UNIVERSITY OF TWENTE

# Improving purchasing performance using enabling performance measures

## Benchmark Electronics

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# PREFACE

To complete my Bachelor in Industrial Engineering and Management, I performed a research at Benchmark Electronics Almelo regarding performance measurement systems. After hearing some nice stories of fellow students at the University of Twente, I encountered Ronald Rikmanspoel, who invited me to look into the Benchmark environment. I accepted the offer to research the performance measurement system of Benchmark its purchasing department and so Ronald became my first company supervisor. I want to thank him for the opportunity of having my internship at Benchmark, for his critical feedback on my performance and holding op the mirror to me quite some times. It has given me a lot of extra luggage for later in my career.

My second company supervisor was Erik Eilering, with whom I worked together nicely. Even though he was busy with the Thales transfer and the improved personal security devices, he planned quite a lot of time to help me when I needed him. With his help, some nice research results were achieved and my understanding of a company its reporting system has increased a lot.

Furthermore, I would like to thank the purchasing department's employees for their collaboration with special attention to the purchasing manager Henk van Kooten, Jeroen van der Heijden and Nardi Soerodimedjo. Henk always gave critical feedback during interviews; Jeroen had the deepest understanding of the problems with the performance measurement system and managed to let me improve those. In addition, with Nardi I worked together for about 6 sessions to get a deeper understanding of the business processes and the importance of many different factors to be taken into account when preparing for a BAM session.

From the University of Twente, I would like to thank Chintan Amrit. During the research he provided me with some insights I could not find myself and which could also not be found within Benchmark. He also gave valuable advice in which data to analyze and what to do in order to fulfill a research at Bachelor thesis level. In addition, I would like to thank Sina Behfard, who was the co-reader of my thesis and helped review my concept report.

As a final remark, I hope that the research will contribute to a better reporting service and I hope the recommendations towards future research will be embraced.

Sincerely,

Olaf de Kruijff

## MANAGEMENT SUMMARY

In recent years, Benchmark has developed a control mechanism, called Benchmark Accountability Management (BAM). BAM is tiered, visual management system used to drive daily focus on continuous improvement using the elements of lean and six sigma. BAM has been implemented in the Almelo plant about a year ago, but it is encountering some issues. One of the problems is that the reports are processed by Excel macros and have to be started manually to obtain recent information. The reporting structure thus is not optimal and because of that, BAM sessions are not very effective.

Furthermore, the performance of Benchmark's purchasing department has many improvement opportunities. The new purchasing manager saw the reduction of supply times as the biggest opportunity within his department. This is because it has become a trend for customers to request their products in a smaller time window. Therefore, the supply chain should become more flexible to respond to customer demand. This research will thus also review the possibilities of reducing the supply times within Benchmark. These two points have led to the following main research question:

*'How should Benchmark Almelo design their performance measurement system in order to enable the purchasing department to improve the supply delivery performance?'*

In this research, we mainly focused on the purchasing department, but there has also been a close collaboration with the business intelligence department. After reviewing literature and analyzing Benchmark's current situation, a few causes for the problems have been identified. First of all the data is not properly organized for analysis purposes. The second thing is that the current reports are sometimes too complicated or do not really seem to make sense. The third thing is that BAM was not implemented the way it should be implemented.

Too organize data properly for analysis purposes a data warehouse has to be in place and this currently is not in place within Benchmark. However, Benchmark Corporation has been busy for a while and some of the data marts are slowly being released to all the Benchmark sites. To make appropriate performance measures, the reporting system should be hooked to this data warehouse. As an alternative, the data is organized in a regular database, which can handle current data fine and due to an integration script, it is possible to filter data you do not want to have in your database before it gets in.

When digging into the literature to find methods of reducing lead-times multiple methods were found. The current efforts encountered support from the literature to achieve the goals intended by Benchmark. The Vendor Managed Inventory (VMI) has a big support within the literature and Benchmark. Furthermore, supply contracts are embraced because they give the opportunity to specify flexibility requirements under which can be collaborated and working on basis of a rolling forecast reduces demand uncertainty.

In conclusion it can be stated BAM in itself is a quite good mechanism to use for performance measurement; however some changes need to be made in both data organization as well as in living by the protocols. For now, three reports have been built within the SSRS alternative, a reporting tool on top of a database. These reports are found in section 6.2 and one of them is given in Figure 1.

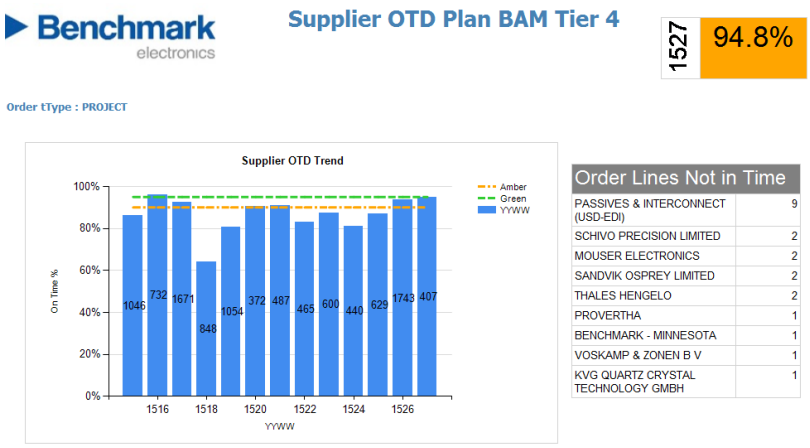


**Figure 1 - New Supplier OTD**

All three reports have encountered improvements from the previous versions. The data is more accurate, because delivery data has been linked to the actual delivery to the dock, rather than the moment it is put in stock. Furthermore, the unknown supply times have been put in perspective of the total amount of items, unnecessary information has been left out and the reports are set to a default that is ready for BAM. In addition to these reports, also an effort has been put into mining the delivery data of the past 13 months. This however did not give clear predictions, because the data was too randomly distributed.

These are however not the only findings within the literature and current situation combined. The supply contracts on itself are a good thing, but in Benchmark's case they depend on the forecast based on the customers forecast. Forecast inaccuracy leads to inappropriate high lead-times. Increasing forecast accuracy thus yields a decrease in lead-time. Given the enormous amount of signals to delay, expedite or even cancel an order, this forecasting mechanism needs researching.

To achieve supply network flexibility (the end of the mean, which is supply time reduction) also extra efforts have to be done in terms of research. Literature suggests are supplier flexibility portfolio. This type of portfolio should be researched deeper to make recommendations on which suppliers to focus on in improving the purchasing performance.

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# 1. INTRODUCTION

In this chapter, Benchmark Electronics as a company is presented, with specific focus on the Almelo plant. It is also explained why this research is of importance to Benchmark Almelo as a company.

## 1.1. INTRODUCTION TO BENCHMARK ELECTRONICS

Benchmark Electronics started in 1979 in Clute, Texas, specializing in low-volume, complex assembly of medical products as an outsourcing partner of a company called Intermedics. Back then, Benchmark was simply known as "Electronics, Inc." In 1988, the word "benchmark" was added, changing the name to "Benchmark Electronics, Inc.", as it is still known today.

Over the years, Benchmark grew primarily by acquisition. For instance, in 1998, Benchmark acquired Lockheed Martin Commercial Electronics Company, one of the largest electronics manufacturing service (EMS) companies in New England. Just one year later, AVEX Electronics was acquired in the largest acquisition of its kind in the Contract Manufacturing industry at the time. The acquisition of Pemstar in 2007 represented Benchmark's first merger with another global, publicly traded company. Today, Benchmark is located at 19 sites around the world, in nine different countries.

Benchmark played a part in developing a lot of ground breaking technological innovations. These include: the first swallowable camera for transmitting live video of its journey through the body; the first prescription medicine vending machine; the first FDA-approved drug eluting stent; the first portable Braille PDA, telephone and organizer; the first laser-accurate, hand-held vein-finding device and the first fully-automated, dual-ear, hand-held newborn screening device.

Benchmark provides services to original equipment manufacturers (OEMs) of computers and related products for business enterprises, medical devices, industrial control equipment for aerospace and defense, testing and instrumentation and telecommunication equipment. In Almelo, the focus lays the development and production of test- and measurement equipment. Benchmark offers customers comprehensive and integrated design and manufacturing services from initial product design to volume production. Their manufacturing and assembly operations include printed circuit boards and subsystem assembly, box build and systems integration.

Currently Benchmark employs about 12000 people. Approximately 400 of them are located in the Almelo plant. The plant in Almelo originally was a subsidiary of Philips, specialized in designing and manufacturing test and measurement equipment. Currently the plant is in a state of production line transfer. Therefore, the company has expanded fast over the last few months. They have acquired a full production line for Thales and this will be integrated in the plant its operational system.

## 1.2. BACKGROUND OF THE RESEARCH

In recent years, Benchmark has developed a control mechanism, called Benchmark Accountability Management (BAM). BAM is tiered, visual management system used to drive daily focus on continuous improvement using the elements of lean and six sigma. BAM has been implemented in the Almelo plant about a year ago, but the implementation has not been going flawless and the implementation is not complete yet. BAM can be seen as an enabling performance measurement system (Wouters, 2009). Performance is monitored with the goal of activating employees to improve the business performance by taking action to reduce weaknesses in the process. Meetings are being held to discuss the performance and improvement opportunities it according to the six sigma (PDCA)-cycle. BAM is a company-wide system that spreads across five different tiers:

1. Tier 1 BAM meetings will consist of manufacturing cells.
2. Tier 2 BAM meetings will be second level manufacturing for sites that have manufacturing supervisors managing multiple cells or managing multiple supervisors.
3. Tier 3 BAM meetings will be used for Customer Focus Teams.
4. Tier 4 BAM meetings will be used for internal department meetings.
5. Tier 5 will be the site General Manager and het direct reports.

At these tier levels, different BAM sessions are being held based on different BAM boards, where the performance measures and metrics are put in place. We will explore the BAM board in more detail in section 4.1. To have a nice overview of the measures that are in place throughout different BAM tiers, an application has been launched within the intranet environment of Benchmark, which is SharePoint. At SharePoint, the different cells within the tiers can be overviewed as shown in Figure 2. Within a click on the button, the underlying reports can be obtained.

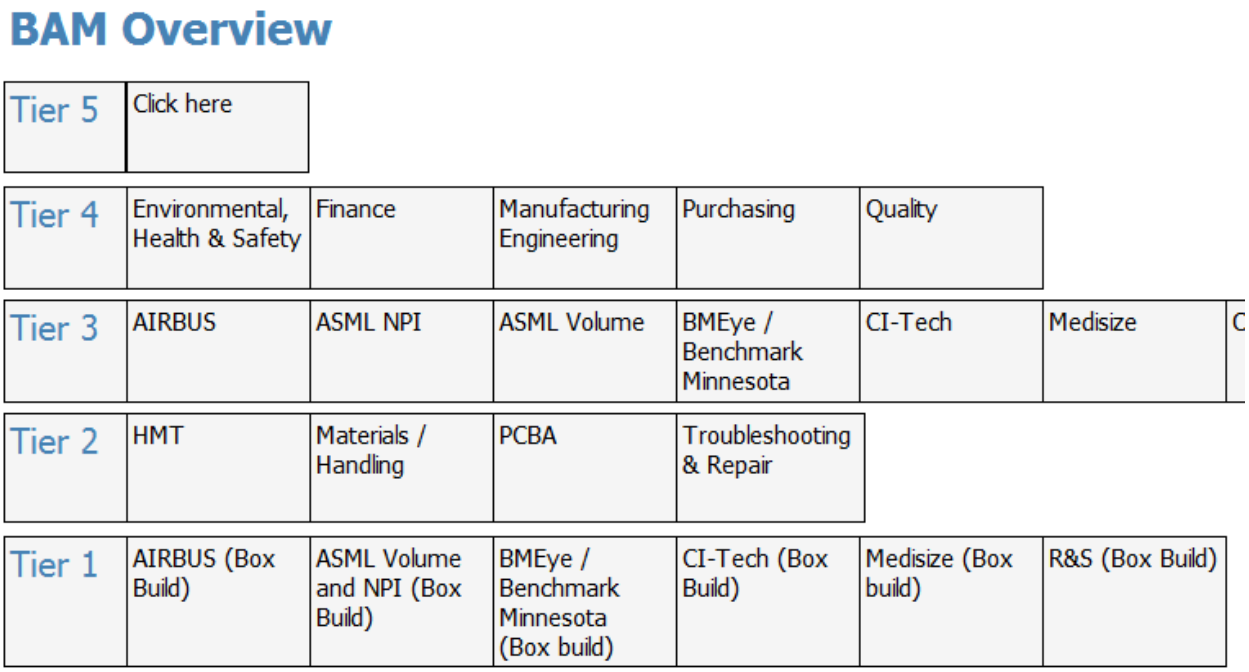



**Figure 2 - SharePoint BAM Overview**

The performance metrics are partially defined and are partially not defined by Benchmark Corporate. The metrics start with the corporate goals and flow down all the way to the manufacturing cell metrics in Tier 1. The only exception is at Tier 4, the internal department Tier. Only within the engineering and warehouse department the metrics are defined at a corporate level, the other departments do not have a predefined set of measures and metrics.

The focus of this research will be directed towards the purchasing department of Benchmark Almelo, one of the departments situated in tier 4. Within the purchasing department, some things have been going wrong lately. Until November 2014, there was one individual responsible for providing all performance reports needed at the purchasing BAM board. The data flow of generating these reports is found in Figure 3.

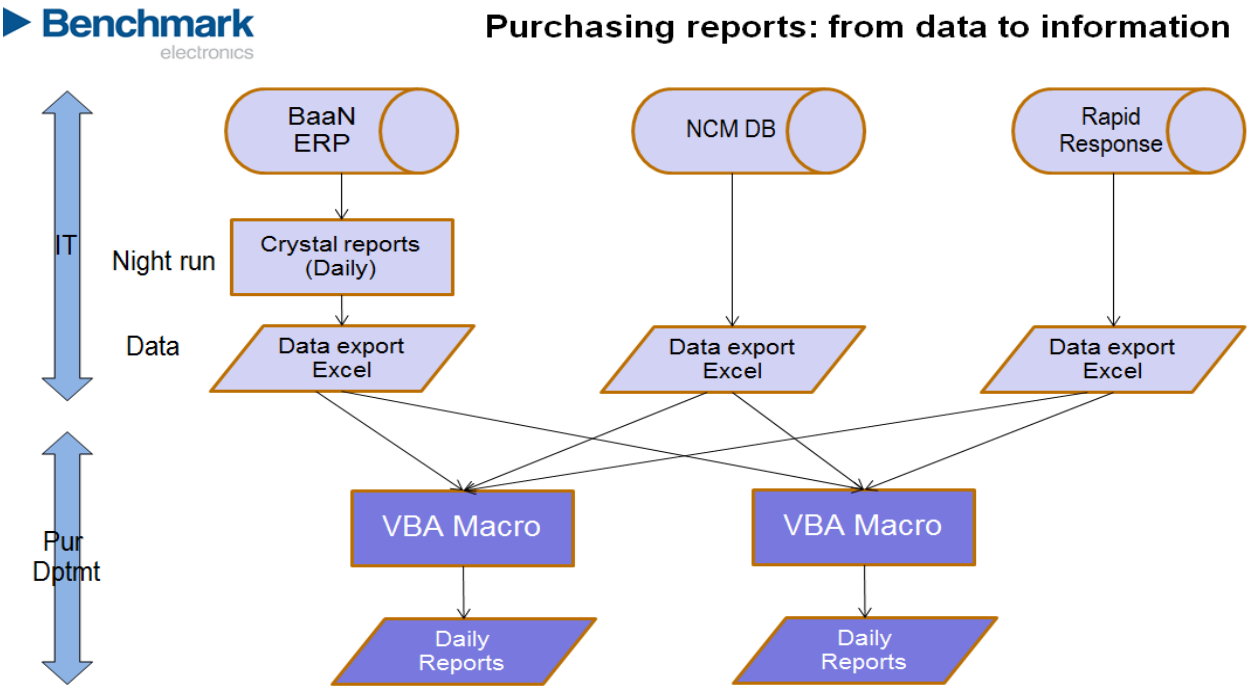



Figure 3 - Information processing

In the first step, data is dumped from multiple databases into Excel sheets, either through a direct export or by using Crystal Reports, a BI-application. This all falls within the responsibility of the IT-department. These dumped Excel sheets are processed by macros in Visual Basic for Application (VBA). Using these macros, many reports are generated for the purchasers.

