.600,000	0,187	92,579	1.600,000	0,031	69,143
GBRUIN011B	Syntreco Silane 565	B	12.850,000	0,177	92,756	1.000,000	0,020	69,162
GROOD0019A	DESMODUR E 21	B	12.555,000	0,173	92,929	2.700,000	0,053	69,215
GPAARS003A	DABCO T-12N	B	12.444,000	0,171	93,100	680,000	0,013	69,228
GBRUIN005B	ADD-3772	B	12.402,750	0,171	93,271	755,000	0,015	69,243
EPALHT002A	Pallet 1200x1000 mm (CP1), gegast hout	B	11.920,000	0,164	93,435	2.384,000	0,047	69,290
EFLSPE005A	Fles 2 liter, PE, rechthoek	B	11.826,860	0,163	93,598	9.072,000	0,177	69,467
EPLTHT001A	Tussenplaat voor pallet, MDF	B	11.743,380	0,162	93,759	5.931,000	0,116	69,582
GBRUIN009A	Dynasylan VTMO	B	11.388,000	0,157	93,916	1.560,000	0,030	69,613
GTERRA001A	METHYLEEN CHLORIDE	B	11.046,240	0,152	94,068	15.120,000	0,295	69,908
GBRUIN010A	Dynasylan DAMO-T	B	10.810,000	0,149	94,217	800,000	0,016	69,924
GGROEN005A	Bisomer 1.4 BDDMA	B	10.368,000	0,143	94,360	1.600,000	0,031	69,955
EETKPP022B	Etiket set Dex-L 2K TIX	B	10.084,800	0,139	94,499	11.000,000	0,215	70,170
GGRIJS022A	Portaryte D50, 25kg	B	9.571,320	0,132	94,630	31.800,000	0,621	70,790
GROOD0026A	Anquamine 287	B	9.024,000	0,124	94,755	1.600,000	0,031	70,821
GPAARS010A	Ancamine K54	B	8.980,000	0,124	94,878	2.600,000	0,051	70,872
GTERRA011A	Multisol 210 C	C	8.830,400	0,122	95,000	590,000	0,012	70,884
EBLKST004A	Blik 2,5 liter, chroom	C	8.468,990	0,117	95,117	4.679,000	0,091	70,975
EETKPP004C	Etiket Corkelast VA-60 C2, 12kg	C	8.280,000	0,114	95,231	46.000,000	0,898	71,873
EETKPP004B	Etiket Corkelast VA-60 C2, 12kg	C	8.210,400	0,113	95,344	43.000,000	0,839	72,712
EDOOKT001A	Doos 4 x 3 liter	C	8.079,520	0,111	95,455	10.665,000	0,208	72,920
GCYAAN005A	1.4-Butaandiol	C	7.840,000	0,108	95,563	3.200,000	0,062	72,983
GPAARS009A	SR-Add 6400	C	7.800,000	0,107	95,670	800,000	0,016	72,998
EKOKKT001A	Palletondersteuningskoker karton 430x96x76 mm	C	7.645,100	0,105	95,775	8.590,000	0,168	73,166
GBRUIN004B	ADD-2722	C	7.603,200	0,105	95,880	900,000	0,018	73,184
EFOLPE002A	Krimpfolie 1320/2x600x2650 mm, 175mu, PE	C	7.530,660	0,104	95,984	1.605,000	0,031	73,215
EBLKST009A	Blik 21,7 liter, spanring	C	7.318,080	0,101	96,085	1.584,000	0,031	73,246
EIBCPE001A	IBC 1000 liter, PE+staal, UN Keur	C	7.241,000	0,100	96,184	65,000	0,001	73,247
EETKPP009B	Etiket Corkelast TO C2, 10kg	C	7.089,000	0,098	96,282	71.000,000	1,386	74,633
GAZUUR007A	Kaneka Silyl SAX590	C	6.860,000	0,094	96,376	1.400,000	0,027	74,660
GGRIJS018A	MICRODOL A70	C	6.594,480	0,091	96,467	37.200,000	0,726	75,386
EETKPP005B	Etiket Primer U90WB C2, 3kg	C	6.224,900	0,086	96,553	11.000,000	0,215	75,601
GGRIJS008A	Devolite	C	6.192,000	0,085	96,638	14.400,000	0,281	75,882
EPLTKT002A	Pallet beschermingskarton 2155x800x10 mm	C	6.177,600	0,085	96,723	2.160,000	0,042	75,924
EETKPP014B	Etiket Primer U90WB C1 3kg	C	6.106,100	0,084	96,807	11.000,000	0,215	76,139
EETKPP027B	Etiket Corkelast VA-60 C1, 12kg	C	6.045,000	0,083	96,890	46.500,000	0,908	77,047
GGRIJS016A	Micro Talc IT Extra 585-PB	C	5.990,400	0,082	96,973	4.680,000	0,091	77,138
GAZUUR008A	Kaneka Sylil SAX750	C	5.940,000	0,082	97,055	1.200,000	0,023	77,161
EETKPP027A	Etiket Corkelast VA-60 C1, 12kg	C	5.865,300	0,081	97,136	42.000,000	0,820	77,981
GBLAUW005A	BENZYLALCOHOL	C	5.814,000	0,080	97,216	1.800,000	0,035	78,016
EVELPR001A	Antislippapier 800x600 mm, papier	C	5.752,400	0,079	97,295	26.000,000	0,507	78,524
EFLSPE002A	Fles 500 ml, PE, wit	C	5.713,150	0,079	97,373	16.512,000	0,322	78,846
EEMMPP001A	Emmer 20 liter, rechthoek, wit	C	5.645,500	0,078	97,451	1.750,000	0,034	78,880
EETKPP025A	Etiket Corkelast TO C1, 10kg	C	5.559,000	0,077	97,528	72.000,000	1,405	80,286
EPALHD001A	Pallet hoed, 1195x7950x98 mm	C	5.331,400	0,073	97,601	4.370,000	0,085	80,371
EBLKST012A	Blik 2,5 liter, wit	C	5.328,000	0,073	97,674	2.880,000	0,056	80,427
GPAARS015A	TIB KAT 324	C	5.320,000	0,073	97,748	200,000	0,004	80,431
EBLKST016A	Blik 2 liter	C	5.256,900	0,072	97,820	2.970,000	0,058	80,489
GZWART009A	Ti-pure R-902+	C	5.025,000	0,069	97,889	1.500,000	0,029	80,518
EDOOKT015A	Doos 11x1 liter	C	4.783,700	0,066	97,955	7.855,000	0,153	80,672
GCYAAN018A	DESMOPHEN 4011 T	C	4.575,200	0,063	98,018	1.720,000	0,034	80,705
EDOOKT008A	Doos 16x600 ml (Dex-K 2)	C	4.575,000	0,063	98,081	2.500,000	0,049	80,754
GGRIJS013A	QUARTZ FLOUR SILVERBOND M	C	4.536,000	0,062	98,144	21.000,000	0,410	81,164
EEMMPP004A	Emmer 1,6 liter, wit	C	4.449,580	0,061	98,205	14.768,000	0,288	81,452
GGRIJS014A	Kwartszand S60	C	4.249,000	0,059	98,263	28.000,000	0,547	81,999
EETKPP023B	Etiket set Dex-R 2K	C	4.240,000	0,058	98,322	20.000,000	0,390	82,389
EETKPP020B	Etiket set Dex-K 2K	C	4.240,000	0,058	98,380	20.000,000	0,390	82,779