However, since the assigned individual left Benchmark many things went wrong. The macro that automatically runs all reports needed deletes all format files used to process the different reports after they have been processed. Furthermore not all format files do actually run, so many of the reports being discussed at the BAM board are outdated and will not be updated. The consequences are that the reports are not in place and the attendees of the meeting are dissatisfied. Moreover, all reports need a manual conversion and if the newly assigned individual is out of office, there are no up-to-date reports and there is no recent business performance information available for the purchasing department.

Since BAM is meant to improve the business performance, improvement goals have to be set. A new purchasing manager started in November 2014 and he sought for improvement opportunities. The found key improvement opportunity was found to be the reduction of lead-times within the sourcing side of the supply chain. The reduction of lead-time would then lead to improved supply chain flexibility at the supply side of the supply chain. This lead-time reduction should go hand in hand with inventory reduction, because you do not want to overflow your warehouses in order to respond to market demand. These supply times are quoted based on supply contracts and are assumed deterministic by the ERP system. These quoted supply times will be called fixed lead-time and are item number related. In Appendix B it is further explained how the lead-times are divided within Benchmark and which of those lead-times are of interest in this research.

The information systems Benchmark uses should be supporting the BAM meetings and desirably contribute to decisions of the purchasing department regarding performance improvement. Moreover, the data should be consistent and automatically updated instead of being dependent on manual conversion. The goal is that the reports

come into a state where they are helping instead of causing headaches. Another desire is to try to get the corporate tools up and running, since they do not work for the Almelo plant.

## 1.3. SUMMARY

In this chapter, a background is set regarding the company Benchmark Electronics and its plant in Almelo. Furthermore, some problems they encounter have been discussed. It is important to research these problems more deeply and to generate possible solutions to their problems. The road from data to information (performance measure) needs to be less complex for the end users, the information should be easily accessible and it should identify performance improvement opportunities.

# 2. DEFINING THE RESEARCH

To perform a research it is necessary to set research boundaries and describe the research in detail. To do so a research goal is set, research methods are described and a set of research questions is formulated. In this chapter, these will all be discussed in detail.

## 2.1. RESEARCH GOAL

The main goal of the research is to provide Benchmark with a performance measurement system that enables employees to improve their performance. Therefore, information needs to be actionable and the translation from data to information needs to be readily available. This has to be reported in a clear and simple way, so there can be no misunderstanding of the performance information and BAM meetings can be held accurate and effective. Given the strategic goal of the purchasing manager to reduce supply times, the focus of the enabling performance measures will be on the delivery category of the purchasing department.

## 2.2. RESEARCH DELIVERABLES

In order to make sure the research is not steered in multiple directions, it is necessary to bind the research. Therefore, a set of research deliverables has to be defined at an early stage. The research deliverables will be:

- A detailed description of the current situation.
- Renewed versions of Key Performance Indicators (KPIs) regarding delivery.
- Recommendations on how to let a performance measurement system enable employees in improving their performance.
- Recommendations on how to reduce the supply times in Benchmark's business environment whilst maintaining supply reliability.
- Investigate why the corporate performance measurement tools are not working at Benchmark Almelo.

## 2.3. RESEARCH METHOD

To actually deliver the research deliverables described in section 2.2, a plan has to be put together to achieve the output we aim for. The research deliverables will be discussed point by point and it will be explained how to obtain useful research output.

### 2.3.1. METHOD TO OBTAIN A DETAILED DESCRIPTION OF THE CURRENT SITUATION

Firstly, it is good to explain which current situation we actually want to describe in this research. There are three major points in describing the current situation within Benchmark.

1. The BAM meeting structure at the purchasing department.
2. The current performance measures at the purchasing department.
3. The current initiatives to reduce supply times.

Since we want to describe the current situation regarding BAM at the purchasing department, the BAM sessions will be attended every single morning when present at Benchmark. Since Benchmark has to follow corporate procedures, these will studied and reflected upon in this thesis. Furthermore, BAM will be taken into plant perspective and a look will be taken into the implementation process and intentions of BAM.

While attending the BAM sessions, the current performance measures will be discussed. By attending the sessions, an understanding of these measures will be developed. Furthermore, multiple interviews will take place with the purchasing employees to find the key issues with the reports, as well as which performance measures are found useful or not. The processing of the purchasing reports will also be discussed with those employees with a broad understanding.

The last element of the current situation to be discussed is the initiative to reduce supply times. Which efforts currently are being done in order to reduce and control supply time as much as possible? This information will be obtained by interviewing the strategic buyers. The current situation will be assessed and placed in perspective by doing a literature study.

### 2.3.2. METHOD TO GENERATE NEW DELIVERY KEY PERFORMANCE INDICATORS (KPIS)

In describing the current situation, we will find the KPIs that are currently being used to measure delivery performance at Benchmark. To gain insights in which other measures can be used to assess the delivery performance, a literature review shall be done. In addition, corporate procedures might point out interesting measurements regarding delivery at different Tiers of the supply chain within Benchmark itself. When the interesting delivery KPIs for Benchmark are found, these will have to be implemented. To do so, a new way of generating the performance measures has to be found to get rid of the Excel macros.

### 2.3.3. HOW TO FIND RECOMMENDATIONS ON DEVELOPING A PERFORMANCE MEASUREMENT SYSTEM THAT ENABLES EMPLOYEE PERFORMANCE IMPROVEMENT

At the BAM board, there are many reported performance measures to show the KPIs of the purchasing department. Not all of those performance measures might serve an improvement goal. Therefore, insights need to be obtained on how performance measures facilitate employees in improving performance. This shall be done doing a literature study and this shall then be used to reflect upon the Benchmark procedures. This shall be taken into account when generating the new KPIs.

### 2.3.4. FINDING RECOMMENDATIONS ON HOW TO REDUCE THE SUPPLY TIMES IN BENCHMARK'S BUSINESS ENVIRONMENT WHILST MAINTAINING DELIVERY RELIABILITY

Since it is a goal to reduce the supply times, possibilities have to be found to reduce them. The ERP assumes fixed lead-time as a deterministic variable, so it is important to maintain delivery reliability when reducing the supply times. Fluctuation in supply time might upset the production schedule, thus which needs to be avoided when reducing the supply times. To execute that correctly, Benchmark's business environment needs to be described properly. This business environment needs to be taken into account when assessing the supply time reduction efforts. These will also be compared with the current efforts and from that comparison useful recommendations can be made.

#### 2.3.5. INVESTIGATE WHY THE CORPORATE PERFORMANCE MEASUREMENT TOOLS ARE NOT WORKING AT BENCHMARK ALMELO

Within Benchmark Corporation, multiple tools to generate business reports at different levels are supporting Benchmark sites. For the purchasing department, a tool called Vendor Indicative Performance Rating (ViPeR) is given to measure the supplier performance and easily extract all relevant data from different data sources. Supplier performance evaluation is relevant for the purchasing function, so it would be nice to know if this tool has the possibility of working and if not, what the restrictions are. With assistance of the purchasing manager and the supply chain architects it should become clear why the tool does not work know and which tools can be used otherwise.

## 2.4. RESEARCH QUESTION AND SUB QUESTIONS

In order to fulfill this research, a main research question has to be answered. As stated in the research goal in section 2.1, this will be focused on developing an enabling performance measurement system with the main focus on improving delivery performance. The main question can this be formulated as:

*'How should Benchmark Almelo design their performance measurement system in order to enable the purchasing department to improve the supply delivery performance?'*

To adequately answer the main question it needs to be divided into subquestions . These will be categorized based on the categorized research deliverables.

### QUESTIONS REGARDING THE CURRENT SITUATION

#### HOW IS THE PERFORMANCE MEASUREMENT SYSTEM CURRENTLY SET UP?

*In order to make recommendations towards using the Benchmark performance measurement system, it is useful to investigate its current state. Discrepancies between theory and practice can then be found and examined in more detail.*

#### WHAT EFFORTS ARE CURRENTLY BEING DONE IN ORDER TO REDUCE THE SUPPLY TIMES?

*Since the main strategic purchasing goal is to reduce the supply times, Benchmark is of course already on the go with reducing the lead-times. What are they doing in order to do so and does it rhyme with the efforts they should be taking according to the literature is therefore an important issue for this thesis. This will thus be included.*

#### FOR WHICH REASONS ARE THE CURRENT CORPORATE TOOLS NOT AVAILABLE FOR USE AND WHAT CAN BE DONE TO MAKE THEM WORK?

*Under this question, it will become clear why current corporate tools cannot be used and will be answered why it's not possible or what can be done to make the corporate tools work.*

### QUESTIONS REGARDING THE PURCHASING DEPARTMENT

#### WHAT ARE THE KPIS THAT ARE OF IMPORTANCE IN THE PURCHASING DEPARTMENT REGARDING DELIVERY PERFORMANCE?

*In this section suggestions made within the literature for including delivery KPIs will be presented and afterwards they will be compared with the current measures.*

### QUESTIONS REGARDING PERFORMANCE MEASUREMENT SYSTEMS

#### HOW CAN PURCHASING PERFORMANCE BE MEASURED ACCURATELY?

*In this section the systems behind the measurements are being evaluated.*

#### HOW CAN PERFORMANCE MEASUREMENTS FACILITATE PERFORMANCE IMPROVEMENT?

*Since the goal is to improve the presented performance measures, it's important the performance measures are somehow used to activate employees to improve what has been measured. How that can be done will be found under this section.*

### QUESTIONS REGARDING SUPPLIERS

#### HOW DOES SUPPLIER PERFORMANCE AFFECT PURCHASING PERFORMANCE?

*Supplier performance directly impacts the performance of the purchasing department of the buying firm, but what the impact really is will be discussed in this section.*

#### WHICH SUPPLIER SHOULD YOU ASSIGN TO WHICH CATEGORY?

*Not every supplier is the same and each supplier has different benefits for Benchmark. How to classify them will be discussed under this question.*

### QUESTIONS REGARDING BENCHMARK'S BUSINESS ENVIRONMENT

#### HOW CAN BENCHMARKS BUSINESS ENVIRONMENT BE DESCRIBED AND WHAT KIND OF SUPPLY CHAIN IS NEEDED FOR THAT TYPE OF ENVIRONMENT?

To be able to make good recommendations about the reduction of supply times, the business environment has to be defined and the belonging supply chain type should be identified. This should then also be examined.

### QUESTIONS REGARDING INFORMATION SYSTEMS

#### HOW CAN BUSINESS INTELLIGENCE ASSIST IN REACHING PERFORMANCE IMPROVEMENT GOALS?

*A theoretical base for using business intelligence to improve individual performance is needed to clarify possible research outcomes and also to gain insights for further recommendations.*

## 2.5. SUMMARY

In this chapter the research has been specified in more detail. The main research question that will be answered is: 'How should Benchmark Almelo design their performance measurement system in order to enable the purchasing department to improve the supply delivery performance?' This will be achieved by giving detailed descriptions of the current situation, identifying possibilities to improve, generating possible solutions to the problems and by choosing the final solution.

# 3. LITERATURE REVIEW

In order to make adequate decisions about what to do, Benchmark's business environment has to be defined properly. Given the business environment, a supply chain typology has to be made. Taken into perspective that the goal is to reduce supply times, a literature review has to be performed on how to shorten supply times. This then has to be put into the supply chain perspective and will form a base of comparison against the current situation within Benchmark, which will be done in the next chapter. Also, the role of performance measurements in this supply chain environment is going to be researched.

## 3.1. SUPPLY CHAIN ENVIRONMENT

As stated in the background, Benchmark is an outsourcing partner for complex electronics equipment, or a so called electronics manufacturing service. It does not have an own product, but it helps customers developing their products as well. Products can be viewed as innovative, with a high new product introduction (NPI) rate. These innovative products have a high level of demand uncertainty (Fisher, 1997). Benchmark depends on the forecasts of their customers and if the customer changes its forecast, Benchmark will have to act on this. Benchmark will thus have to cope with the so called bullwhip effect, where the demand uncertainty amplifies the further you come in the supply chain.

In Figure 4 a simplified representation of a supply chain is given (Chen & Paulraj, 2004). The supply chain is typically characterized by forward flow of materials and backward flow of information (Beamon, 1998).

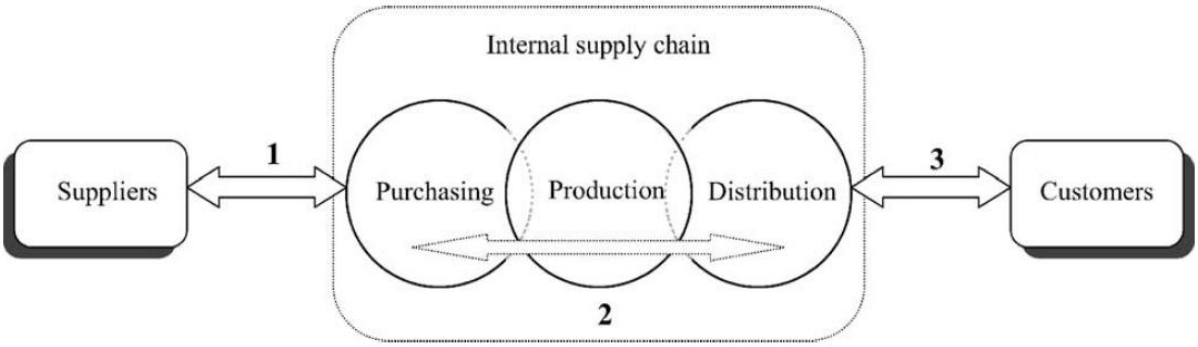



**Figure 4 - Simplified supply chain (Chen & Paulraj, 2004)**

The buyer-supplier dyad, represented by link 1 in Figure 4, is of huge importance to the effective management of the supply chain (Chen & Paulraj, 2004). As can be seen from Figure 4, from an internal supply chain perspective, it's the purchasing department's task to maintain the buyer-supplier dyad. We will come back to this in section 3.1.2.

At its highest level, a supply chain can be divided of two basic, integrated processes (Beamon, 1998): (1) the Production Planning and Inventory Control Process, and (2) the Distribution and Logistics Process. These processes provide the basic framework for the conversion and movement of raw materials into final products. Purchasing activities are a part of the first integrated process, as can also be seen in Figure 4 where the Purchasing and Production functions overlap. The second process is than given from the moment the production overlaps the distribution. We will not discuss that during this thesis.

### 3.1.1. COMPETITIVE PRIORITIES

According to Krause, Handfield & Tyler (2007) buying firms in manufacturing industries, including electronics, have four primary competitive priorities in their end-markets: cost, quality, delivery time and reliability, and flexibility. Time has become a key factor in competitiveness due to customers that are becoming increasingly reluctant to accept long lead-time items (Purvis, Gosling & Naim, 2014). Das & Abdel-Malek (2003) and Purvis et al. (2014) address one other competitive priority compared to Krause et al. (2007). They agree on cost, quality and flexibility, but they call service level instead of delivery time and reliability. These however can be viewed as components of service level, as is stated by Simchi-Levi, Kaminsky & Simchi-Levi (2009). They state service level will be higher for products with:

- High profit margin
- High volume
- Low variability (and thus reliability)
- Short lead-times

### 3.1.2. SUPPLIER MANAGEMENT

As stated in 3.1, the purchasing function is responsible for managing the suppliers. Figure 5, by Das & Abdel-Malek (2003), shows the buyer-supplier dyad accompanied with more details. It can be seen buyer and supplier are linked through a triple flow. Next to Beamon (1998) her forward flow of materials and backward flow of information, there is also the supply contract. The supply contract is the key document. In a supply contract the conditions under which buyer and supplier cooperate are specified. This is typically a legally binding document which forms a protection for the parties in case they have a disagreement. In a supply contract supplier and buyer agree on (Das & Abdel-Malek, 2003; Simchi-Levi et al., 2009):

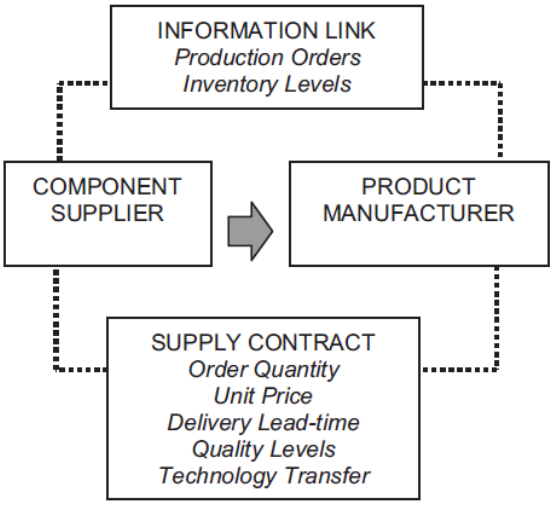



Figure 5 - Buyer-supplier dyad

- Pricing and volume discounts
- Minimum and maximum purchase quantities
- Supply times
- Product or material quality
- Product return policies
- Technology transfers

In supply contracts it is thus defined how the forward flow from the supplier to the manufacturing company goes, in this case to the buying company Benchmark. As stated by Beamon (1998), the information flow typically goes backward. Figure 5 gives production orders and inventory levels as parameters for information transfer, but this information can also be characterized otherwise. For example purchase orders (POs) could be issued, just like Benchmark does.

Effective supply contracts provide incentives for supply chain partners to replace traditional strategies, in which each partner optimizes its own profit, with global optimization, where supply chain profit is maximized. Supply contracts are important because they help firms achieve global optimization, without the need for an unbiased decision maker, by allowing buyers and suppliers to share the risk and the potential benefit. Indeed, it can be shown that carefully designed supply contracts achieve the exact same profit as global optimization (Simchi-Levi et al., 2009).

## 3.2. PERFORMANCE MEASUREMENT

A performance measure can be defined as follows:

*"A performance measure is a translation of a notion of performance into a number that can be calculated with available data" (Wouters, 2009).*

Beamon (1998): An important component of supply chain analysis is the establishment of appropriate performance measures. Available literature identifies a number of performance measures as important in the evaluation of supply chain effectiveness and efficiency. Wouters (2009) states that often, non-financial measures are more actionable than aggregate financial measures. These provide a more direct insight into the causes of good or bad performance.

Essentiality of performance measurement in supply chain is vital, and Gunasekaran and Kobu (2007) mention the following as the purposes of a performance measurement system bases on a literature review:

- Identifying success.
- Identifying if customer needs are met.
- Better understanding of processes.
- Identifying bottlenecks, waste, problems and improvement opportunities.
- Providing factual decisions.
- Enabling progress.
- Tracking progress.
- Facilitating a more open and transparent communication and co-operation.

Also, key elements in the approach of a Performance Measurement System (PMS) design and implementation are the connection between strategy and measures, the validity and reliability of those measures, achieving consistency throughout the company and periodically refining the results of the performance measure. In the implementation phase it is important to set systems and procedures in place to gather the relevant data and enable the measures to be made regularly and reliably (Wouters, 2009). Regarding the usage of macros this is not the case within Benchmark and we want to change that. Developing a PMS that is valid, useful and understandable is challenging and complex. Valid means here that the performance measures actually measure the performance intended.

Gunasekaran, Patel & Tirtiroglu (2001) build a framework for supply chain performance measurement on strategic, tactical and operational level. They state that companies often overuse performance metrics and identify the pitfall of overusing less important metrics. Performance measurement can better be done using a few good metrics. The resulting measures and metrics are identified and discussed along the four links of and integrated supply chain. Gunasekaran, Patel & McGaughey (2004) build on this four links of integrated supply chain, together with an empirical analysis, and build a framework with the four links together with the supply chain level. This framework is found in Figure 6. The four links of integrated supply chain are:

1. Plan
2. Source
3. Make/Assemble
4. Delivery

These are derived from the Supply Chain Operations Reference (SCOR)-model and have a great resemblance with the simplified supply chain of Chen & Paulraj (2004) given in Figure 4. For the purchasing function the first two of the links are the ones mostly discussed. These are the steps resembling the Production Planning and Inventory Control step described by Beamon (1998). The metrics with interest for the purchasing function will be discussed below. Some of them also come from step 4, Delivery. These are of interest due to the flexibility measures.

| Supply chain activity/ process | Strategic | Tactical | Operational |
|---|---|---|---|
| Plan | Level of customer perceived value of product, Variances against budget, Order lead time, Information processing cost, Net profit Vs productivity ratio, Total cycle time, Total cash flow time, Product development cycle time | Customer query time, Product development cycle time, Accuracy of forecasting techniques, Planning process cycle time, Order entry methods, Human resource productivity | Order entry methods, Human resource productivity |
| Source | | Supplier delivery performance, supplier leadtime against industry norm, supplier pricing against market, Efficiency of purchase order cycle time, Efficiency of cash flow method, Supplier booking in procedures | Efficiency of purchase order cycle time, Supplier pricing against market |
| Make/ Assemble | Range of products and services | Percentage of defects, Cost per operation hour, Capacity utilization, Utilization of economic order quantity | Percentage of Defects, Cost per operation hour, Human resource productivity index |
| Deliver | Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule | Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule, Effectiveness of delivery invoice methods, Percentage of finished goods in transit, Delivery reliability performance | Quality of delivered goods, On time delivery of goods, Effectiveness of delivery invoice methods, Number of faultless delivery notes invoiced, Percentage of urgent deliveries, Information richness in carrying out delivery, Delivery reliability performance |

Figure 6 - Supply Chain PMS

### 3.2.1. PLANNING MEASUREMENTS

The purchasing (sourcing) function is a near relative of the planning function. At Benchmark, planners are rarely found at BAM-meetings, even though some of the purchasing BAM metrics do actually evaluate the planning performance. The order lead-time is addressed as an important planning measure. The supply time and on time delivery are part of that and are being evaluated along the BAM board. The other factors of the order lead-time aren't taken into account within the purchasing function. However, Gunasekaran et al. (2001, 2004) state that, based upon multiple sources, a reduction in the order cycle time leads to a reduction in the supply chain response time.

This is an important measure, but also a great source of competitive advantage. It is stated to directly influence the customer satisfaction level, which in turn is regarded as a market winner (Gunasekaran et al., 2001). Equally important is the reliability and consistency of the lead-time.

### 3.2.2. SUPPLY CHAIN PARTNERSHIP MEASUREMENTS

Gunasekaran et al. (2004) also state that the purchasing and supply management department of a buying company must analyze the supplier's ability to meet the firm's long-term needs. Furthermore they find, based on multiple sources, that supply chain partnership is an essential element for efficient and effective sourcing. These partnerships need maintenance, so the partnership needs to be evaluated to create win-win situations for both parties.

Another interesting point within the measurement of suppliers is to not only measure the external performance. The internal performance of a supplier is also an important subject. By collaborating closely with a supplier, a buying firm is able to see if the measurements are in place within the supplying firm. These should enhance performance improvement and these contribute to the overall supply chain performance.

### 3.2.3. DELIVERY MEASUREMENTS

Even though the delivery at the end of the SCOR-model is shows deliveries to the customer, within the purchasing function suppliers are evaluated in a similar way. The delivery measures and metrics thus also apply to evaluate supplier performance. The most important issue addressed is the on-time delivery performance. This evaluates if a delivery was good or bad, and it acts as a measure of the service level a supplier has given a company. According to Stewart (1995), the delivery performance measures should be:

- Delivery-to-request date
- Delivery-to-committed date
- Order fill lead-time (the time between an order and the order delivery)

Delivery performance has two primary components: (1) reliability of delivery, which is the ability to deliver when promised, and (2) delivery speed, which is typically thought of in terms of short delivery times (Krause et al. 2007). The reduction of lead-time is revealed as a trend of operational strategy for improving delivery performance. Moreover, the number of faultless notes invoiced and the supply chain flexibility reflect customer satisfaction. If a note isn't faultless, the areas of discrepancy can be identified so that improvements in delivery performance can be made. Flexibility is regarded as a metric to win customer orders (Beamon, 1998; Carr & Smeltzer, 2000; Gunasekaran et al., 2001; 2004). It is defined as "the degree to which the supply chain can respond to random fluctuations in the demand pattern" (Beamon, 1998; Gunasekaran et al., 2001; Das & Abdel-Malek, 2003; Simchi-Levi et al., 2009; Purvis et al., 2014).

Analysis has found it has a strong correlation with the supply chain response time. So by defining flexibility as a metric and evaluating it, companies can achieve rapid response to meet individual customer needs.

Gunasekaran et al. (2004) point out that most notable about the metrics that evaluate the supplier's performance, is that firms find the delivery performance of suppliers more important than their cost performance. Earlier in this thesis Wouters (2009) was referenced for a similar opinion.

### 3.2.4. INVENTORY MEASUREMENTS

Gunasekaran et al. (2001) state that measuring inventory at supply, production, distribution and scrap levels can provide insights into the cost performance, but also reduce the lead-time in the supply chain. Another factor that is mentioned is the measuring of the accuracy of forecasting techniques. In the empirical study of Gunasekaran et al. (2004), one of the survey participants emphasizes the need of accurate forecasting especially. The forecasts of all supply chain links influence the supply chain as a whole, so a concerted effort should be made in improving the forecasting accuracy. Better forecasting methods should then result in a reduction of supply chain uncertainty and enhance performance improvement. Many of the participants understand the consequences of poor forecasting techniques and agree on the need of measuring it to be able to improve it.

## 3.3. INFORMATION (TECHNOLOGY)/BUSINESS INTELLIGENCE

Prajogo & Olhager (2012) test a bunch of hypotheses regarding factors contributing to performance improvement. This framework is presented in Figure 2Figure 7. All of their links are tested as a hypothesis of contribution to the next link in the chain. Logistics integration has a significant positive effect on a firm's operational performance. Information technology capabilities and information sharing both have significant effects on logistics integration. Furthermore, long-term supplier relations have both direct and indirect significant effects on performance; the indirect effects through the effect on information integration and logistics integration (Prajogo & Olhager, 2012). All hypotheses are thus confirmed. One way to achieve supply chain integration is collaborative planning, forecasting and replenishment (CPFR). Information sharing can lead to lower cost through reductions in stock levels and shortages. However, to realize this, changes in the logistics process has to be made. Vendor Managed Inventory (VMI) programs could be started, lead-times could be reduced or deliveries could occur more frequently with smaller order sizes (Prajogo & Olhager, 2012).

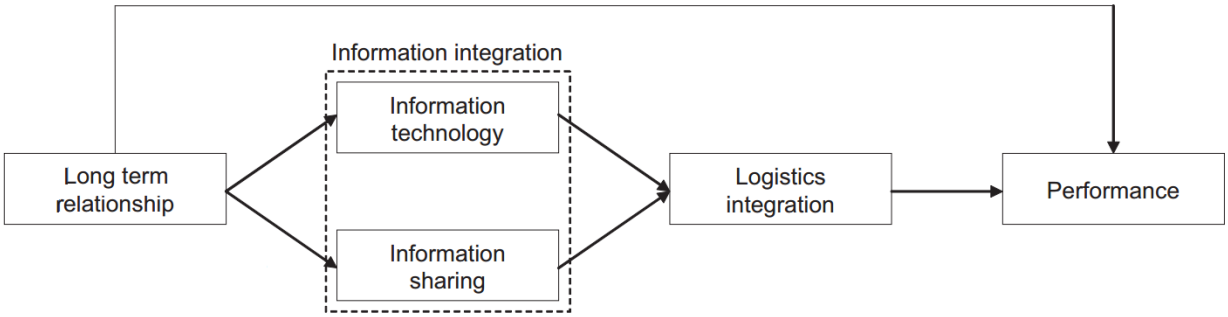



**Figure 7 - Performance improvement contributors (Prajogo & Olhager, 2012)**

In the Das & Abdel-Malek (2003) case, the information link is considered to be real time. In Benchmark's case this is not really true, since the information is based on weekly updated forecasts and the issued purchase orders and deliveries.

The risk of putting huge investments in IT and sharing sensitive information is a serious hindrance which can only be taken when firms have a strategic and long-term relationship.

Simchi-Levi et al. (2009) state information is important in a supply chain environment. It reduces variability in the supply chain, helps in more accurate forecasting, helps production and distribution coordination, increases response time and reduces lead-time. The embracement of good information systems is thus of importance for a supply chain company.

## 3.4. SUPPLIER DEVELOPMENT

Across various fields associated with organizational research there has been a growing recognition of interorganizational relationships as a source of competitive advantage and value creation (Krause et al., 2007). A form of interorganizational exchange that is part of supply chain management, is a practice known as supplier development. Krause et al. (2007) define supplier development as any activity initiated by a buying organization to improve the performance of its suppliers. Supplier development is an important strategy, because it could enhance shared knowledge and shared asset investments, which may lead to improved performance. Supplier development may include goal setting, supplier evaluation, performance measurement, supplier training, and other related activities (Krause et al. 2007). Gunasekaran et al. (2001, 2004) also emphasized these kind of practices to increase supply chain partnerships and thus increase sourcing efficiency.

Supplier development programs are designed to create and maintain a network of competent suppliers and to improve supplier relationships in order to be more competitive as a buying firm (Hahn, Watts & Kim, 1990). Monczka & Trent (1995) state buying firms have become increasingly reliant on the supply base and the need for supplier development thus exists. The purchasing function objective is to secure competent sources of supply. This involves the selection of suppliers and requires working with them to upgrade their capabilities.

Supplier development programs should be translated into a set of objectives dealing with the performance measures. These development programs typically are being set up after an evaluation of the supplier. The supplier development priorities should go to key suppliers that have the potential to meet the criteria. In terms of delivery, these are divided as follows:

| Related areas / Capabilies | Product Related | Process Related | Operating Systems Related |
|---|---|---|---|
| Delivery capability | • Product Mix<br>• Materials Lead-time | • Capacity Level<br>• Process Flexibility<br>• Setup Times | • Order Entry System<br>• Scheduling Flexibility<br>• Transportation/Inventory System |

**Table 1 - Supplier Development Delivery Priorities**

## 3.5. SUPPLY CHAIN FLEXIBILITY

It has been mentioned before in section 3.2 at the performance measurements, but the supply chain flexibility is something to discuss further since it is the main reason for Benchmark to reduce the supply times. The prime motivation for supplier flexibility is the uncertainty in product demand experienced by the manufacturer (Beamon, 1998; Gunasekaran et al., 2001; Das & Abdel-Malek, 2003; Simchi-Levi et al., 2009; Purvis et al., 2014). According to Simchi-Levi et al. (2009) components that are not of strategic importance don't have to benefit from long-term buyer-supplier relationships. Beamon (1999) states that resources are directly related to the systems output and the flexibility performance. The output is important in determining the system flexibility.

A key factor facilitating the growth of outsourcing is the lead firm's desire to achieve greater strategic flexibility and lower risk by reducing fixed investments, especially in manufacturing facilities. Such considerations are especially important when the technological change is rapid and market volatility is high, like in the electronics industry (Sturgeon & Lee, 2001).

Two key concepts are consistently linked to supply chain agility: flexibility and speed (Purvis et al., 2014). Time has become a key factor in competitiveness due to customers that are becoming increasingly reluctant to accept long

lead-time items. Lean and agile appear to address the same competitive priorities (cost, quality, service, flexibility), but they emphasize different elements. One of the greatest distinctions between agile and lean performers lays within the flexibility performance dimensions.