EVATST004A	**Vat 216 liter, Staal, Ringband, ingenekt, blauw**	C	4.000,000	0,055	98,435	100,000	0,002	82,781
EDOOKT012A	**Doos 14x600 ml**	C	3.945,550	0,054	98,490	5.935,000	0,116	82,897
EETKPP025B	**Etiket Corkelast TO C1, 10kg**	C	3.475,000	0,048	98,537	25.000,000	0,488	83,385
EETKPP023A	**Etiket set Dex-R 2K**	C	3.465,000	0,048	98,585	21.000,000	0,410	83,795
EEMMPE001A	**Emmer 3 liter, Oranje**	C	3.320,000	0,046	98,631	4.000,000	0,078	83,873
EETKPP014C	**Etiket Primer U90WB C1 3kg**	C	3.280,000	0,045	98,676	10.000,000	0,195	84,068
EETKPP009C	**Etiket Corkelast TO C2, 10kg**	C	2.907,000	0,040	98,716	25.500,000	0,498	84,566
EETKPE064B	**Etiket Mat zilver polyester Void permanent (blanco) AA 973**	C	2.868,000	0,039	98,755	160.800,000	3,139	87,705
GPAARS008A	**4-MHHPA**	C	2.750,000	0,038	98,793	220,000	0,004	87,709
EETKPP007B	**Etiket Dex-G 20 C2, 10kg**	C	2.688,000	0,037	98,830	6.000,000	0,117	87,826
EETKPE053A	**Etiket TRACKELAST mat, 130x70mm**	C	2.614,500	0,036	98,866	41.500,000	0,810	88,636
EETKPP005C	**Etiket Primer U90WB C2, 3kg**	C	2.499,000	0,034	98,901	10.500,000	0,205	88,841
EETKPP010C	**Etiket Primer 21 2K C1**	C	2.420,000	0,033	98,934	10.000,000	0,195	89,036
GBRUIN013A	**Dynasylan IBTMO**	C	2.377,500	0,033	98,967	150,000	0,003	89,039
GGRIJS033A	**Cenospheres PCS-UG**	C	2.360,000	0,032	98,999	2.000,000	0,039	89,078
GCYAAN011A	**DESMOPHEN 4051 B**	C	2.328,900	0,032	99,031	630,000	0,012	89,090
GPAARS012A	**PERGASLOW BK-10**	C	2.306,250	0,032	99,063	225,000	0,004	89,095
GPAARS006A	**ACCELERATOR 3130 CH**	C	2.275,000	0,031	99,094	100,000	0,002	89,097
GBRUIN012A	**Dynasylan Glymo**	C	2.260,000	0,031	99,126	200,000	0,004	89,101
GROOD0008A	**EPIKURE Curing Agent 934**	C	2.242,000	0,031	99,156	200,000	0,004	89,104
EZAK00002A	**Document A4, zelfklevend, transparant**	C	2.226,000	0,031	99,187	14.000,000	0,273	89,378
GPAARS001A	**Lupragen N 103**	C	2.190,600	0,030	99,217	180,000	0,004	89,381
EIBCPE003A	**IBC 1000 liter, PE+staal (rebuild), vulopening 400mm**	C	2.142,000	0,029	99,247	18,000	0,000	89,382
GROOD0024A	**DESMODUR E 23**	C	2.137,500	0,029	99,276	450,000	0,009	89,390
EETKPP022C	**Etiket set Dex-L 2K TIX**	C	2.120,000	0,029	99,305	10.000,000	0,195	89,586
GPAARS011A	**PERGAQUICK A150**	C	2.106,000	0,029	99,334	180,000	0,004	89,589
EVATPE001A	**Vat 60 liter, PE, blauw**	C	2.065,500	0,028	99,363	162,000	0,003	89,592
EETKPE064A	**Etiket Mat zilver polyester Void permanent (blanco)**	C	2.058,000	0,028	99,391	105.000,000	2,049	91,642
EETKPR001A	**Etiket edilon)(sedra 96x195mm groot**	C	2.045,250	0,028	99,419	101.250,000	1,976	93,618
EETKPE014B	**Etiket Dex-G20 C1, 10kg**	C	1.968,000	0,027	99,446	6.000,000	0,117	93,735
GGRIJS019A	**MAGLITE DE**	C	1.950,000	0,027	99,473	600,000	0,012	93,747
GGRIJS005A	**AEROSIL 300**	C	1.836,000	0,025	99,499	180,000	0,004	93,750
GZWART004A	**ORANGE REPITAN 39731**	C	1.820,000	0,025	99,524	200,000	0,004	93,754
EDOOKT003A	**Doos 4x2,5 liter**	C	1.659,200	0,023	99,546	2.720,000	0,053	93,807
EETKPP001C	**Etiket Primer 21, 3kg**	C	1.639,000	0,023	99,569	5.500,000	0,107	93,915
GBRUIN001A	**BYK-P 104S**	C	1.604,000	0,022	99,591	100,000	0,002	93,917
GGRIJS015A	**Kwartsmix C1-0.06 t/m 3.5mm**	C	1.600,000	0,022	99,613	8.000,000	0,156	94,073
EKOKPP002A	**Koker 2x300 ml, PP, oranje, Ritter**	C	1.575,600	0,022	99,635	1.560,000	0,030	94,103
EBLKST015A	**Blik 500 ml, balgsluiting**	C	1.425,600	0,020	99,654	1.760,000	0,034	94,138
EEMMPP002A	**Emmer 33 liter, rechthoek, wit**	C	1.423,200	0,020	99,674	300,000	0,006	94,143
VHVEER006A	**Gasveer 180N**	C	1.215,800	0,017	99,691	20,000	0,000	94,144
EETKPR002A	**Etiket edilon)(sedra 105x140mm klein**	C	1.200,000	0,017	99,707	120.000,000	2,342	96,486
GGROEN007A	**Epilox A 19-00**	C	1.172,000	0,016	99,723	400,000	0,008	96,494
GGRIJS026A	**Portariet B10**	C	1.152,000	0,016	99,739	2.400,000	0,047	96,541
EETKPE013B	**Etiket Dex-GF C2, 12kg**	C	918,000	0,013	99,752	5.400,000	0,105	96,646
EFLSPE001A	**Fles 250 ml, PE, transparant**	C	900,000	0,012	99,764	3.600,000	0,070	96,716
EETKPE056A	**Etiket Dex-G20 C2 USA, 10kg**	C	840,000	0,012	99,776	500,000	0,010	96,726
GZWART005A	**BLACK REPITAN/IN 99430**	C	840,000	0,012	99,787	200,000	0,004	96,730
EETKPE054A	**Etiket TRACKELAST pallet, 300x160mm**	C	810,000	0,011	99,799	5.000,000	0,098	96,828
EETKPP028A	**Etiket SEDRAFER PU EXTRA 15 C1, 200l**	C	796,000	0,011	99,810	2.000,000	0,039	96,867
EETKPP029A	**Etiket SEDRAFER PU EXTRA 15 C2, 20l**	C	796,000	0,011	99,821	2.000,000	0,039	96,906
EQUAPP003A	**EDILON Extension Tube for Static Mixer, PP**	C	750,200	0,010	99,831	24.200,000	0,472	97,378
EEMMPE004A	**Emmer 32 liter, Wit**	C	738,000	0,010	99,841	180,000	0,004	97,382
EFOLPE005A	**Krimpfolie 1250/2x425x2510 mm, 175mu, PE**	C	726,000	0,010	99,851	150,000	0,003	97,384
GBRUIN007A	**INCOZOL 2**	C	694,800	0,010	99,861	20,000	0,000	97,385
EZAKVC001A	**Buisfoliezak 200x1000 mm, PE**	C	690,000	0,010	99,870	3.000,000	0,059	97,443
GZWART002A	**NEBOTINT M 7045**	C	538,560	0,007	99,877	57,600	0,001	97,445
EBLKST003A	**Blik 1 liter**	C	528,000	0,007	99,885	480,000	0,009	97,454
VHHDVT001A	**ediMix Handvat 5708**	C	514,500	0,007	99,892	10,000	0,000	97,454
EETKPE012C	**Etiket Dex-GF C1, 12kg**	C	440,500	0,006	99,898	5.000,000	0,098	97,552
GGRIJS034A	**Laponite EP**	C	421,250	0,006	99,904	25,000	0,000	97,552

EJRCPE001A	**Jerrycan 10 liter, PE, blauw**	C	407,820	0,006	99,909	210,000	0,004	97,556
EETKPE023C	**Etiket Edilon shims**	C	400,000	0,006	99,915	1.000,000	0,020	97,576
EETKPE022A	**Etiket Edilon Spacers**	C	380,000	0,005	99,920	1.000,000	0,020	97,595
GPAARS013A	**DABCO 33 LV**	C	376,960	0,005	99,925	38,000	0,001	97,596
EETKPE013D	**Etiket Dex-GF C2, 12kg**	C	364,000	0,005	99,930	5.200,000	0,101	97,698
EETKPE013C	**Etiket Dex-GF C2, 12kg**	C	350,000	0,005	99,935	5.000,000	0,098	97,795
EETKPE012A	**Etiket Dex-GF C1, 12kg**	C	350,000	0,005	99,940	5.000,000	0,098	97,893
EBLKST011A	**Blik 25 liter, Blauw UNX45/S, 2 handv. incl. deksel en spanr**	C	328,500	0,005	99,944	30,000	0,001	97,893
EETKPR041A	**Etiket DB - EBA (Fluor geel) 60x40mm**	C	320,000	0,004	99,949	20.000,000	0,390	98,284
GTERRA010A	**Clearox**	C	310,500	0,004	99,953	30,000	0,001	98,284
EETKPE016C	**Etiket Editack N BLACK, 20kg**	C	305,000	0,004	99,957	500,000	0,010	98,294
EETKPE016D	**Etiket Editack N BLACK, 20kg**	C	305,000	0,004	99,961	500,000	0,010	98,304
EETKPE059B	**Etiket Editack N WHITE, 20kg**	C	305,000	0,004	99,966	500,000	0,010	98,314
EBLKST017A	**Verbindingsring blikken 99 mm**	C	285,000	0,004	99,970	1.500,000	0,029	98,343
EVATST002A	**Vat 200 liter, Staal, Ringband, rechte wand, blauw**	C	260,000	0,004	99,973	8,000	0,000	98,343
EETKPR010A	**Etiket ADR LQ 10x10 cm**	C	216,000	0,003	99,976	9.000,000	0,176	98,519
EETKPP026B	**Etiket Corkelast VA-40 C1, 9kg**	C	200,000	0,003	99,979	20.000,000	0,390	98,909
EETKPP006C	**Etiket Corkelast VA-40 C2, 9kg**	C	200,000	0,003	99,982	20.000,000	0,390	99,299
EETKPE059A	**Etiket Editack N WHITE, 20kg**	C	183,000	0,003	99,984	300,000	0,006	99,305
EETKPE025A	**Etiket Installatiepakket Edilon ERS Harmelen 6m**	C	180,000	0,002	99,987	200,000	0,004	99,309
EFLSPE007A	**Fles 60 ml, HDPE, naturel**	C	178,500	0,002	99,989	1.050,000	0,020	99,330
EETKPP032A	**Etiket Corkelast VA-40 & VA-60 C2, 1000kg**	C	125,000	0,002	99,991	100,000	0,002	99,332
EETKPR028B	**Etiket CDM Seal**	C	100,000	0,001	99,992	200,000	0,004	99,335
EETKPP011C	**Etiket Primer 21 2K C2**	C	100,000	0,001	99,994	10.000,000	0,195	99,531
EETKPR026A	**Etiket ADR 5.2 rood/geel**	C	60,000	0,001	99,994	2.000,000	0,039	99,570
VHSTEK005A	**NEMA stekker 125V (USA)**	C	57,150	0,001	99,995	5,000	0,000	99,570
EETKPR038B	**Etiket CDM Cleaner**	C	50,000	0,001	99,996	100,000	0,002	99,572
EETKPR016C	**Etiket CDM last C1**	C	50,000	0,001	99,997	100,000	0,002	99,574
EETKPR017C	**Etiket CDM last C2**	C	50,000	0,001	99,997	100,000	0,002	99,576
EETKPR018C	**Etiket CDM-1K Primer**	C	50,000	0,001	99,998	100,000	0,002	99,578
EETKPR019C	**Etiket CDM-2K Primer C1**	C	50,000	0,001	99,999	100,000	0,002	99,580
EETKPR020C	**Etiket CDM-2K Primer C2**	C	50,000	0,001	99,999	100,000	0,002	99,582
EETKPR040A	**Etiket Behandelingsetiket 11 pijl 74x105 mm**	C	29,000	0,000	100,000	1.000,000	0,020	99,601
EETKPR025A	**Etiket edilon)(sedra 45x200mm**	C	18,230	0,000	100,000	50,000	0,001	99,602
GBRUIN004A	**EFKA-2722**	C	0,000	0,000	100,000	0,000	0,000	99,602
EETKPP006B	**Etiket Corkelast VA-40 C2, 9kg**	C	0,000	0,000	100,000	10.000,000	0,195	99,797
EETKPP030A	**Etket Dex-L 2K Tix C1, 266kg**	C	0,000	0,000	100,000	100,000	0,002	99,799
EETKPP031A	**Etket Dex-L 2K Tix C2, 323kg**	C	0,000	0,000	100,000	100,000	0,002	99,801
EETKPP026A	**Etiket Corkelast VA-40 C1, 9kg**	C	0,000	0,000	100,000	9.000,000	0,176	99,977
EBLKST019A	**Blik 1 liter, QC monster (blank UN + deksel)**	C	0,000	0,000	100,000	1.190,000	0,023	100,000
Totaal		**219**	**7.262.833,800**	**100**		**5.123.338,960**	**100**	

Appendix F: Raw materials for A-rated products including delivery time and minimum order quantity

Raw material	VA 60 [12 days]	VA 70 [5 days]	TO [7 days]	STP 25 [12 days]	Delivery time in days	min. order quantity [kg/pcs]
GGRIJS011A	390 kg	115 kg			60	12000 kg
GCYAAN001A	24,64 kg				42	800 kg
GBLAUW002A		760 kg	381 kg	683 kg	30	1000 kg IBC/20.000 kg tank
GCYAAN003A			887 kg		30	1000 kg IBC/20.000 kg tank
GCYAAN004A		305 kg			30	1000 kg
GROOD0018A	3173,9 kg				28	1000 kg IBC/20.000 kg tank
GROOD0017A		4420 kg			28	1000 kg IBC/20.000 kg tank
GBLAUW004A	35,88 kg				24	210 kg
GAZUUR001A				721 kg	21	1000 kg
GAZUUR002A				721 kg	21	1000 kg
GGRIJS032A				1609,2 kg	21	1500 kg
GBRUIN011A				51,9 kg	21	200 kg
GPAARS015A				1,071 kg	21	50 kg
GBRUIN006A	19,48 kg	27 kg	6,79 kg		18	720 kg
GROOD0006A			52,32 kg		14	1200 kg [CS]
GPAARS003A	2,962 kg		0,71 kg		14	20 kg
GPAARS004A	15,072 kg		0,94 kg		14	15 kg
GGRIJS021A	345 kg	80 kg	109 kg		14	480 kg
GROOD0005A	135,05 kg	302 kg			14	1000 kg [CS]
GBRUIN008A	6,08 kg				14	200 kg
GGRIJS007A		1800 kg			14	1000 kg
GBLAUW008A		150 kg			14	250 kg
GGRIJS031A	2038 kg	600 kg	612 kg		10	1200 kg
GBRUIN009A				28,83 kg	10	195 kg
GBRUIN010A				20,18 kg	10	200 kg
GGRIJS004A			715 kg		7	12.000 kg
GROOD0016A			816,2 kg		7	5000 kg
GCYAAN008A	3310 kg	794 kg			7	20.000 kg tank
GZWART001A	125 kg	125 kg		41,81 kg	7	600 kg
GGRIJS025A	310 kg	200 kg			7	1125 kg
GGRIJS008A		200 kg			7	1200 kg
GPAARS008A		2,11 kg			7	220 kg
GCYAAN005A			8,38 kg		4	200 kg
GTERRA002A				15,3 kg	0	-

Appendix G: Service Level Agreement (SLA)

Service Level Agreement between Edilon Sedra BV an Edilon Sedra Group BV

Regarding availability of products, following is agreed:

Trade Goods

1. BV does not keep stock of trade goods, and purchases based on confirmed orders in Exact Globe.
2. Lead time is order-specific and will be confirmed by BV within 48 hours after placing the order. At the request of Group, BV will confirm a lead time in advance.
3. BV will keep (minimum) stock of specified products and quantities, if Group requires BV to do so (based on an agreement with their client). Group is obligated to sell this product/volume within 6 months, until further notice.
4. BV guarantees on time delivery, after confirmation of order.
5. In case of acts of god/force majeure, BV will immediately inform Group. Guarantee then no longer applies.
6. In case of delay of the sales order that exceeds 2 weeks, BV will charge 0.45% per month (based on ICP price) to Group to cover capital and storage costs. This is calculated pro rata.