The two types of flexibility in which the most distinction is to be found between agile and lean systems, are volume flexibility and mix flexibility. Volume flexibility is defined as the ability to change the level of aggregated output, mix flexibility as the ability to change the range of products made within a given time period, while maintaining the same aggregated output. These two types of flexibility are 'external flexibility types.' They determine the actual or perceived performance of the company and are viewed externally by customers (Purvis et al., 2014). An other external flexibility type relevant in the Benchmark environment is delivery flexibility, which Gosling, Purvis & Naim (2010) describe as the range of and ability to change the delivery dates.

Flexibility is generally perceived as an adaptive response to environmental uncertainty (Purvis et al., 2014). More specifically, it is a reflection of the ability of the system to respond to volatile changes with little penalty in time, effort, cost or performance. Das & Abdel-Malek (2003) define supply chain flexibility as the elasticity of the buyer-supplier relationship under changing supply conditions. They also suggest that order quantities and supply times are the two most common changes in supply chains.

Supply network flexibility can be rationalized as a compromising of two key concepts: vendor flexibility and sourcing flexibility (Gosling et al., 2010; Purvis et al., 2014). Vendor flexibility refers to the flexibility related to the individual vendors within the supply base. Sourcing flexibility refers to the ability of the system coordinator to reconfigure a supply chain network through (de-)selection of vendors. This enables the supply system to adapt to market requirements. If a strategic partnering is in place, the flexibility requirements should be specified in a supply contract.

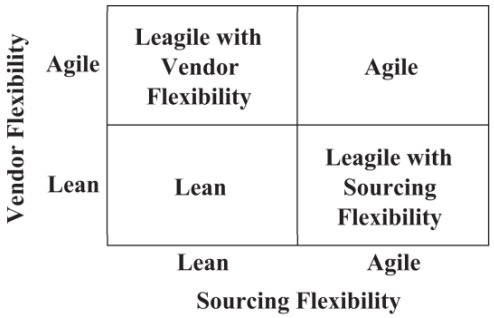



Figure 8 - Supply chain flexibility matrix (Purvis et al. (2014)

Purvis et al. (2014) provide a flexibility matrix to characterize the four different supply chain strategies. Applying this to Benchmark Electronics, different characteristics can be defined. NPI-parts for example require a different type of flexibility than the volume production goods. Therefore, a combination of both is optimal. This is also emphasized by Purvis et al. (2014), since they also provide a supply network flexibility framework. This implies having both types of flexibility as well as some other types of flexibility (like mix flexibility).

Supply chain flexibility is a key to cope with high levels of uncertainty. Gosling et al. (2010) performed a study in the construction industry, where high levels of uncertainty arise from project specific demands. This is similar to the environment of Benchmark, which operates project lines for different customers, each project line with different specific demands.

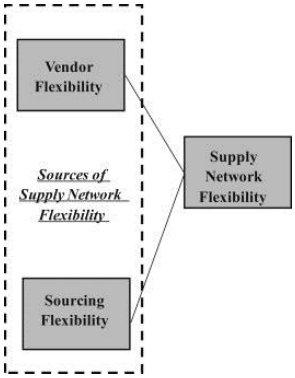



Figure 9 - Supply network flexibility framework (Gosling et al., 2010)

### 3.5.1. SUPPLIER PORTFOLIO'S

Network coordinators, in Benchmark's case Supply Chain Architects, can group their suppliers under three different categories, framework agreement suppliers, preferred suppliers and approved suppliers (Gosling et al., 2010). By using this framework, Gosling et al. (2010) argue that a network coordinator can maintain flexibility by maintaining a pool of suppliers within each of the categories. These classifications are used to inform sourcing and procurement decisions for different projects.

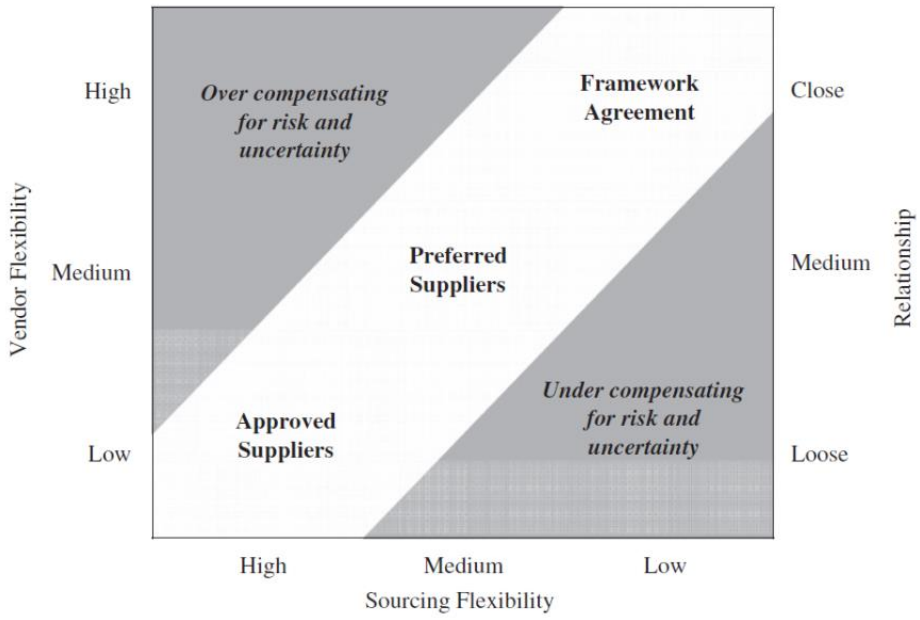



**Figure 10 - Supplier flexibility portfolio (Gosling et al., 2010)**

The diagonal line through the matrix shows the vendor and sourcing flexibility associated with each type of relationship. If the type of relationship is not on the diagonal, something is going wrong. If it is moving towards the top left of the diagonal, it's moving to a strategy in which high vendor flexibility and high sourcing flexibility are required. In this case the strategy is overcompensating for risk and uncertainty, which lead to extra costs. If it moves towards the bottom right of the matrix, a supply chain might not be prepared enough for the risk and uncertainty levels that arise within the chain.

- Framework Agreement: Recognizes the benefits of strategic partnering, just as Gunasekaran et al. (2001, 2004), Simchi-Levi et al. (2009) and some literature resources we will exploit later. Strategic suppliers are selected for key elements. Framework agreement suppliers are those suppliers that are most important to the buying company. Therefore they should be well integrated in the supply chain. The aim is to build close relationships by investing in the development of a supplier in order to achieve high vendor flexibility. Framework agreement suppliers are usually the suppliers that supply items that are critical for the project. In the research paper of Gosling et al. (2010), this is the manufacturer of the elevator. It invests heavily in new technology development and modular design principles. The product range is wide, as it is possible to adapt to project specific technical product designs.
- Preferred Supplier: The approach of the preferred supplier balances the level of both vendor flexibility and sourcing flexibility. Usually the network coordinator only considers the external flexibility of this type of supplier, but if a supplier is moving towards the framework agreement category, interest may be taken in the internal flexibility. The preferred suppliers are those suppliers that are used frequently for different

projects that require their products or services, in the case example: windows, pre-cast concrete and roof trusses suppliers.

- Approved Supplier: The approach of approved suppliers is to develop sourcing flexibility, rather than vendor flexibility. In the case example the approved suppliers are the suppliers that deliver the metalwork and brickwork. These are relatively standard items, with many potential suppliers within the supply chain.

Within the Benchmark environment other types of portfolio's are being held in terms of suppliers, the Kraljic statuses are not being kept up to date and a renewed type of portfolio is being used. This uses approved and preferred, but also a variety of other types like corporate preferred and customer prescribed. Framework agreement suppliers are not in it.

## 3.6. FORECASTING

As stated in section 3.1, Benchmark relies on the forecasts of their customers and they need to translate that into their own forecast. As Gunasekaran et al. (2001, 2004) and Prajogo & Olhager (2012) state the accuracy of the forecasts is important to measure. Terwiesch, Ren, Ho & Cohen (2005) show by empirical analysis that suppliers penalize buyers for unreliable forecasts by providing lower service levels. Vice versa, buyers penalize suppliers by providing overly inflated forecasts.

Sharing demand forecast information to suppliers has long been recognized as a key element in supply chain coordination. Terwiesch et al. (2005) address two issues regarding forecast sharing that occur in practice.

- Forecast volatility: Forecasts change and are continually updated as the buying firms gets new updates about the demand it faces. This problem is called forecast volatility. The question regarding forecast volatility is when the forecast information is accurate enough for suppliers start acting upon the given forecast and to justify it.
- Forecast inflation: Forecasts have the intention to provide information on what the supplier is planning to do in the future. These intentions are not verifiable and cannot be enforced. In the absence of a contractual obligation to actually buy what is forecasted, the buyer has an incentive to inflate forecast to assure sufficient supply. Fearing inflated forecasts, a supplier might delay its production until the point at which a buyer commits to its forecast. In Benchmarks case, this is the firm commitment zone that is embedded in the LFA.

In the provided two-by-two matrix, the setup is quite similar to the well-known prisoner's dilemma. If the buyer and supplier both choose to not cooperate, the forecast sharing benefit will disappear. The extent to which the two parties will choose cooperative actions depends on the relevant planning horizon. In a one-shot game both parties will most likely not choose to cooperate, but Terwiesch et al. (2005) show that in a multi-period game the parties will follow the last move of their opponent, creating a tit-for-tat strategy.

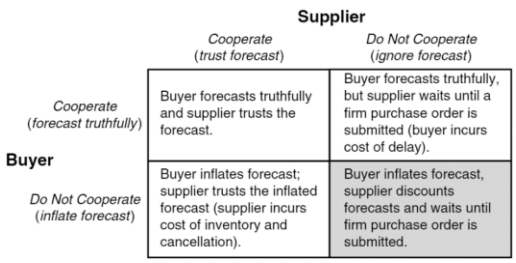



Figure 11 - Forecast cooperation prisoner's dilemma (Terwiesch et al., 2005)

Furthermore, they show that suppliers that have experienced large amounts of forecast volatility are less willing to allocate capacity to the buyer with the volatile forecast. This leads to overproporionally long lead-times. Also, suppliers that have been exposed to excessive order cancellations are less willing to allocate capacity towards forecasted orders. This again leads to overproportionally long lead-times.

They also identify a dilemma for the semiconductor supply chain, like the Printed Circuit Boards (PCBs) within the Benchmark environment. Just like in many customized capital goods industries, there is an order-fulfillment dilemma. Buyers expect their suppliers to be able to fulfill orders within in relatively short time. On the other hand, the high customization and value of the goods makes it risky for suppliers to keep finished assemblies in inventory, leading to long and also variable lead-times. To solve this dilemma, buyers send forecast, or "soft orders". These are just to show the intent of the buyer, but aren't binding.

In the Terwiesch et al. (2005) case, the semiconductor manufacturer uses a rolling forecast horizon principle, just like Benchmark does. These product level demand forecasts are used to forecast capacity requirements to existing and potentially new assemblies.

The buyer will probably update a soft order until the point in time it issues a purchase order. This gives the buyer a strong bargaining position. During the time the initial soft order has been issued until the placement of the purchase order, buyer and supplier will exchange information from one to another. Mostly, the buyer will update the supplier about changes in delivery dates, order sizes and other specific information. What will not be changed in here is the specification of the designed equipment. In the absence of such specification changes, soft orders have three modification scenarios.

1. The delivery date may be deferred or expedited. When changes are made in the planning horizon of the manufacturing plant, order dates may be rescheduled. Given the high capital costs associated with the high capital costs associated with the equipment, the buyer prefers to delay the delivery date over delivering the equipment and having it idle for quite some time.
2. The soft order might be completely cancelled. This is the case when the market demand levels are less than initially projected or when existing equipment operates at a higher yield/productivity level.
3. The soft order specifications remain the same.

The process from soft order to delivery is captured in the figure below.

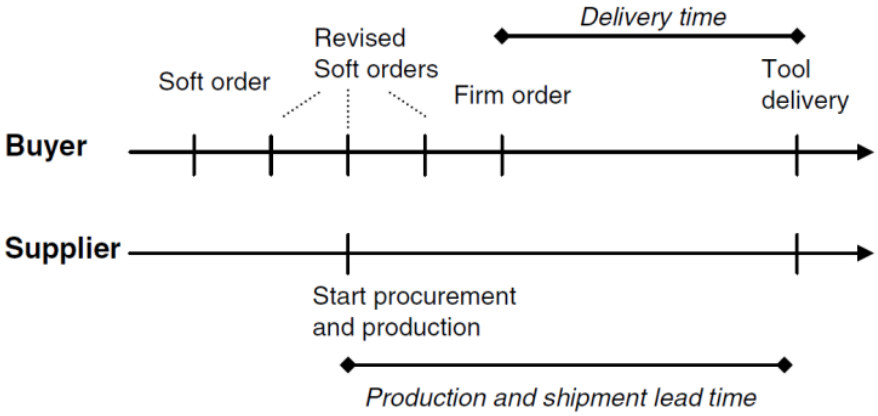



Figure 12 - Order process (Terwiesch et al., 2005)

In the Terwiesch et al. (2005) case, on average, buyers tend to place more soft orders than actual purchase orders. Their aim was to identify patterns of shared order forecasting that lead to on-time tool delivery. As can be seen in Figure 12, the delivery time is lower than the combined manufacturing and shipment lead-time. Therefore, if an order is to be delivered on-time, a supplier should be working on an order before the actual purchase order has been issued.

Sharing the latest forecast information with the supplier seems like a reasonable action, but from the supplier's point of view this is disturbing and viewed as less reliable information. Suppliers will thus act upon shared forecasts on the moment these forecasts are stabilized.

## 3.7. LEAD-TIME REDUCTION

Improved logistics integration yields lead-time reduction (Prajogo & Olhager, 2012). By shortening the lead-time, safety stocks can be lowered, the losses caused by stock outs can be improved as well as customer service level and the competition ability in business (Pan & Yang, 2002).

A good vendor will work with a purchaser closely to reduce lead-time as much as possible down to a point where it is acceptable to the purchaser, and also reasonable for the vendor to maintain a stable production and delivery schedule (Pan & Yang, 2002). To discuss the optimal balance supplier development initiatives can be initiated like those discussed in section 3.4.

Simchi-Levi et al. (2009) also state lead-time reduction has as benefit that supply chain uncertainty also reduces. Other benefits are the ability to quickly fill customer orders that can't be filled from stock, less finished goods inventory and an increase in forecast accuracy due to the shortened forecast horizon.

As Krause et al (2007) also stated, lead-time reduction is discovered as a trend of operational strategy and given the benefits of a reduced lead-time that doesn't seem weird. Fisher (1997) also states that the correct strategy within a company that provides innovative products is to aggressively invest in ways to reduce lead-times.

In the previous sections multiple factorials of increase or decrease in lead-time have been discussed. These factorials are summarized below:

- Forecast inaccuracy leads to inappropriate high lead-times. Increasing forecast accuracy thus yields a decrease in lead-time.
- Strategic partnerships and supply contracts give the opportunity to specify flexibility requirements under which can be collaborated.
- A flexible supply chain has the benefit a being able to respond quicker to market adaptions, this rapid response is a factor of short lead-time. To obtain a flexible supply network a supply flexibility portfolio can be used.
- Supplier development initiatives can be started to improve suppliers that do not meet requirements but do have the opportunity to do so.

## 3.8. SUMMARY

In this section multiple things have been sorted out regarding Benchmark's business environment and the supply chain function to regard in this thesis, namely the purchasing function, which primarily includes the managing of supplies and suppliers. For this business environment, multiple measurements have been identified within different segments of the purchasing responsibility. It has also been identified that information technology significantly contributes to business performance and it will provide a helpful tool in generating these measurements. Since creating supply chain flexibility with the use of lead-time reduction is the main strategic goal of Benchmark's purchasing function, supply chain flexibility and lead-time reductions have also been reviewed. Further emphasis has been laid on the impact of forecasting and also on supplier development initiatives.