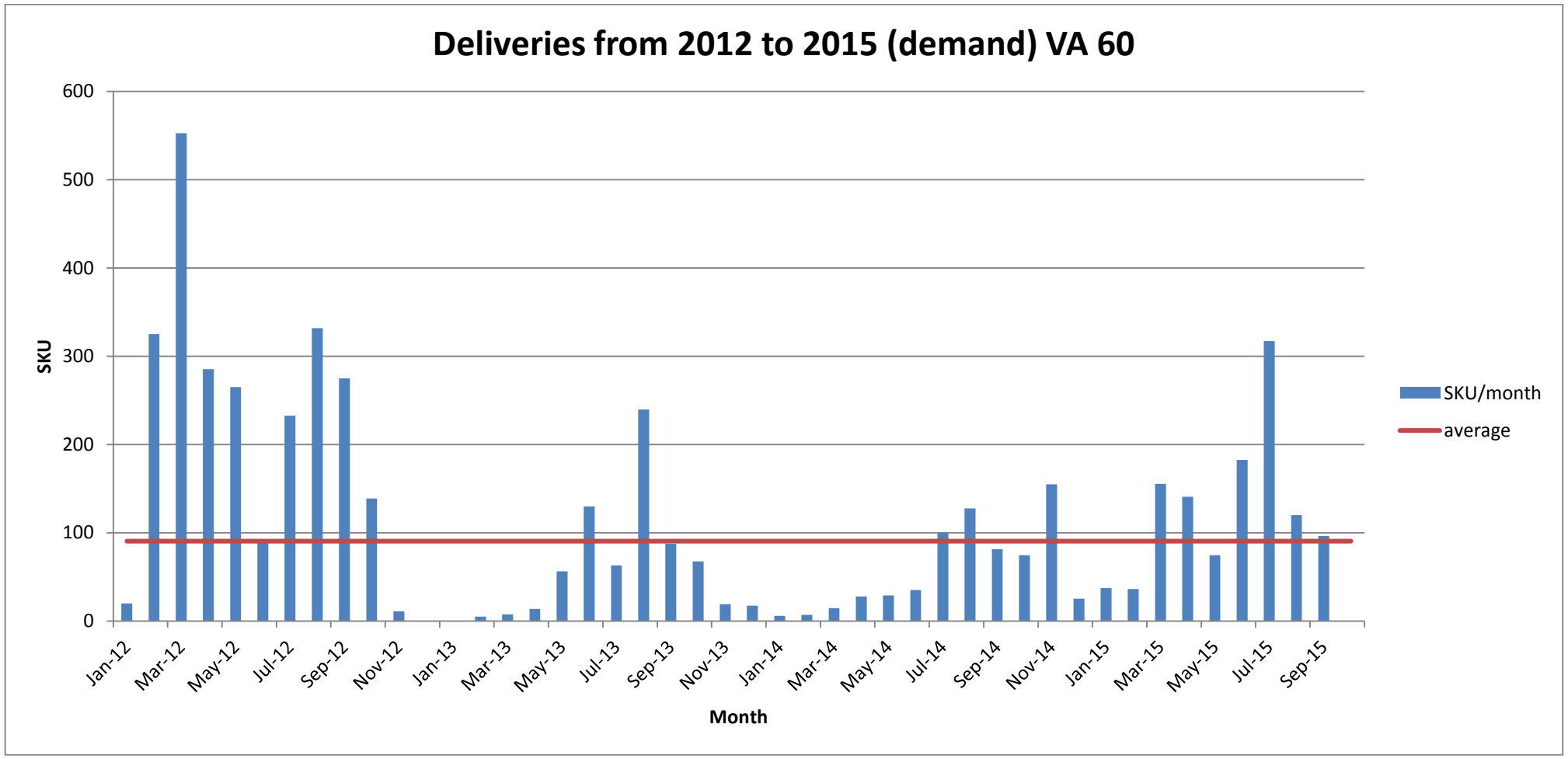
Finished Goods

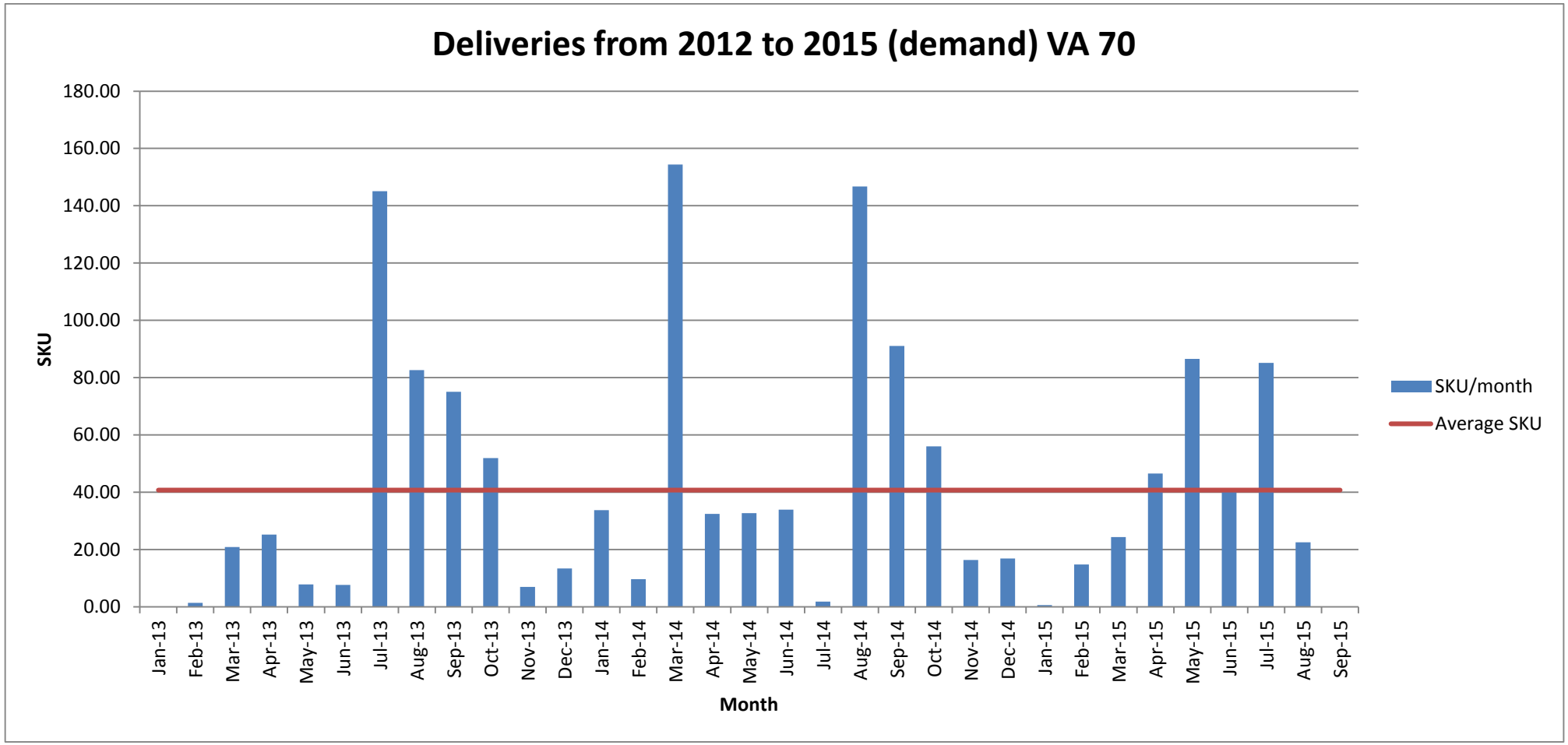
1. BV does not keep stock of finished goods, and produces based on confirmed orders in Exact Globe.
2. BV guarantees a partial delivery within a period of 6 weeks after order confirmation.
3. Lead time is order-specific and will be confirmed by BV within 48 hours after placing the order. At the request of Group, BV will confirm a lead time in advance.
4. BV will keep (minimum) stock of specified products and quantities, if Group requires BV to do so (based on an agreement with their client). Group is obligated to sell this product/volume within 6 months, until further notice.
5. In the first week of every month Group will provide a detailed forecast (so excluding already confirmed orders) indicating product, volume, delivery date/schedule and success rate % over a period of 3 months ahead. Reason for this forecast is for planning to observe potential bottleneck situations and anticipate on that. Lacking of such information may influence lead times (negatively) in specific cases.
6. BV guarantees on time delivery, after confirmation of order.
7. In case of acts of god/force majeure, BV will immediately inform Group. Guarantee then no longer applies.
8. Prices are fixed for a yearly period.
9. In case of delay of the sales order that exceeds 2 weeks, BV will charge 0.45% per month (based on ICP price) to Group to cover capital and storage costs. This is calculated pro rata.

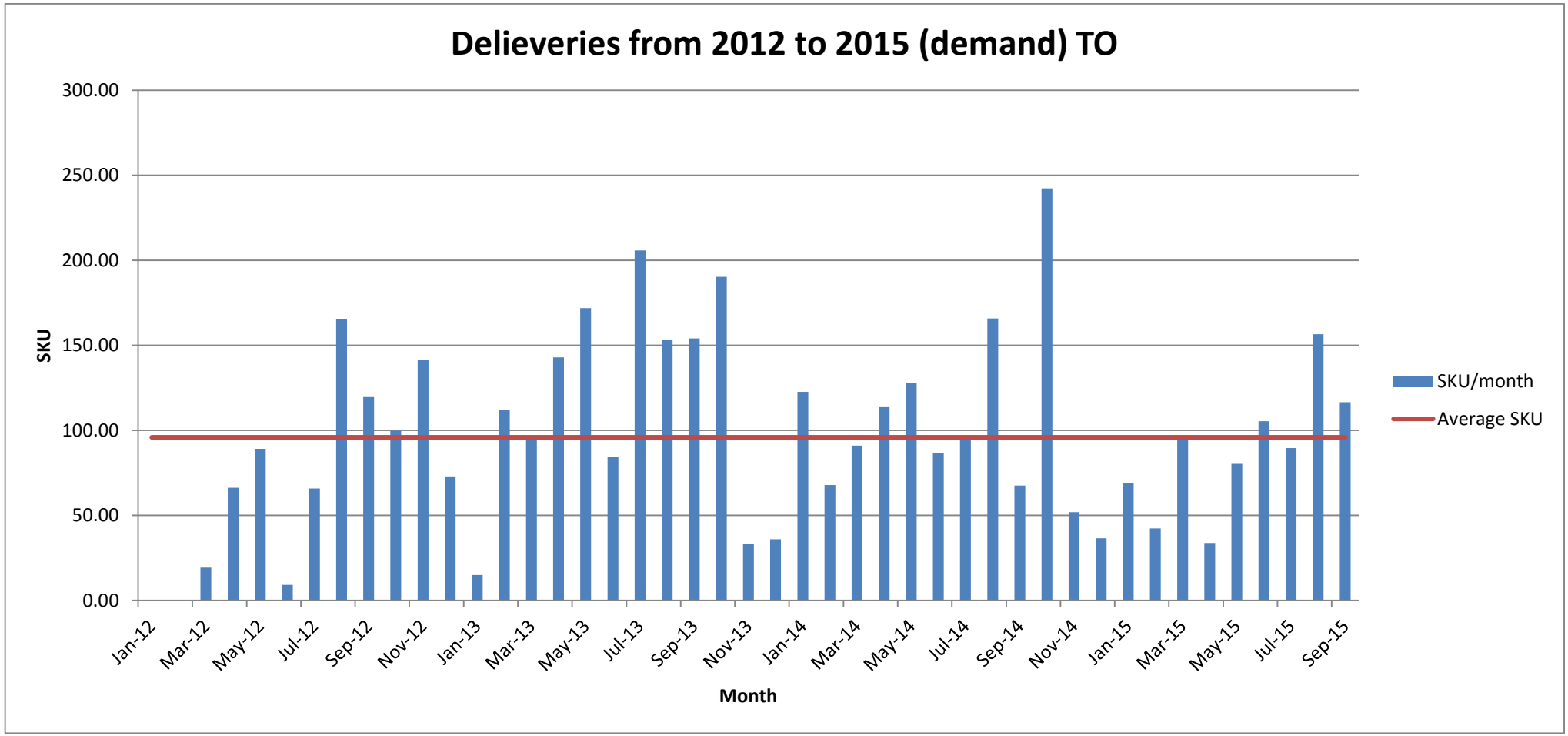
General

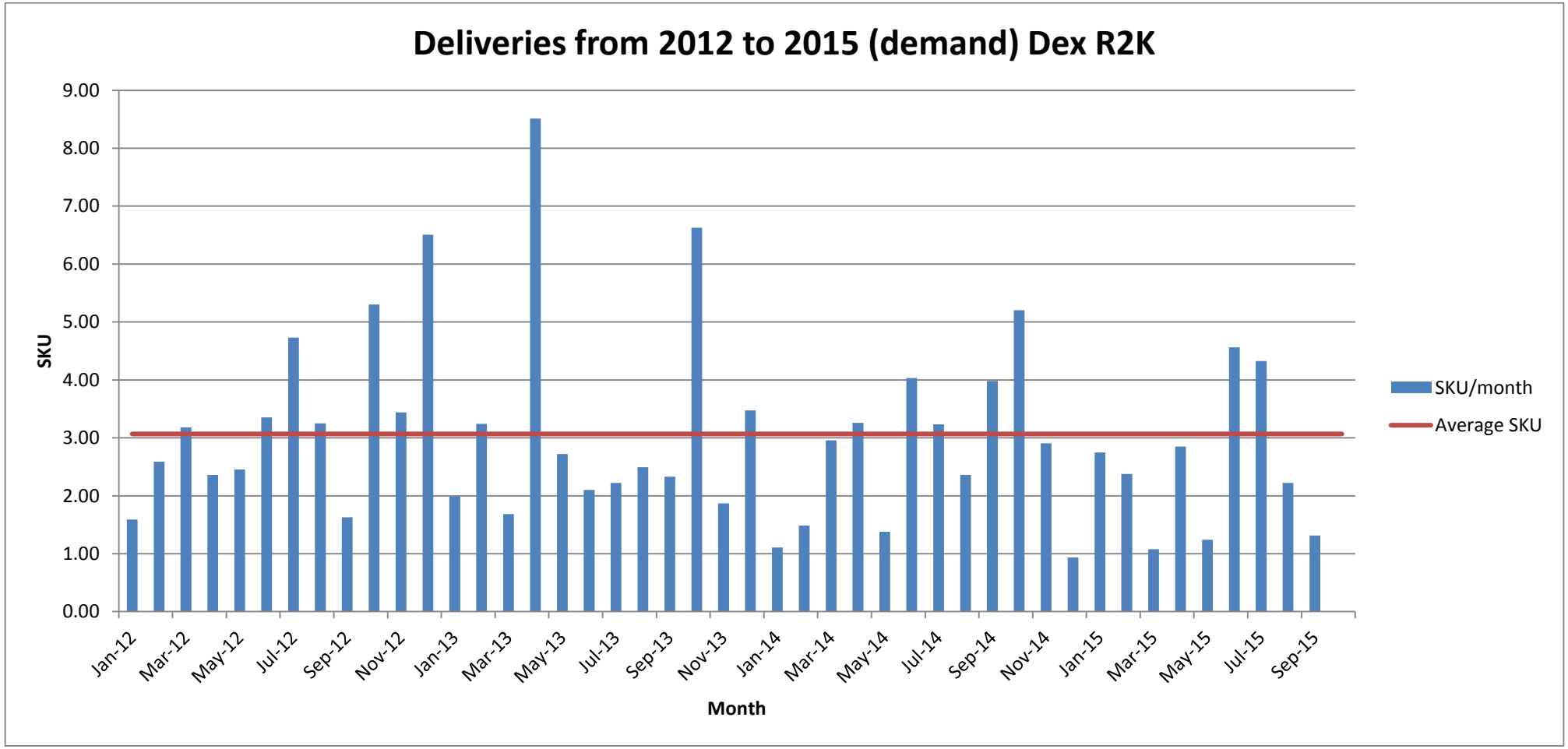
1. This agreement applies also to direct BV clients.