# 4. DESCRIBING THE CURRENT SITUATION

Now that we discussed different views generated by researchers, it's time to investigate the current situation at Benchmark. After the identification of Benchmark's practices, these practices need to be assessed based on literature and opinions of the stakeholders. Also, it's time to dig into some corporate protocols regarding Benchmark Corporate and Benchmark Almelo. The focus will be on BAM, delivery performance measures and supply time reduction.

## 4.1. BAM

For performance monitoring and continuous improvement, Benchmark uses Benchmark Accountability Management (BAM). At the BAM, different reports are being presented across five different tiers:

1. Tier 1 BAM meetings will consist of manufacturing cells.
2. Tier 2 BAM meetings will be second level manufacturing for sites that have manufacturing supervisors managing multiple cells or managing multiple supervisors.
3. Tier 3 BAM meetings will be used for Customer Focus Teams.
4. Tier 4 BAM meetings will be used for internal department meetings.
5. Tier 5 will be the site General Manager and het direct reports.

Within the BAM meetings, different reports are being presented every day. These are located on the BAM board of the given tier. It is built up out of 4 different components, which are divided like in figure 1. The 4 components will be explained individually, but are listed below.

A. Safety, Quality, Delivery, Inventory and Costs (SQDIC) section
B. Daily Accountability Tracker section
C. A3 tracker section, a section for solving complex issues
D. Continuous Improvement section

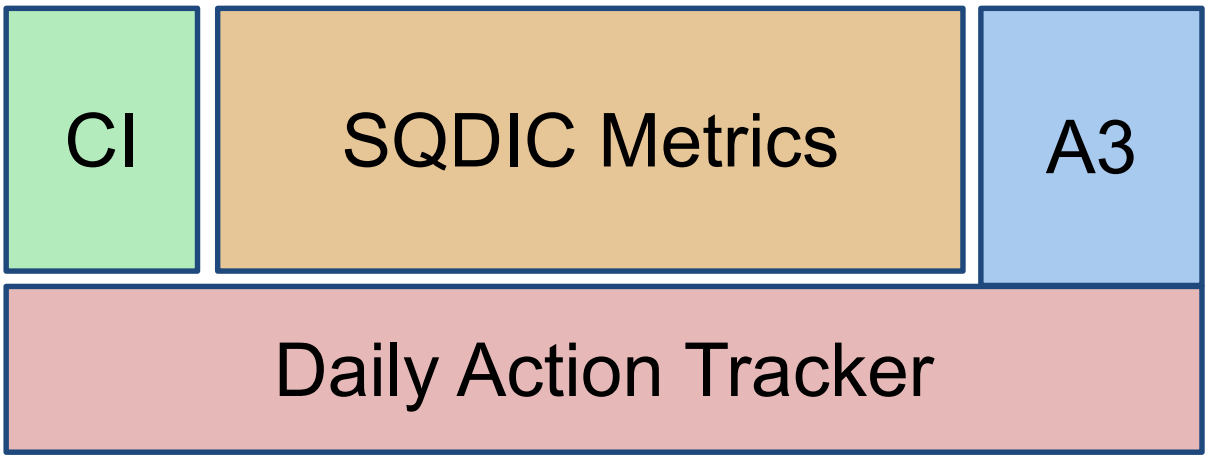



Figure 13 - BAM Board

## A. SQDIC SECTION

The SQDIC-section is the section in which the reports are found. These are divided in 5 different categories: Safety, Quality, Delivery, Inventory and Costs. Within these categories metrics are defined to monitor the performance within the given Tier. The metrics start with the corporate goals and flow down all the way to the manufacturing cell metrics in Tier 1. The only exception is at Tier 4, the internal department Tier. Only within the Engineering and Warehouse Department the metrics are defined at a corporate level. The metrics are posted on a wall that looks like in figure 2 and are then discussed in the BAM meeting.

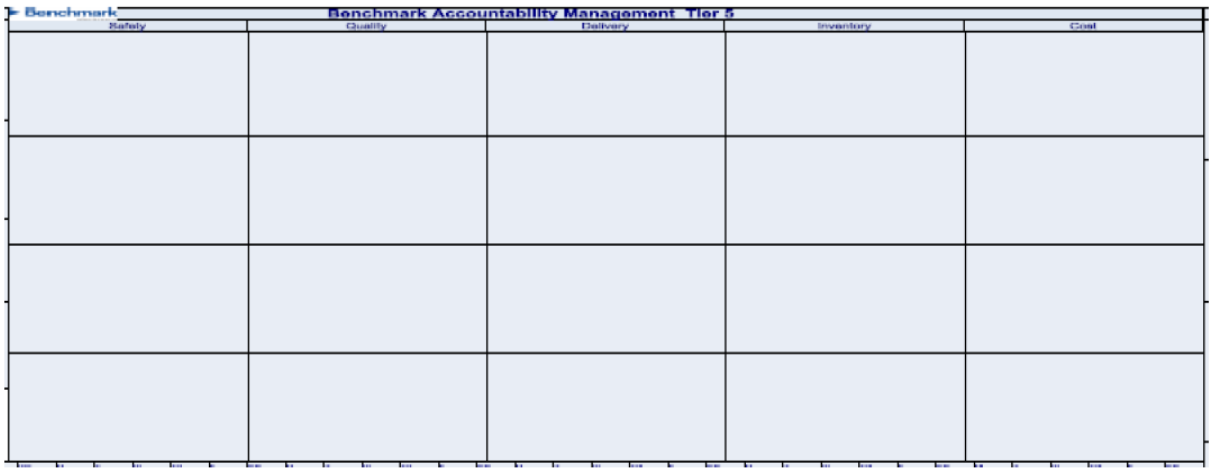



**Figure 14 - SQDIC metrics**

Because these reports are meant to monitor current performance and rate it, Benchmark uses the so called traffic light system. Within the KPIs a double target is set, an amber target and a red target. If performance is better than all targets a green smiley is shown, if performance is worse than all targets a red smiley is shown and if it's in between an amber smiley is shown.

## B. DAILY ACCOUNTABILITY TRACKER (DAT) BOARD

The Daily Accountability Tracker (DAT) Board shown in figure 3 is used to track specific tasks needed to ensure that the Tier team can meet the tactical SQDIC objectives.

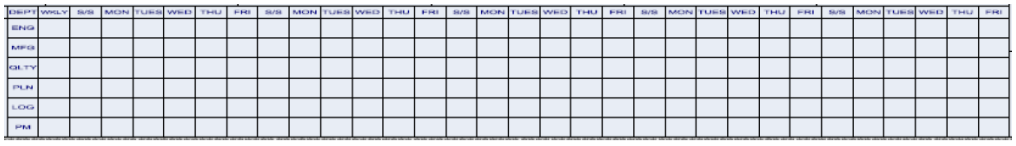



**Figure 15 - DAT Board**

Task slips need to be generated to define the task needed, task owner and required date due. Once agreed, the task is then placed in the row associated with Department/Area Representative for the date that it is due. The task will be reviewed at the DAT on this date and every day until the task is completed. All tasks that are at or beyond their assigned due date should reviewed daily. If an over-due task has been assigned a sufficient number of red dots (normally 5), it is escalated to the next logical Tier Meeting for resolution, which means that if a Tier 4 action tag is escalated it will be discussed in the next Tier 5 meeting. This DAT protocol is currently hardly used within the purchasing department. Post-Its are being used, but compared to the amount of actions to be taken the amount of DAT-related stuff is low.

### C. A3 SECTION

An A3 can be used wherever there is a need for people to work together to get clarity on a problem or proposal and then to create a set of realistic and effective countermeasures. A3s can be prepared by individuals, teams, or any leader with his or her reports.

The method in which the A3 is formatted is the main and most important message. You will need to follow the PDCA in these steps:

1. Situation or the Story
2. Plan
3. Do
4. Check or Learn
5. Act

The goal is to capture an entire improvement idea on one sheet of paper. Visuals are preferred to using words on the A3, making the document very easy to understand and enable quick decision making. If this procedure needs to come in place at Benchmark, a KPI is added to the SQDIC section. This seems to work just fine as well, but it's hardly used.

### D. CONTINUOUS IMPROVEMENT SECTION (CI-SECTION)

The Continuous Improvement (CI)-section of the BAM Board is being used to elicit employee suggestions for improvement ideas, and suggestions are submitted on a simple task slip (normally colored to identify them as CI suggestions). The CI Board should be an integral part of the weekly BAM operating system, but it's most certainly not.

Improvement suggestions are placed by employees in the top quadrant of the CI board and are reviewed weekly during the BAM. Once reviewed, the team should be putting the suggestions in one of these quadrants.

- Actions In-Progress: Once agreed to, the CI suggestion should be assigned (by name) and briefed weekly as part of the CI Board review process. Once completed, the CI suggestion should be filed as a record of the action taken.
- Parking Lot: Since these ideas are not declined, they should be reviewed periodically to move into the Actions In-Process quadrant.
- Declined: Suggestions that are declined by the team should be reviewed with the individual submitting the idea to see if the idea can be recast or revised for resubmission and to encourage him/her to continue to submit ideas for gaining better operational efficiency, mistake proofing, etc. Care should be taken to ensure that the rejections are not done in a way that discourages future submissions. After review with the individual, these suggestions will be removed from board.

## 4.2. DELIVERY PERFORMANCE MEASURES

The delivery performance is being reported in numerous ways. What can be categorized as delivery are the On Time Delivery (OTD) and the lead-time quotations. The OTD report gives us knowledge upon the deliveries that passed in the last trend period, with specific data of the last week provided in a table. It also gives insights in which suppliers do or do not meet the firm's requirements and are the ones disturbing the supply chain. Furthermore, the lead-time quotations are reported upon to gain information on the time frame in which a certain part can be delivered.

This information is spread across the different tiers within the company. For example, Program Managers need to obtain the quoted lead-times to inform the customers upon its flexibility possibilities. It's possible to access this data within a report, after a few different data selections. To gain insights on the delivery time reports, they will be discussed below.

### 4.2.1. ON TIME DELIVERY PERFORMANCE

The OTD Performance report is divided in 6 different charts/tables. One of them is misplaced within the reporting structure, because the base data is used for the full supplier balanced scorecard evaluation. Because the chart evaluates the quality performance, this chart is left out of discussion. The other charts and tables will be discussed, starting with the only chart shown in Figure 16.

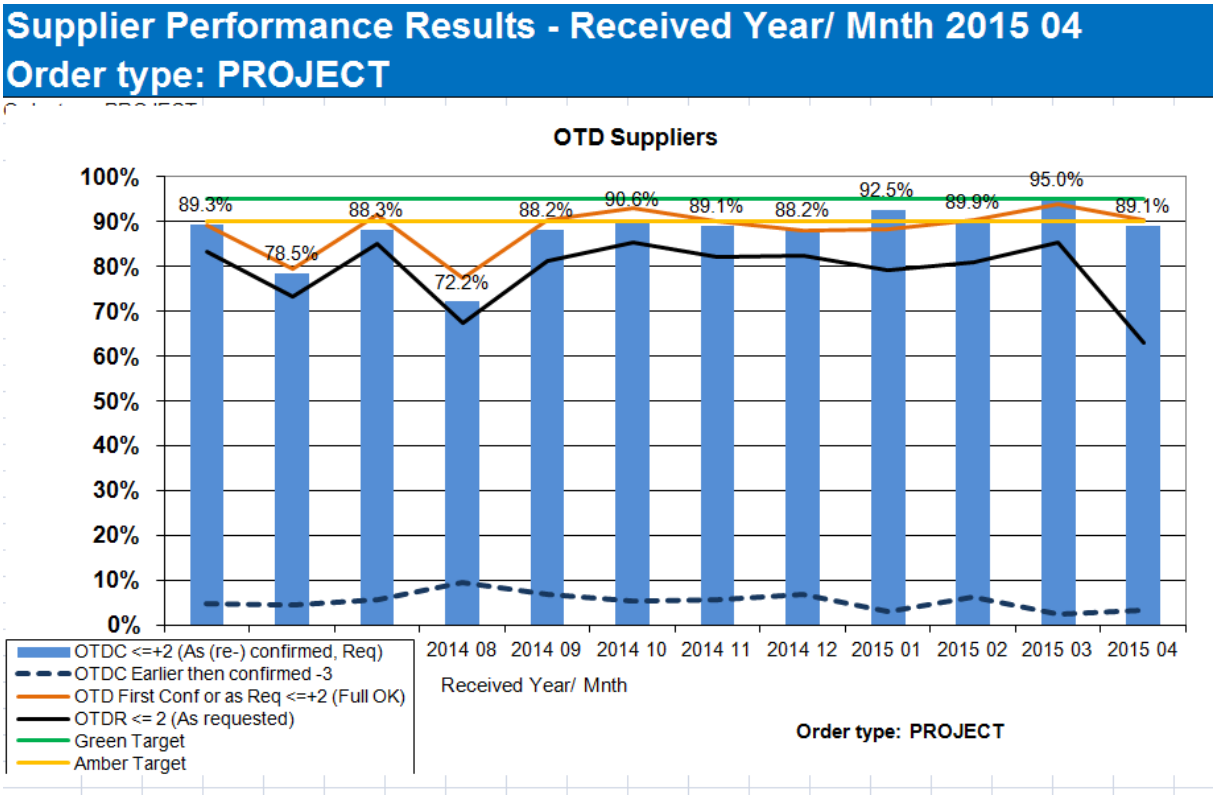
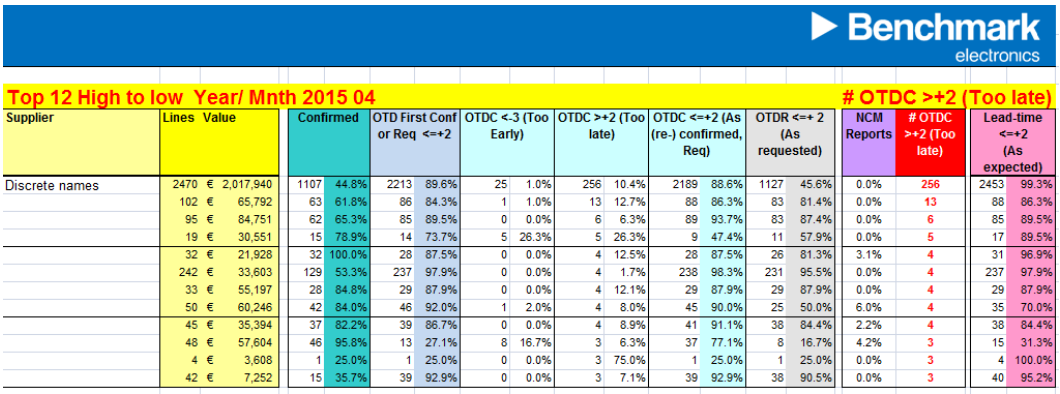



Figure 16 - Supplier OTD

This chart shows a variety of measures, as can be seen in the legend. However, only one percentage is being shown within the chart. This is the percentage measuring the On Time Delivery to Confirmation (OTDC), based upon the latest confirmation date. In case a Purchase Order (PO) remains unconfirmed, the requested date is used for measurement. A PO is marked 'On Time' if the delivery is received within -3 to 2 days from the confirmation date. This is the delivery date based upon the day the received item is taken into stock.

This is the only OTD-result being discussed within the BAM-sessions of Tier 4 Purchasing. The other results are measured, but remain out of discussion.