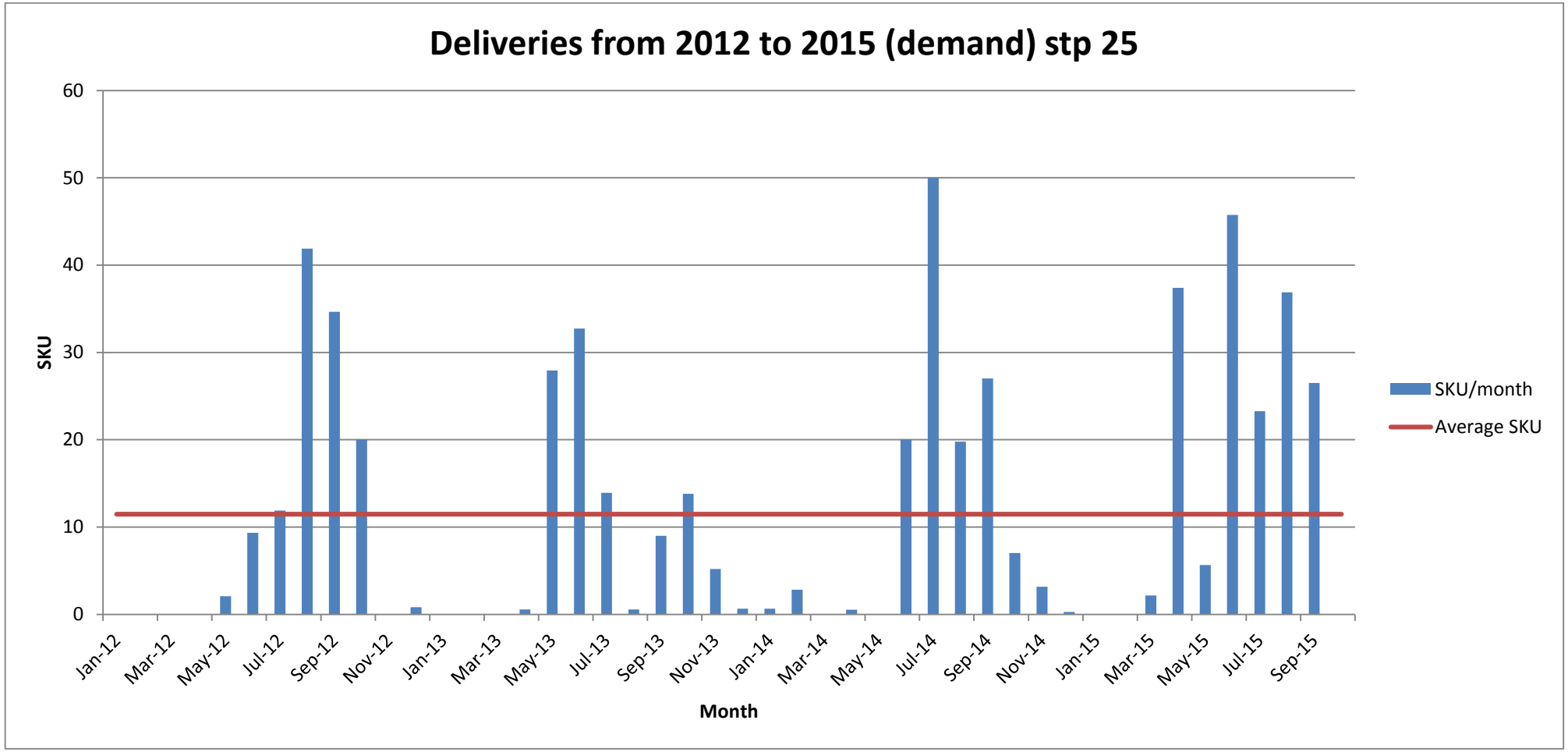
Appendix H: Deliveries per month from 2012 to 2015 for A-rated finished goods.