Benchmark electronics

Top 12 High to low Year/ Mnth 2015 04 — # OTDC >+2 (Too late)

| Supplier | Lines | Value | Confirmed | | OTD First Conf or Req <=+2 | | OTDC <-3 (Too Early) | | OTDC >+2 (Too late) | | OTDC <=+2 (As (re-) confirmed, Req) | | OTDR <=+ 2 (As requested) | | NCM Reports | # OTDC >+2 (Too late) | Lead-time <=+2 (As expected) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Discrete names | 2470 | € 2,017,940 | 1107 | 44.8% | 2213 | 89.6% | 25 | 1.0% | 256 | 10.4% | 2189 | 88.6% | 1127 | 45.6% | 0.0% | 256 | 2453 | 99.3% |
| | 102 | € 65,792 | 63 | 61.8% | 86 | 84.3% | 1 | 1.0% | 13 | 12.7% | 88 | 86.3% | 83 | 81.4% | 0.0% | 13 | 88 | 86.3% |
| | 95 | € 84,751 | 62 | 65.3% | 85 | 89.5% | 0 | 0.0% | 6 | 6.3% | 89 | 93.7% | 83 | 87.4% | 0.0% | 6 | 85 | 89.5% |
| | 19 | € 30,551 | 15 | 78.9% | 14 | 73.7% | 5 | 26.3% | 5 | 26.3% | 9 | 47.4% | 11 | 57.9% | 0.0% | 5 | 17 | 89.5% |
| | 32 | € 21,928 | 32 | 100.0% | 28 | 87.5% | 0 | 0.0% | 4 | 12.5% | 28 | 87.5% | 26 | 81.3% | 3.1% | 4 | 31 | 96.9% |
| | 242 | € 33,603 | 129 | 53.3% | 237 | 97.9% | 0 | 0.0% | 4 | 1.7% | 238 | 98.3% | 231 | 95.5% | 0.0% | 4 | 237 | 97.9% |
| | 33 | € 55,197 | 28 | 84.8% | 29 | 87.9% | 0 | 0.0% | 4 | 12.1% | 29 | 87.9% | 29 | 87.9% | 0.0% | 4 | 29 | 87.9% |
| | 50 | € 60,246 | 42 | 84.0% | 46 | 92.0% | 1 | 2.0% | 4 | 8.0% | 45 | 90.0% | 25 | 50.0% | 6.0% | 4 | 35 | 70.0% |
| | 45 | € 35,394 | 37 | 82.2% | 39 | 86.7% | 0 | 0.0% | 4 | 8.9% | 41 | 91.1% | 38 | 84.4% | 2.2% | 4 | 38 | 84.4% |
| | 48 | € 57,604 | 46 | 95.8% | 13 | 27.1% | 8 | 16.7% | 3 | 6.3% | 37 | 77.1% | 8 | 16.7% | 4.2% | 3 | 15 | 31.3% |
| | 4 | € 3,608 | 1 | 25.0% | 1 | 25.0% | 0 | 0.0% | 3 | 75.0% | 1 | 25.0% | 1 | 25.0% | 0.0% | 3 | 4 | 100.0% |
| | 42 | € 7,252 | 15 | 35.7% | 39 | 92.9% | 0 | 0.0% | 3 | 7.1% | 39 | 92.9% | 38 | 90.5% | 0.0% | 3 | 40 | 95.2% |

**Figure 17 - Supplier OTD table**

The items contributing to the downgrading of the OTD-grade because of lateness are highlighted in Figure 17, which is a table given next to the chart in Figure 16. For the sake of supplier anonymity the names of the suppliers have been deleted from the table. A lot of information can be obtained by reading the table. The instant question that arises is which of these percentages are relevant and what do they tell about the supplier's performance in the given period?

1. The amount of delivered order lines with the value of these order lines
2. The amount of confirmed order lines, with a percentage of the order confirmations
3. The OTD, based upon the first confirmation date, or the requested date in case the order remains unconfirmed. Given is the amount of order lines that are in time, together with its percentage.
4. The amount of order lines that is delivered too early, according to the OTDC, together with its percentage.
5. The amount of order lines that is delivered too late, according to the OTDC, together with its percentage.
6. The OTDC-amount of order lines and percentage.
7. The OTD to Requested date (OTDR), with amount and percentage
8. The percentage of order lines containing Non-Conforming Material (NCM)
9. Another column containing the amount of too late delivered order lines according to the OTDC-measure, highlighted in red color, to show that it's the amount to be discussed.
10. The amount and percentage of order lines that have been delivered according to the mutually agreed upon lead-time. For this measure, the following is being checked:

    $$Delivery\ date - order\ date\ \leq Quoted\ delivery\ lead\ time?$$

    If this is the case, a supplier has performed correctly according to the lead-time expectations. If this is not the case, a supplier has failed to order according to the quoted delivery lead-time.

This is just one out of four tables containing information. The others are summarized below, since they are equal for table headers:

- A trend table of the top 12 high to low: This is a summation of the last 12 time units. This is to keep track of the more structural underperformers.
- A top 12 table of the suppliers that caused disturbances in the OTD-performance because of delivering items too early. There is one difference in table headers between this table and Figure 17. The difference is in the field that has been marked in red. In this table the amount highlighted in red concerns the deliveries that have been too early.
- Another trend table of the top 12 high to low: This time concerning the underperformers that have delivered order lines too early.

### 4.2.2. ITEM LEAD-TIME QUOTATIONS

| | Totals Items | Avg LT Weeks | 12 Month Demand |
|---|---|---|---|
| Total | 9924 | 10.0 | € 20,645,707 |

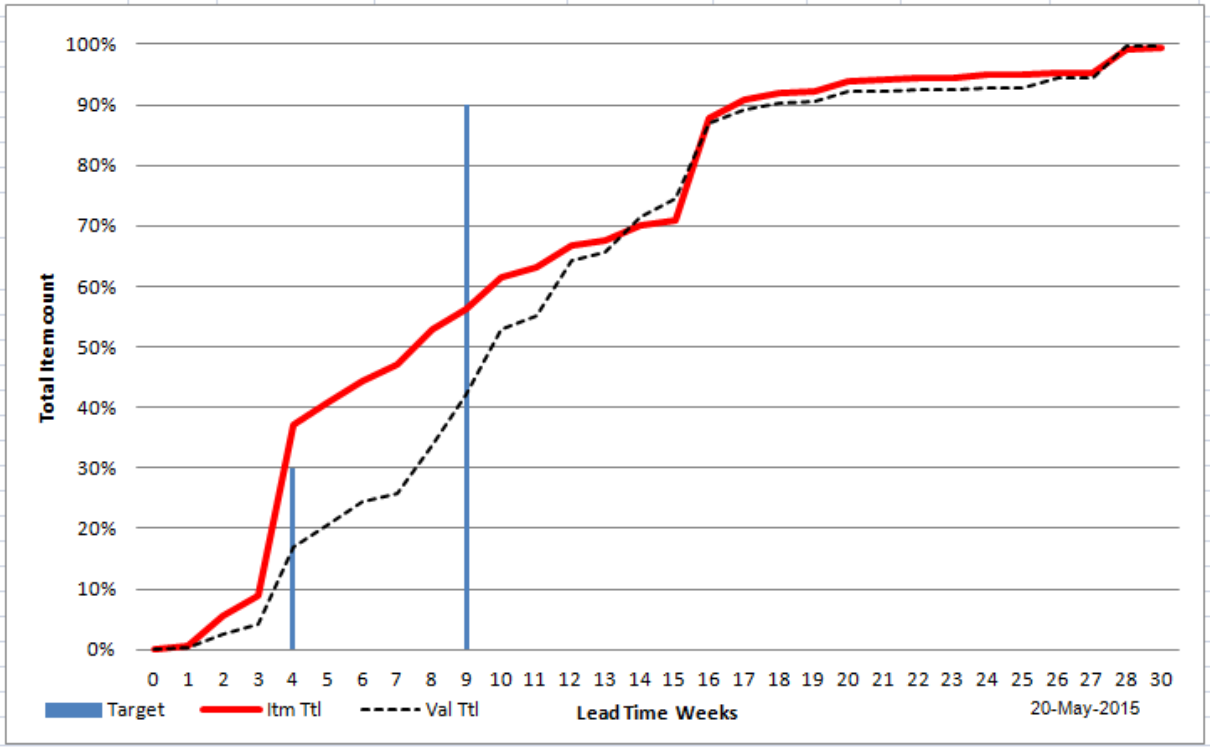



Figure 18 - Item Lead-time Graph

In the Item Lead-time Graph the percentage of the total item count, excluding items with signal code NPR, are set out against axes of percentage and lead-time weeks. Also, the value total of those items is set out against the lead-time weeks. In the chart, two vertical lines are represented. These are the corporate targets of the item lead-time quotation performance. Within this report there are also two extra tables, which are given in Figure 19 and Figure 20.

**Top 15 priorities on Lead Time towards Suppliers**

| B-Partner | Suppl Name | Initial purch | Resp Buyer | SDE | # Items | Avg LT Weeks | Demand 12Mnth | % LT Impact | % Value |
|---|---|---|---|---|---|---|---|---|---|
| SCN000002 | ANY | | | | 2292 | 16 | € 3,843,299 | 36.9% | 18.6% |
| SCN026893 | | | | | 1447 | 8 | € 327,927 | 12.3% | 1.6% |
| SCN026901 | | | | | 518 | 11 | € 205,490 | 5.8% | 1.0% |
| SCN029624 | | | | | 441 | 11 | € 905,305 | 5.1% | 4.4% |
| SCN026894 | | | | | 365 | 10 | € 232,990 | 3.8% | 1.1% |
| SCN026895 | | | | | 401 | 8 | € 124,492 | 3.2% | 0.6% |
| SCN028617 | | | | | 192 | 14 | € 32,086 | 2.6% | 0.2% |
| SCN012226 | | | | | 362 | 6 | € 59,013 | 2.2% | 0.3% |
| SCN037543 | | | | | 200 | 9 | € 154,444 | 1.9% | 0.7% |
| SCN026896 | | | | | 257 | 6 | € 645,278 | 1.5% | 3.1% |
| SCN029167 | | | | | 127 | 12 | € 368,483 | 1.5% | 1.8% |
| SCN028822 | | | | | 112 | 9 | € 136,291 | 1.0% | 0.7% |
| SCN026892 | | | | | 52 | 14 | € 335,051 | 0.7% | 1.6% |
| SCN039135 | | | | | 239 | 3 | € 548,873 | 0.7% | 2.7% |
| SCN004661 | | | | | 99 | 7 | € 320,964 | 0.7% | 1.6% |
| **Totals:** | | | | | **7104** | **10** | **€ 8,239,986** | **79.9%** | **39.9%** |

Figure 19 - LT Priorities

For the sake of anonymity the cells with names have been made blank. Except for the standard business partner code SCN000002, which is the default supplier if an item number doesn't have a registered supplier yet, or item settings might have changed. It shows the top 15 suppliers based upon the percentage of lead-time impact (% LT Impact). The total lead-time impact of a supplier is calculated as $Supplier\ LT\ Impact = \#Items * Avg\ LT\ Weeks$. The percentage of the lead-time impact is then calculated as $\%\ LT\ Impact = \frac{Supplier\ LT\ Impact}{\sum Supplier\ \ LT\ Impact}$. The only filter that applies to this is the NPR signal code. The Lead-time Priorities will be discussed later in this report.

It can be seen the number of item codes SCN000002 is fairly high, containing $\frac{2292}{9924} * 100\% \approx 23\%$ at the moment of making the screenshot of the report. Even though this may seem like a lot (and it is a lot), it's explainable due to the fact of the transfer of a new Thales product line. This is left out of further discussion.

**Top 15 priorities on Liability towards Suppliers**

| B-Partner | Suppl Name | Initial purch | Resp Buyer | SDE | # Items | Avg LT Weeks | Demand 12Mnth | % LT Impact | % Value |
|---|---|---|---|---|---|---|---|---|---|
| SCN000002 | ANY | | | | 2292 | 16 | € 3,843,299 | 36.9% | 18.6% |
| SCN028797 | | | | | 11 | 16 | € 1,755,825 | 0.2% | 8.5% |
| SCN029624 | | | | | 441 | 11 | € 905,305 | 5.1% | 4.4% |
| SCN026896 | | | | | 257 | 6 | € 645,278 | 1.5% | 3.1% |
| SCN016333 | | | | | 114 | 4 | € 633,307 | 0.5% | 3.1% |
| SCN036949 | | | | | 1 | 9 | € 620,326 | 0.0% | 3.0% |
| SCN039135 | | | | | 239 | 3 | € 548,873 | 0.7% | 2.7% |
| SCN029727 | | | | | 24 | 16 | € 523,537 | 0.4% | 2.5% |
| SCN029140 | | | | | 20 | 12 | € 488,840 | 0.2% | 2.4% |
| SCN029420 | | | | | 4 | 26 | € 403,717 | 0.1% | 2.0% |
| SCN029167 | | | | | 127 | 12 | € 368,483 | 1.5% | 1.8% |
| SCN043286 | | | | | 2 | 10 | € 355,650 | 0.0% | 1.7% |
| SCN026892 | | | | | 52 | 14 | € 335,051 | 0.7% | 1.6% |
| SCN040399 | | | | | 4 | 8 | € 333,485 | 0.0% | 1.6% |
| SCN026893 | | | | | 1447 | 8 | € 327,927 | 12.3% | 1.6% |
| **Totals:** | | | | | **5035** | **11** | **€ 12,088,903** | **60.2%** | **58.6%** |
| **Grand Totals:** | | | | | **9924** | **10.0** | **€ 20,645,707** | **100%** | **100%** |

Figure 20 - Liability Priorities

Both of these priorities aren't really actionable. The LT priorities make no sense, because the items below 4 weeks aren't filtered. The liability priorities only summarize the monetary impact of a supplier. Not really actionable as it is.

**Lead Time Analysis Summary - Programs**

Updated: 20-May-2015

Product Line (All)
Fixed LT (Multiple ms)

Percent of Item count

| Demand Customer | Items 1-4 Wks | 5-9 Wks | 10-12 Wks | 13-16 Wks | 17-20 Wks | 21-24 Wks | 25+ Wks | Grand Total |
|---|---|---|---|---|---|---|---|---|
| AIB | 54.5% | 20.4% | 9.5% | 5.6% | 3.8% | 1.3% | 4.9% | 100.0% |
| ASM | 54.9% | 21.9% | 14.1% | 3.0% | 4.2% | 0.6% | 1.5% | 100.0% |
| BEI | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| BME | 32.2% | 26.1% | 9.7% | 14.9% | 14.0% | 0.7% | 2.4% | 100.0% |
| FLU | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| GND | 53.8% | 23.9% | 11.1% | 4.9% | 4.6% | 0.0% | 1.6% | 100.0% |
| MRO | 73.0% | 21.6% | 5.4% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| MSZ | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| OTN | 49.4% | 20.2% | 8.1% | 7.6% | 9.2% | 0.8% | 4.8% | 100.0% |
| RNS | 32.5% | 28.2% | 12.6% | 11.5% | 8.4% | 0.7% | 6.2% | 100.0% |
| THL | 25.1% | 21.2% | 16.3% | 12.5% | 9.5% | 2.4% | 13.1% | 100.0% |
| ZEH | 42.5% | 19.2% | 19.9% | 8.9% | 8.2% | 1.4% | 0.0% | 100.0% |
| SIR | 45.9% | 13.1% | 8.2% | 19.7% | 13.1% | 0.0% | 0.0% | 100.0% |
| **Grand Total** | **42.7%** | **21.8%** | **13.2%** | **7.9%** | **7.2%** | **1.2%** | **5.9%** | **100.0%** |

Figure 21 - LT Program Summary

In Figure 21, information can be won regarding the lead-time percentages per product line. The item lead-times are divided in categories, and the given percentages are item codes per product line. These lead-times are of importance for Program Managers, to communicate supply possibilities for the items of these customers. They however do not appear in the

## OPEN PURCHASE ORDERS (POS)/EXPEDITING LIST

Since Benchmark strives to maintain a flexible supply chain, the purchasers needs to get operating signals. These signals a summarized in a pivot table and shown at the BAM-meetings as a delivery KPI using a pivot chart and this table by buyer of project line. This KPI is shown in Figure 22. As can be seen there are quite some actions to be undertaken, with a total of 1521 PO lines that need action on a total of 2574 PO lines. These actions vary in need. The actions that have a need for a flexible supply chain are listed in Table 2.

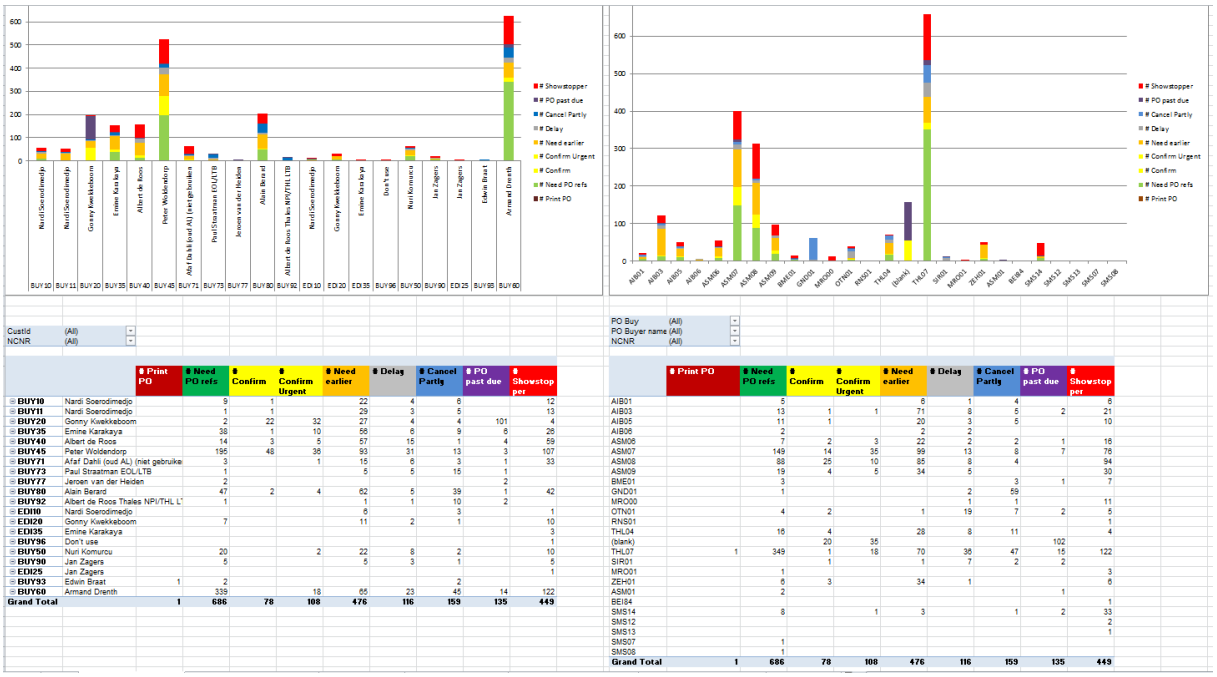



Figure 22 - Open PO/Expediting List

| Action | Why is the signal generated? |
|---|---|
| Need earlier | Customers update their forecasts regularly. It could thus very well be that their sales plan has increased the sales and they need the product earlier. One of the consequences might be a PO line is needed earlier. If a part is needed earlier, suppliers thus have to be contacted. |
| Showstopper | A showstopper in this report is a PO that is needed earlier, but with the need earlier date that is today or earlier. These POs are thus very urgent! |
| Cancel (Partly) | An other thing that might happen is that a customer might cancel an PO because of a PO they are not going to sell anymore. This has consequences for the Benchmark's purchasing department as well. If the PO will be delivered to Benchmark, it will become excess or obsolete inventory. POs thus have to cancelled as quickly unless planners tell at the BAM session certain signals should not be followed. |

| | |
|---|---|
| Delay | If a PO is needed later because of customer requirements, it needs to be delayed. A delayed PO has a delay benefit because the item then remains in stock for a shorter period of time and it thus the holding costs are lower. |

Table 2 - Rescheduling signal types

The other signals that are generated don't have anything to do with changing the PO in terms of delivery due date and thus flexibility. These are POs that need to be printed, unconfirmed POs, past due POs or POs that need PO references, like a Supplier Order Number.

If a supplier is flexible the flexibility signals will not cause any problems. However, every signal is based upon forecasts and demand is quite uncertain. As the purchasing employees have stated, they sometimes have to delay a PO first and need it earlier in a later point of time on the date that was first set. These shift in due date occurs because of changes in production planning and customer forecasts. As could be seen in the analysis of Terwiesch et al. (2005), the changing of due dates can lead to a dramatic decrease in delivery reliability. Moreover, the employees are doing irrelevant work. If supply times are low, the assumption is less of these signals will be generated and it's influence will be positive on the purchasing performance in terms of delivery reliability.

## 4.3. SUPPLY TIME REDUCTION

Within Benchmark Electronics all lead-times are quoted. These quoted lead-times are divided within categories of a specific amount of weeks. For measurement purposes only items with demand are being considered for commissioning the lead-time. Items with lead-time 111 are items that are not commissioned yet and need a fixed lead-time to be taken into the simulations and measurements with the correct lead-times. Also, items with item signal end of life (EOL) are set to 199 by default. For correct measurements, all lead-times need to be filled. If an item is new and not production released (NPR), it also gets set to lead-time 111 by default. This item code is not being considered in measurements, because the main issues with those items is that they aren't commissioned into the system correctly and because of the item signal code will not be ordered yet.

Because of the business environment Benchmark Electronics operates in, with a high NPI-rate, it's important those items are commissioned correctly in a timely manner. Even though items may not be production released, it is still possible there is demand on the item. This will result in a planned purchase order that has a default lead-time and will not be permitted to buy.

Another result of the business environment is the high lead-times components might have. A lot of complex electronics equipment is manufactured with a defined percentage of specifically designed products for the customer.

To reduce lead-times, two different measures are being undertaken by Benchmark Electronics. To specify which items to take for which agreement, items are divided in two separate categories: electronics and mechanics.

### 4.3.1. ELECTRONICS

Electronics components are the components which 'can be found at every single corner of the street'. Since the primary goal is to quote 80% of the lead-times on 4 weeks or below, the first thing to do was mail all suppliers for the electronics components: 'Which items are always to be found in stock at your location?'. Items with a standard level of inventory are quoted on 4 weeks as a standard. This already reduced the lead-time for quite some components. However, not nearly all components are to be found in a supplier's inventory. To manage demand uncertainty, Benchmark uses a rolling forecast.

The second focus was on items that are standard components, but for which Benchmark customers aren't liable and which cannot be found in the supplier's inventory. For these items it's important for Benchmark to be able to cancel, defer or expedite them at all time. Why? As a contract manufacturer, you don't want to create excess or obsolete inventory. If this becomes the case, extra effort has to be done to sell the inventory to customers which don't have a product line. The items in this category are obtainable for the supplier at different suppliers of theirs.

The third focused item groups are the NCNR-items, which are non cancelable and non returnable. About 10% of all items, electronics and mechanics, are NCNR. A lot of these items are specifically made, so Benchmark has to accept them if a PO is made. This means Benchmark has two focuses concerning NCNR items. They need to have the shortest delivery time as possible and the aim is to make all customers liable for the NCNR parts.

As stated earlier, Benchmark uses a rolling forecast to indicate when and which quantity of an item is to be bought probably. An effect of shorter lead-times on the forecasts is that the forecast will be more accurate. This means that the supplier's chances of actually selling the part to Benchmark will grow and so the buyer-supplier dyad is performing better.

### 4.3.2. MECHANICS

For mechanical parts, the stakes are a little different than for electronics parts. A lot of the mechanical parts are specifically made and NCNR, so something has to be done in order to make sure the part processing starts before an order is placed, Benchmark aims to set up a lot of Logistic Forecast Agreements, which actually are agreements for VMI. Also, it creates a shared commitment in the buyer-supplier dyad. Summarized the aims of the agreement are to:

- Share a limited risk within the supply base related to the rescheduling of required delivery dates.
- Supplier lead-time reduction
- Improve (either party's) logistic performance under the agreement
- Create flexibility in supply.

The purposes for the supplier herein are as follows:

- Allocate raw materials, partially completed products and capacity for products as indicated in the rolling forecast.
- Deliver products upon a mutually agreed delivery time from the moment a Benchmark PO is released.
- Improved flexibility to anticipate on Benchmark business demand and therefore Benchmark's customer demand plan.

The Liability Window defines the time frame and liability for VMI. This window is divided in two different zones, the Firm Commitment Zone (FCZ) and the Limited Commitment Zone (LCZ). Within the FCZ, Benchmark is fully liable for the product the supplier delivers. The FCZ is thus equal to the lead-time of this product. The LCZ describes a period in weeks, applicable for all VMI-products. Product deliveries that are currently scheduled to occur outside the LCZ but within the liability window can be found in the LCZ. This is a period which is agreed upon between Benchmark and the supplier. Terwiesch et al. (2005) state that this kind of coping with forecast cooperation dilemmas is the way to go.

The scope of the supply chain architect is reducing lead-times of two types: The 'quick scores' and the longest lead-time items. The quick scores are a bunch of items from a single supplier to be set to a FCZ of 4 weeks and therefore

gaining the most items to be set within the corporate standard of 4 weeks delivery lead-time. This is the first focus. If there are few quick scores open, the focus will be on long lead-time items (25+ weeks).

## 4.4. SUMMARY

In this section some of the current procedures of Benchmark have been explained. It has been defined how BAM works in general according to the BAM corporate protocol. This has also been assessed by the findings at the purchasing BAM sessions themselves. Furthermore the current delivery reports have been discussed and improvement opportunities have been found. Also, the supply time reduction strategies currently embraced by Benchmark's purchasing department have been reviewed.

# 5. LITERATURE REVIEW – PERFORMANCE IMPROVEMENT

## 5.1. SUPPLY CHAIN PERFORMANCE IMPROVEMENT

Good supplier management does not constitute to good supply chain management if the other factorials are left behind in attentie. De Treville, Shapiro & Hameri (2004) performed a study in which the focus was on reducing the production cycle time. One of the companies achieve a reduce in production cycle from 4 weeks to one week, implying that all products would be made each week if needed. This required improvement in the consistency of the process after each change, but was easy to accomplish. The 1 week production cycle meant that the lot sizes entering the pipeline were much smaller and were more likely to respond to actual customer demand.

This reduction in lead-times encouraged supply chain participants to work together to exchange information. As a result, the demand chain has achieved a reasonable level of market mediation. Service levels and profitability had improved. This is an interesting result for this thesis, since this reduction in manufacturing time meant shorter supply times. With initiating a supplier development program like discussed in section 3.4 it might be an interesting opportunity to reduce the supply times from Benchmark's perspective. This would also lead to increased supply chain flexibility.

In the study of Krause et al. (2007), support was found for several hypotheses. A positive relationship between buying firms' commitments to long-term relationships with key suppliers and the buying firms' performance improvement was found. Furthermore, the hypothesis of a positive correlation between the buyer's performance improvement and shared values between buyers and its key suppliers was confirmed. This is a confirmation of the contribution of supply contracts to the performance improvement.

Krause et al. (2007) also confirmed that for the performance improvement in the sections of quality, delivery and flexibility, direct involvement is better than sharing information or evaluating suppliers. Direct involvement activities are for example supplier training, regular visits to the suppliers' facilities and supplier development initiatives.

## 5.2. ENABLING PERFORMANCE MEASURES

In the study of Wouters (2009), an effort has been made to create an enabling performance measurement system. In other words, the effort was to establish a PMS with the goal of activating the employees to improve that performance instead of just using it as a control device, exactly like the BAM system. During a 4 year period, he used the developmental approach to design a performance measurement system, based primarily on findings at the company, rather than literature. The intention of the case study of Wouters (2009) was to create a PMS employees would be able to use for their own purposes. It could then be used to prioritize the employee's actions, identify problems, develop ideas for improvement, engineer solutions for concrete problems or make decisions. No direct link to finance was made.

Adler & Borys (1996) state that people are more likely to have a positive attitude towards formalization, like a PMS, when it enables them improve their own performance. They will be more negative when it functions as a means to inform management of the current performance and coerce employees' effort. In order to improve this performance, it is important a PMS is flexible. "Flexible systems encourage users to modify the interface and add functionality to suit their specific work demands" (Adler & Borys, 1996, p.74). Also, Wouters (2009) states that involving users and building on their experience is a necessity to be able to have a flexible and transparent enabling PMS. This implies that the measures are understandable for employees and that it's something they can influence.

In order to facilitate the usage among the employees it's important the information systems are easiliy handled. In the research paper of Wouters (2009), an employee had to run Excel macros to be able to get the relevant data out of the ERP system. With the introduction of a business warehouse-module (which is a data warehousing tool), working with performance measures became easy and understandable for the employee. The specific employee states "performance measures should be a help and not a cause of extra work", a phrase similar to those spoken within the Benchmark environment where macros are also used.

One of the most effective ways for creating a transparent PMS is to let the measures be produced by the people whose performance is going to be measured rather than a controlling department. If the employees lacked skills to do this, operational managers should facilitate extra training. It is a prerequisite to make IT tools available with which non-specialists can work. Organizational change processes that use existing local knowledge are more likely to lead to sustainable changes and improvements (Wouters, 2009).

Wouters (2009) also counters the idea of letting an external consultant make a PMS with standardized measures etc. Performance measures are specific for a company and need to fit within the context of this company. They aren't generic or easily passed between different companies.

One of the results of using the developmental approach is that a set of thorough metrics has been found. Other results are that it contributes to the belief in a PMS by the employees, increasing their commitment to performance improvement. Furthermore, one of the results is that modern information technology should be embraced to analyze data. If information systems are understandable, it is possible to give employees the responsibility to periodically report. Furthermore it should ease them into finding the causes of the bad performance and investigate the improvement opportunities.

## 5.3. TACKLING DEMAND UNCERTAINTY

An interesting finding is that the buyer cost performance is positively associated with supplier performance. However, the supplier cost performance is not a significant effect indicator for supplier performance. This implies that the cost reduction within a buyer company in a supply chain could be achieved by the suppliers' quality or delivery performance, but not by the cost performance.

Das & Abdel-Malek (2003) also address some issues in the perspective of supply chain partnering. One of the prime relationships utilities is that a manufacturer (Benchmark) is able to transfer some of the uncertainties regarding customer demand to the supplier. This reduces the production risks of the manufacturer and also decreases the reliance on enormous inventory levels to be able to counter the uncertainty in customer demand.

Shin, Collier & Wilson (2000) test a range of hypotheses and come up with interesting results. Four performance characteristics regarding Supply Management Orientation (SMO) are tested to contribute to supply chain performance in general. These are long-term relationships with suppliers, supplier involvement in the product development process, a reduced number of suppliers and a focus on quality. Higher levels of SMO resulted in improved performance of both buyer and supplier.

### 5.3.1. VENDOR MANAGED INVENTORY

Benchmark's explaining of Vendor Managed Inventory (VMI) is a little different than in literature. In literature, VMI is explained as a strategic partnership in which the vendor is able to monitor the inventory levels at the buyer's Stock Keeping Units (SKUs) (Xu, Dong & Evers, 2001). Within Benchmark, items are marked as VMI-items in case an

agreement is made upon the delivery time of a part which actually has a longer lead-time than quoted. Because of the forecast and the partnerships supply times are then shortened.

According to Achabal, Mcintyre, Smith, & Kalyanam (2000) one of the VMI benefits is defined as follows:

*"More effective inventory management and less uncertainty regarding inventory turnover and customer service levels. Because of the VMI-system it's also possible to set targets for these factors and to also be able to achieve them in a proper manner."*

VMI is shown to be significantly better at responding to volatile changes in demand such as those due to discounted ordering or price variations (Disney & Towill, 2003). In a classic VMI situation the supplier makes the replenishment decision, rather than waiting for the customer to reorder the product (Dong & Xu, 2002). This is not the case, since Benchmark issues purchase orders to derive the goods from the customer. But since there are a lot of innovative products this doesn't seem like a weird thing to do. According to the findings of Claassen, van Weele & van Raaij (2008), VMI leads to three performance outcomes: Higher customer service levels, improved supply chain control and to a lesser extent, cost reduction.