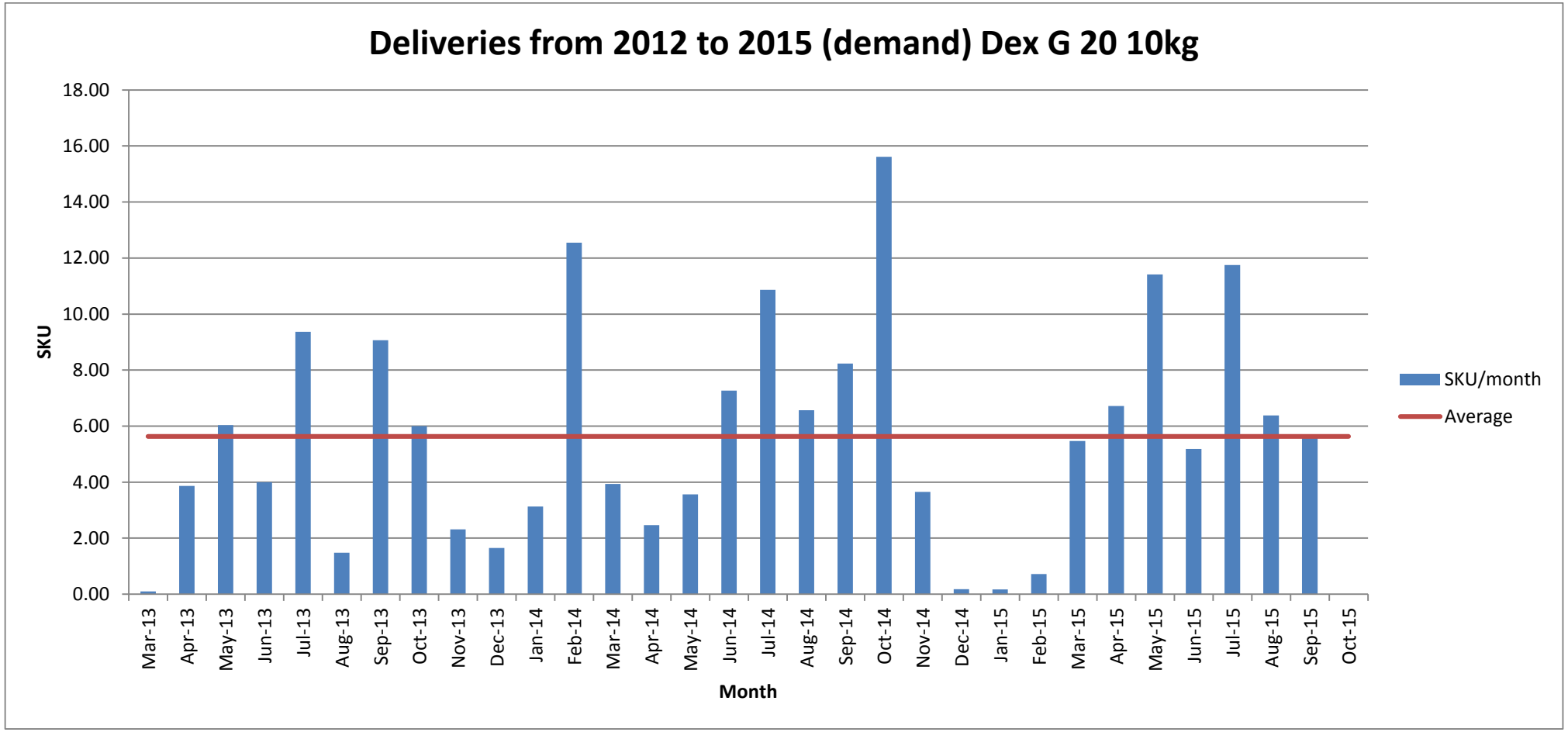


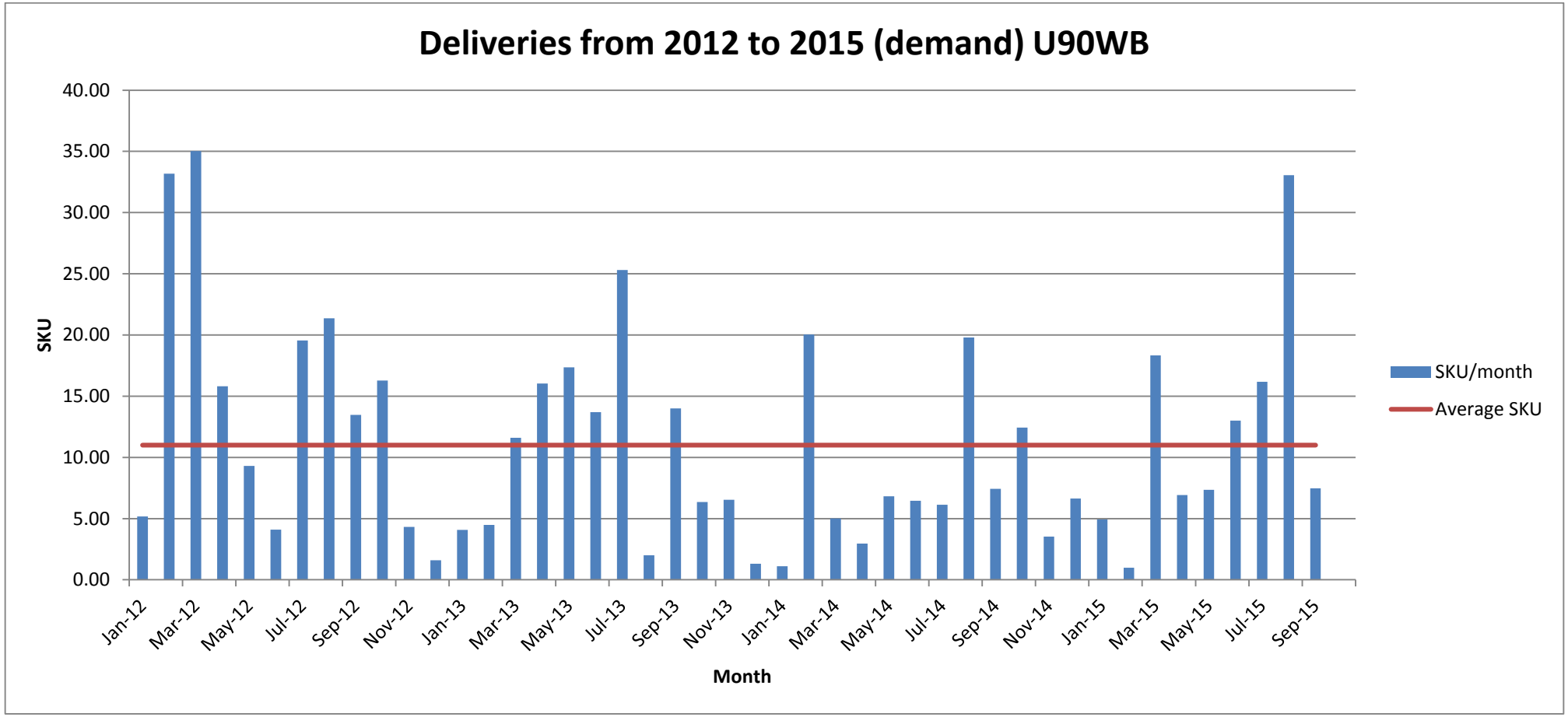

Deliveries from 2012 to 2015 (demand) VA 70
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
SKU
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Month
SKU/month
Average SKU


Delieveries from 2012 to 2015 (demand) TO
300.00
250.00
200.00
150.00
100.00
50.00
0.00
SKU
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Month
SKU/month
Average SKU


Deliveries from 2012 to 2015 (demand) Dex R2K
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
SKU
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Month
SKU/month
Average SKU


Deliveries from 2012 to 2015 (demand) stp 25
60
50
40
30
20
10
0
SKU
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Month
SKU/month
Average SKU


Deliveries from 2012 to 2015 (demand) Dex G 20 10kg
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
SKU
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Month
SKU/month
Average


Deliveries from 2012 to 2015 (demand) U90WB
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
SKU
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Month
SKU/month
Average SKU

Appendix I: Raw materials for the A, B and C rated finished goods including supplier's delivery time and minimum order quantity.

The values in the table show the quantity needed for the production of one batch. The finished goods and raw materials, hightlighted in red, indicate that the material is only used for a C-rated finished good. The raw materials, highlighted in yellow, indicate that the raw material is used in only B- and C-rated products. The materials not hightlighted are used in A-rated products.

As appendix E shows only the materials needed for A-rated products, appendix H gives the total overview of all raw materials with the corresponding finished goods, as can be seen below.

	A-Class							B-Class				C-Class									
Raw material	VA 60 [12 days]	VA 70 [5 days]	TO [7 days]	STP 25 [12 days]	Dex R2k [6 days]	U90WB [5 days]	Dex-G 20 [6 days]	Dex-L 2K tix [6 days]	Dex K2K [6 days]	VA 40 9kg [6 days]	VA 60 DB-EBA [6 days]	Release agent 10 kg [4 days]	Cleaner S 5g [4 days]	Dex RH [5 days]	Dex WR [5 days]	Ediseal 600ml [6 days]	21 2K [5 days]	Editack N Black [4 days]	21, 3kg [5 days]	Delivery time in days	min. order quantity [kg/pcs]
GGRIJS011A	390 kg	115 kg								109,4 kg	520,5 kg									60	12000 kg
GROOD0012A							802,286 kg													56	204 kg
GCYAAN001A	24,64 kg															34,4 kg				42	800 kg
GGRIJS029A			15 kg																	40	15 kg
GBLAUW002A		760 kg	381 kg	683 kg						1000 kg	1044 kg									30	1000 kg IBC/20.000 kg tank
GCYAAN003A			887 kg							1316 kg										30	1000 kg IBC/20.000 kg tank
GCYAAN004A		305 kg									344,565 kg									30	1000 kg
GGROEN002A						84,11 kg	138 kg	208,75 kg	232,08 kg					88,5 kg	88 kg					30	15000 kg in tank
GROOD0018A	3173,9 kg									2548 kg						202,345 kg				28	1000 kg IBC/20.000 kg tank
GROOD0017A		4420 kg									5710,51 kg									28	1000 kg IBC/20.000 kg tank
GBLAUW004A	35,88 kg										92,344 kg					49,95 kg				24	210 kg
GAZUUR001A				721 kg																21	1000 kg
GTERRA005A												200 kg								21	-
GAZUUR002A				721 kg																21	1000 kg
GGRIJS032A				1609,2 kg																21	1500 kg
GBRUIN011A				51,9 kg																21	200 kg
GPAARS015A				1,071 kg																21	50 kg
GROOD0008A					5,94 kg															21	200 kg
GBLAUW003A					18,35 kg			47,03 kg	52,23 kg											21	200 kg
GBRUIN004B							6,09 kg													21	180 kg
GTERRA003A													200 kg							21	200 kg
GCYAAN011A																	37,19 kg			21	-
GBRUIN006A	19,48 kg	27 kg	6,79 kg							16,7 kg	17,642 kg									18	720 kg
GROOD0006A			52,32 kg																	14	1200 kg [CS]
GPAARS003A	2,962 kg		0,71 kg													1,123 kg			0,55 kg	14	20 kg
GPAARS004A	15,072 kg		0,94 kg													11,135 kg				14	15 kg
GGRIJS021A	345 kg	80 kg	109 kg					12,46 kg	13,83kg	200 kg	300 kg					169 kg				14	480 kg
GROOD0005A	135,05 kg	302 kg								117,3 kg	332,712 kg					188,15 kg				14	1000 kg [CS]
GBRUIN008A	6,08 kg				2,25 kg	1,8 kg	5,41 kg									8,45 kg				14	200 kg
GGRIJS007A		1800 kg									2000 kg									14	1000 kg
GBLAUW008A		150 kg									164,013 kg									14	250 kg
GPAARS007A					22,91 kg			41,81 kg	46,5 kg											14	227 kg
GROOD0004A						179 kg														14	1000 kg
GBRUIN002A						0,2 kg														14	25 kg
GBRUIN005B							6,09 kg													14	190 kg
GGRIJS026A								36,79 kg	73,02 kg					31,3 kg	31 kg					14	-
GGRIJS022A								58,84 kg	82,76 kg		275 kg									14	-
GZWART006A																3,952 kg				14	-
GTERRA004A																		4000 kg		14	-
GPAARS005A										66,7 kg										14	1130 kg
GROOD0024A																	89,9 kg			12	-
GGRIJS031A	2038 kg	600 kg	612 kg		82,6 kg	194 kg		77,56 kg	141,87 kg	854 kg	600 kg									10	1200 kg
GBRUIN009A				28,83 kg																10	195 kg
GBRUIN010A				20,18 kg																10	200 kg
GGRIJS004A			715 kg																	7	12.000 kg
GROOD0016A			816,2 kg																	7	5000 kg
GCYAAN008A	3310 kg	794 kg														3706 kg				7	20.000 kg tank
GZWART001A	125 kg	125 kg		41,81 kg	0,19 kg	6,81 kg	1,8 kg	0,2 kg	0,25 kg	50 kg	50 kg					38,45 kg				7	600 kg
GGRIJS025A	310 kg	200 kg			6,79 kg		5,16 kg	29,42 kg	2,44 kg	267 kg	400 kg									7	1125 kg
GGRIJS008A		200 kg					25,85 kg	58,84 kg	62,95 kg		150 kg									7	1200 kg
GPAARS008A		2,11 kg									1,888 kg									7	220 kg
GPAARS009A					14,29 kg															7	200 kg
GGRIJS019A					5,78 kg															7	600 kg
GGRIJS013A					108,8 kg		129 kg													7	7000 kg
GROOD0007A					112,81 kg															7	1000 kg
GBLAUW006A						86,22 kg	24,37 kg							15,8 kg	15,7 kg					7	1000 kg
GZWART009A						68,98 kg	0,83 kg													7	300 kg
GGRIJS014A							207 kg							234,3 kg	58 kg					7	1400 kg
GBLAUW005A							11,46 kg													7	200 kg
GPAARS010A							165,857 kg													7	200 kg
GGRIJS005A														8,9 kg	8,8 kg					7	180 kg
GROOD0001A								55,45 kg	61,64 kg					180 kg	180 kg					7	200 kg
GGRIJS023A															175 kg					7	1000 kg
GGRIJS006A								11,02 kg	5,08 kg							22,932 kg				7	200 kg
GBRUIN001A								1,83 kg	2,05 kg											7	50 kg
GZWART002A																	5,58 kg			7	57,6 kg (30 liter)
GROOD0019A																			111 kg	7	-
GGROEN003A					205,8 kg															5	1000 kg
GBRUIN007A																	2,86 kg			5	-
GTERRA001A																	374,5 kg		443 kg	5	-
GCYAAN005A			8,38 kg																	4	200 kg
GTERRA002A				15,3 kg		94,2 kg														0	-
GGRIJS002A					13,41 kg					133,3 kg										0	350 kg

Appendix J: Spreadsheet determination production capacity

In this appendix we see the production capacity of EdilonSedra BV. The company wanted to investigate what the bottlenecks would be in case of a very high demand within 8 months. Below, two tables with quantities of finished goods are shown whereby the total demand in kgs is equal to 3.972.500. This amount far exceeds the amounts produced in the previous years. In the left table we see the quantities in kgs determined per year (12 months). The third column of that table converts this quantity to a required amount which is needed if produced within 8 months. The right table is more detailed and shows the exact amount needed per finished good in a product group. This is based on a predefined ratio among the finished goods. The name of the product group is shown in the dark grey part. light grey area shows the corresponding finished goods and in the first column the ratio of these finished.

In order to satisfy this demand, a schedule is made which can be seen below. This is based on an average of 21 working days per month with one shift from 08:00 to 17:00. On the left side of the spreadsheet we can see the names of the products, number of operators needed and how the production takes place. The numbers in the first row (green) represent the working days and the numbers in blue represent the number of batches produced. The orange color is for filling the product in the packing materials. Yellow means that the mixer has to be cleaned. As can be seen in the table we see that the Dex and the Primer family does not fit in this schedule. This problem will be tackled by the production manager by increasing the capacity in winschoten which makes it possible to shift the whole red area to the left side, in case this high demand would occur.

Product	[kg/year]	[kg/month in 8 months]
Cork VA	1600000	250000
Sedrafer	150000	23437,5
STP	150000	23437,5
Cork M	35000	5468,75
Cork TO	1000000	156250
Dex G	75000	11718,75
Cartrdges	60000	9375
Primers	100000	15625
Specials	8000	1250 +
		496562,5

Totaal	250000	[kg]	Cork VA				Locatie	
[%]		Producten	Batch grootte	# [kg]	# batches	# batches afgerond	Haarlem	Winschoten
80		VA60, 12kg	9036	200000	22,1	22	22	
5		VA40	7280	12500	1,7	1,5	1,5	
5		VA-40 N/-60 N C1	4200	12500	3,0	3	3	
5		VA70	5840	12500	2,1	2,0	1,5	
5		VA90	4300	12500	2,9	3	3	
		Totaal					27,0	0,0
Totaal	**23437,5**	**[kg]**	**Sedrafer**					
[%]		Producten	Batch grootte	# [kg]	# batches			
100		sedrafer 15 c1	6080	23438	2,6	2,5	2,5	
100		sedrafer 15 c2	1035		7,2	7	7	
		Totaal					9,5	0
Totaal	**23437,5**	**[kg]**	**STP**					
[%]		Producten	Batch grootte	# [kg]	# batches			
85		STP 25	4250	19922	4,7	4,5		4,5
15		STP 15	540	3516	6,5	6,5	6,5	
		Totaal					6,5	4,5
Totaal	**5468,75**	**[kg]**	**Cork M**					
[%]		Producten	Batch grootte	# [kg]	# batches			
100		M95	2160	5468,75	2,5	2,5		
		Totaal					2,5	0
Totaal	**156250**	**[kg]**	**Cork TO**					
[%]		Producten	Batch grootte	# [kg]	# batches			
100		TO	3040	139840	46,0	46		36,0
			4050	16410	0,0	0	11,5	
		Totaal					10	38,0
Totaal	**11718,75**	**[kg]**	**Dex G**					
[%]		Producten	Batch grootte	# [kg]	# batches			
80		Dex-G 20	600	9375	15,6	15,5		
15		Dex-G 40	960	1757,813	1,8	2		
5		Dex-G 80	990	585,9375	0,6	1		
		Totaal					18,5	0
Totaal	**9375**	**Cartrdges**						
[%]		Producten	Batch grootte	# [kg]	# batches			
30		K2k	790	2812,5	3,6	3,5		
20		L2k tix	580	1875	3,2	3		
50		R2k	690	4687,5	6,8	7		
		Totaal					13,5	0
Totaal	**15625**	**Primers**						
[%]		Producten	Batch grootte	# [kg]	# batches			
27		primer 21	540	4166,667	7,7	8		
27		primer 21 2k	480	4166,667	8,7	9		
27		primer u90wb	600	4166,667	6,9	7		
10		primer 24	520	1562,5	3,0	3		
10		primer js	576	1562,5	2,7	3		
		Totaal					30,0	0
Totaal	**1250**	**Specials**						
[%]		Producten	Batch grootte	# [kg]	# batches			
60		WR	399	750	1,9	2		
40		RH	399	500	1,3	1,5		
		Totaal					3,5	0
							Haarlem	Winschoten
						Totaal vp batches per maand	179,5	83,0
						Totaal vp batches per week	41,4	19,2

Operators	Uitzendkrachten	Molen	Product	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	1	6000	VA60	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
1	2	4000	VA40	1		1																																			
			VA70						1		1																															
			TO											1	1	1	1	1	1	1	1	1	1	1	0,5																
1	1	1800	VA90	1		1		1																																	
			M95								1	1	1																													
		300	WR / RH												1	1	1	1																							
		Reactor	va40/60 N																1	2 x 0,5	1	2 x 0,5	1																		
1	1		Sedrafer	1		1		1																																	
Win	Win	Win	TO Win	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2																
			Slurry																					2	2	2	2	2	1												
			STP-25 C1																					1	0,5	1	0,5	1	0,5												
1	2	Diss1	Dex-G C1	2	2	2	2	2	2	2	2	2																													
			Dex-L2k Tix + K2k										1	1	1	1	1	1	1																						
			Dex-R 2K																	0,5	1	1	1	0,5	0,5	1	1	0,5													
			P21 2k C1																										1	1	1	1	1	1	1	1	1				
1	1	Diss 2 (zwart)	P21 2k C2	1	1	1	1	1	1	1	1	1																													
			Dex-L2k Tix + K2k										1	1	1	1	1	1	1																						
			Kleurpastas																										2	2	2	2	2	2	2	2	1				
			Dex-R 2K																	0,5	1	1	1	0,5	0,5	1	1	0,5													
1	1	Diss 3	U90 C2	1	1	1	1	1	1	1																														
			STP 25&15 C2																						3x	3x	3x	3x													
			STP-15 C1								1		1		1		1		1		1		1		1																
2	4	Aftappen	Dex-G C2									1	2x0,5	1	2x0,5	0,5																									
			Primer 21	1	1	1	1	1	1	1	1																													
			Sedrafer c2																				2	2	2	0,5															
			TO C2	1	1	1	1	0,5																																	
			M95 C2						1	0,5																															
			WR/RH C2							1	1	1	1																												
			U90 C1											1	1	1	0,5																								
			P24 C1 + C2																	1	1	1																			
			Primer JS C1																				1	1	1																
			Primer JS C2																							1	1	1													
	2	Blikken aftaplijn	Blikken c2	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22																
1		wandmenger	voormengsels	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2																
			benodigde pallets met blikke	43,5	17	43,5	17	45,5	17	35,5	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17																
			Aantal pallets vp	22	66	22	66	22	49	41	24	43	22	28	27	29	27	29	26	33	26	34	32	28	25	1	1	1	1	1	1	1	1	1	1	1	1			
1	2		Som te etiketteren #	4437	2077	4437	2077	2937	3277	2077	3144	1764	1500	2308	2308	2308	2308	2308	2308	2308	2308	2308	2308	2308	0	0	0	480	480	480	480	480	480	480	480	240			
			Uren te etiketteren	17,748	8,308	17,748	8,308	11,748	13,108	8,308	12,576	7,056	6	9,232	9,232	9,232	9,232	9,232	9,232	9,232	9,232	9,232	9,232	9,232	0	0	0	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1			
			uren te kort	10	0	10	0	4	5	0	5	-1	-2	1	1	1	1	1	1	1	1	1	1	1	1	-8	-8	-8	-6	-6	-6	-6	-6	-6	-6	-6	-7			
1	1		Werkvoorbereiding																																						