In the early 1980s, when VMI originated, mass retailers demanded vendors to take up the responsibility for inventory replenishment based on their available sales figures (Claassen et al., 2008). However, VMI has spread to industries outside retailing. The goal of VMI is to create a win-win situation for both the buyer and the supplier. In a true VMI setting, the supplier is free to plan its own production and replenishment schedule, as long as the agreed customer service levels are met (Claassen et al., 2008). Enhanced collaboration between both supply chain partners should reduce lead-times and also the bullwhip effect. Furthermore the manufacturer encounters smaller inventory levels to manage demand.

In order for the supplier to manage the inventory at the buyer's site, information about inventory levels, expected demand and product related costs should be available to the supplier. This information enables suppliers to make better replenishment decisions based on total supply chain costs. This prevents local sub-optimization. Early availability of this information enables a more active supplier approach, which should result in reduced lead-times. This again underlines the impact of accurate forecasting in the Benchmark environment.

## 5.4. SUMMARY

In this section multiple things have been pointed out. First of all it's important to not only focus of the supplier management performance, but also take other things into account when improving supply chain performance. Furthermore a broad explaining has been given on enabling performance measures which should facilitate performance improvement. In addition to what should be measured, explained in section 3.2, it is further explained how to measure. Emphasis has been laid on two major components: Modern IT systems should be embraced within a company to make working with data easy for non-professionals and the PMS should be built on existing local knowledge within the company. Last but not least it has been explained why VMI contributes to the strategic goal of the purchasing department: Reducing supply times with a reduction in inventory levels.

# 6. PRACTICAL IMPLICATIONS

## 6.1. WHY NOT TO CHOOSE TO BUILD A DATA WAREHOUSE

The initial goal of the project was to improve on the BAM-reports. The focus was on the meeting structure and how to enable employees to come into a state of performance improvement. The underlying data gave the possibility to hide behind the data, because the data was somewhat inconsistent. Therefore the information coming from the data wasn't always being taken seriously. Moreover, to get access to the information, a single computer had to be started in order to start the visual basics macro processing. This also resulted in complaints from employees rather than facilitating them in analyzing the data.

During the project, it was found the solution to this problem would lie in building a data warehouse. The company however didn't agree to really building a data warehouse. Why not? Data warehousing is about decision support, making sure data is consistent and making it easy for the user to analyze the data. These are all functionalities Benchmark would like to see from the information systems used for the purchasing department, and throughout the company. Benchmark Almelo makes up for a small amount of Benchmark Corporate. This problem has been widely addressed throughout the complete company, not just the Benchmark Almelo site. Therefore, Benchmark Corporate is already busy building a data warehouse. Besides, the current system is capable of gaining from some of the benefits too. The Extract-Transform-Load (ETL) step, in which data gets integrated from multiple sources, is still possible for the current amount of data. Using Microsoft SQL Server Integration Services (SSIS), data can be integrated from multiple sources for the reports.

Also, a big advantage of a data warehouse is processing speed; the database of Benchmark Almelo is however fast enough, because there is no huge amount of entries. The processing speed thus is not a big issue. With the reporting tool used by the BI-coordinator, SSRS, it is possible to build reports in a way everybody understands, it's accessible and speedy enough.

## 6.2. NEW DELIVERY REPORTS

Generating new reports can be done in several ways. As described earlier in the section above, Benchmark used SSRS to do so. First of all this results in a more efficient way of generating information. As can be seen in Figure 3, the information flow was really inefficient. With the embracement of SSRS to generate the reports this information flow now looks like in Figure 23.

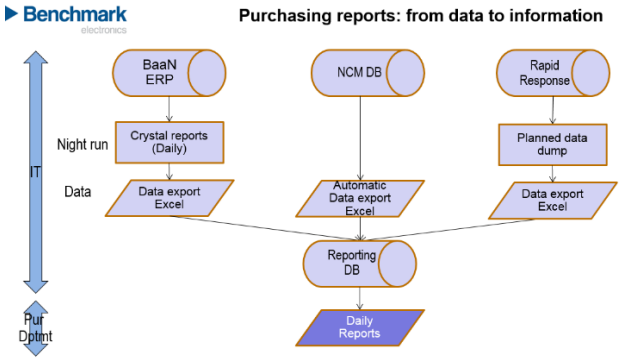



Figure 23 - New data flow

This thus reduces the amount of steps quite a lot. Moreover none of the steps has to be done by manual conversion anymore. The only minus still available in this data stream is that the data is not directly extracted into the Reporting

DB. The optimized version of this data flow would be that the data is extracted, transformed into the right format for a data warehouse and then loaded into the reporting database, which will be the data warehouse discussed in section 6.1.

### 6.2.1. ON TIME DELIVERY REPORT (TO LATEST CONFIRMATION DATE)

The On Time Delivery report is found to be the most important report to improve, based on the opinions of almost every employee and is also the most commonly mentioned KPI in literature. This was thus the first of the KPIs to focus on. The old Excel report had a lot of tabs and a lot of different features which resulted in a complex sheet. Furthermore multiple manual steps had to be undertaken to have the wished for report. These manual steps could take a few minutes in addition to the macro that runs all different Excel files. The improved version is found in Figure 24.

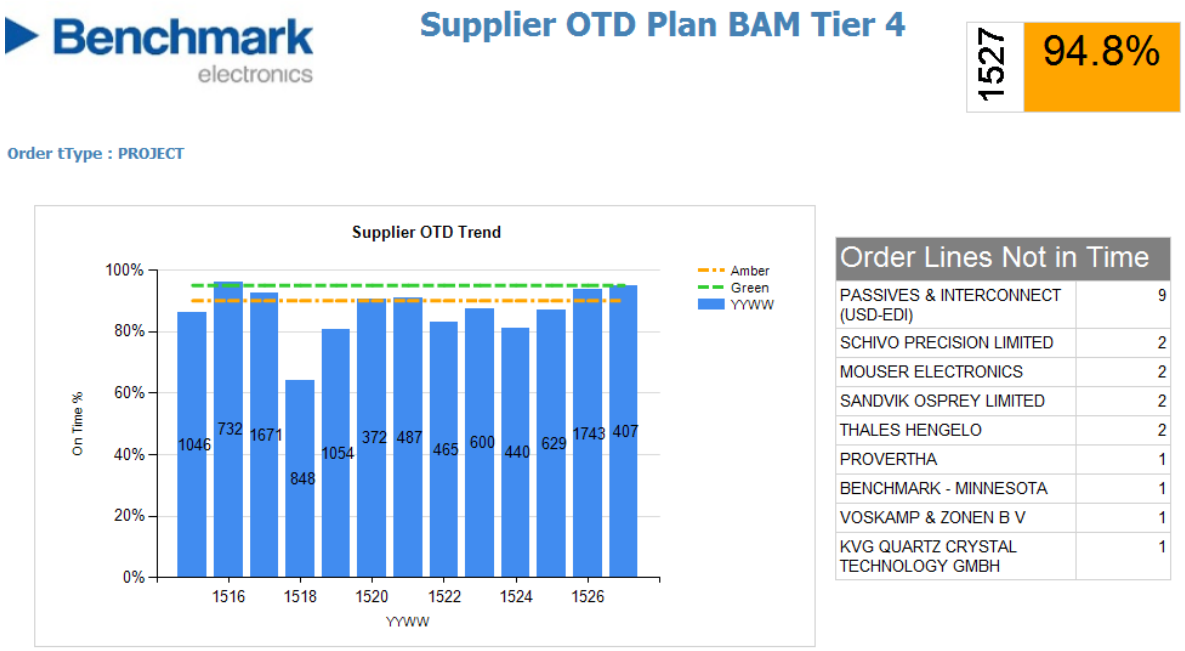



**Figure 24 - Supplier OTD**

Its simplicity compared to the old OTD is what stands out. In one view you have a chart with the on time delivery trend, given per month or week interchangeably, the amount of order lines not in time per supplier and the percentage delivered on time with an assessment of that performance based on the traffic light targets of the BAM system. This can also be filtered per buyer, supplier, project line, customer of order type.

If we click on the trended bar chart we can find more useful information about the deliveries that have been taking place during the selected period. As can be seen in Figure 25 these include multiple data views which include de relevant delivery data. Only the order lines that didn't come on time will be shown to focus only on the errors. A performance percentage will be shown, so it can be seen if the relative performance was good or bad. This is accompanied by a Pareto chart of the five suppliers that delivered the most order lines not in time and their relative performance.

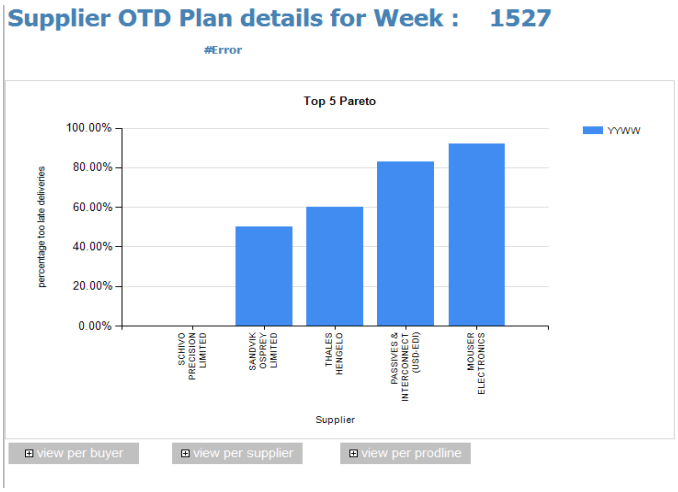



Figure 25 - OTD details with Pareto

The trend for individual performances can also be obtained. For BAM purposes you want to highlight the biggest underperformers to start a supplier development process. These can be obtained by filtering or by clicking the highlighted order lines that have not come in time. In Figure 24 it can be seen in YYWW 1527 Passives & Interconnects has been the supplier delivering the most amount of order lines not on time. If someone would like to know if this seems like a structural problem or not it can be seen by clicking on it and then Figure 26 would appear. It can then be seen that except for the week before and in 1520, they haven't met the delivery targets and their performance needs to be improved.

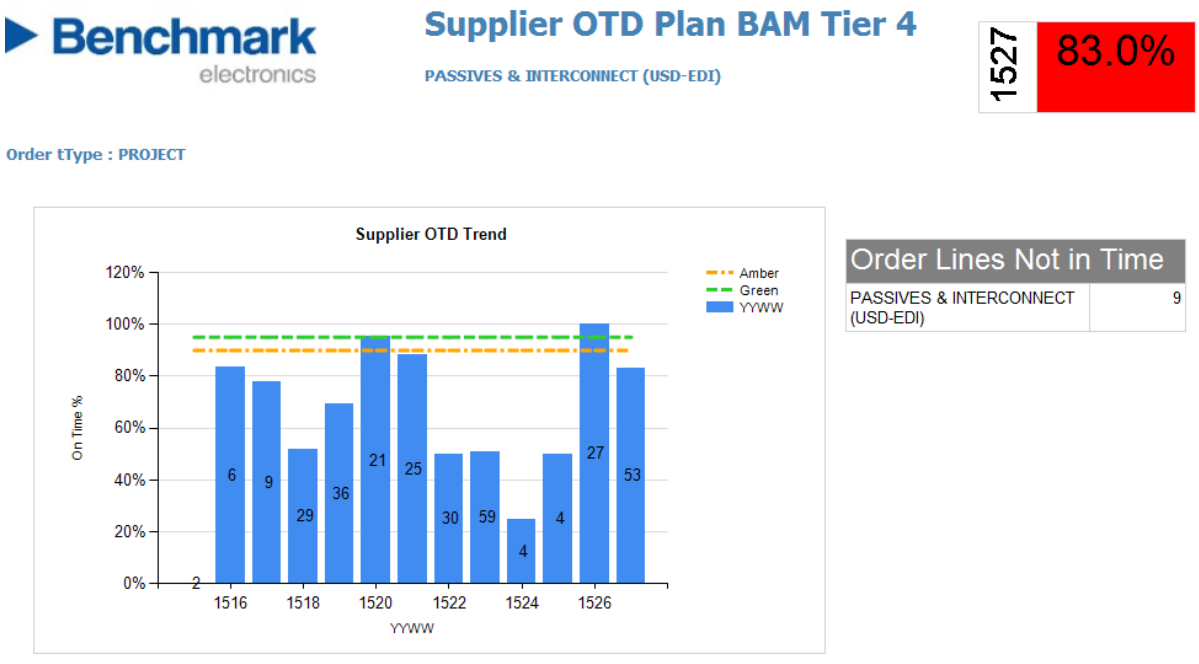
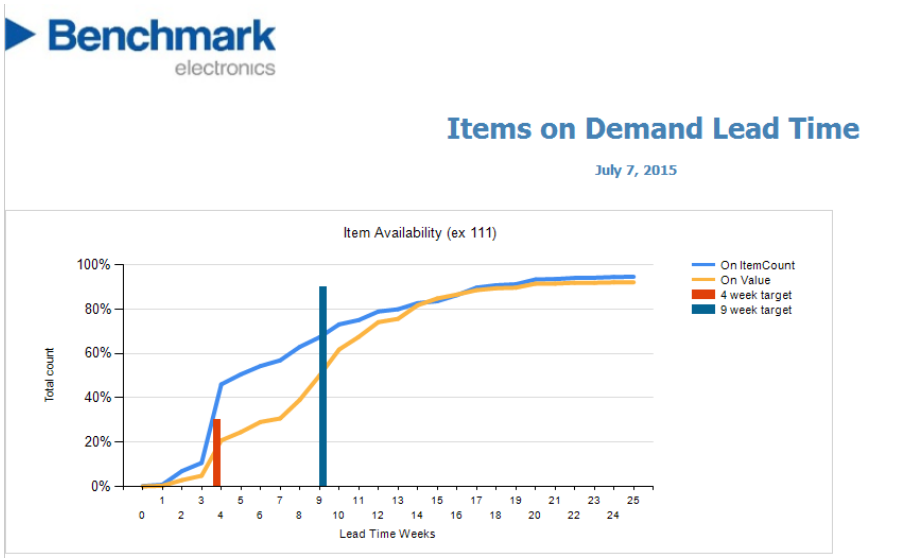



Figure 26 - P&I OTD Trend

### 6.2.2. ITEM LEAD-TIMES

Benchmark Corporation measures the item lead-times (the supply times) for all Benchmark sites. The Item lead-time KPI is thus a corporate measurement that is reported on by the management. These are the lead-times the purchasing manager wants to decrease as much as possible. In Figure 27 the new report can be seen. When starting at Benchmark this report was unavailable in Excel since there were difficulties in running the macro properly. Moreover, the report itself was a bit free of interpretation, since it didn't involve numbers and a lot of people didn't even know where to find the relevant number.

Now it can be seen in Figure 27 how the report looks. It has a little bit of the same, but it adds some extra in the insights of the supply times. The chart itself hasn't really been changed other than that the legend has been made clearer and the LT111 items are filtered by default. The lead-time and liability priorities given per supplier have been deleted, since these were kind of useless. The addition has been made to give the percentages of certain lead-time categories as well as the amount of items that fall within the categories. The amount of LT111 items is given on the side, so it now also put into perspective how many of the items have an unknown supply time. Furthermore it can be viewed per product line how the items are divided. This is useful for the Program Managers, since they use this list to communicate to customers.




| | ItemCount | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-4 Wks | 5-9 Wks | 10-12 Wks | 13-16 Wks | 17-20 Wks | 21-24 Wks | 25+ Wks | Total | LT111 | Total + 111 | % 111 |
| | 3971 | 1738 | 1119 | 637 | 613 | 101 | 478 | 8658 | 1758 | 10416 | 17% |
| | 46% | 20% | 13% | 7% | 7% | 1% | 6% | | | | |

VIEW DETAILS PER PRODUCT LINE

**Figure 27 - Item Lead-times**

### 6.2.3. LT 111

Next to the mentioning of the LT111 items within all items on demand, there also is a separate report in which the LT111-items are being highlighted. Because a lot of these LT111 come from the NPI-stage, not all of them need to be spoken about. A default filter is set for the operational buyer codes, because these LT111-items need special attention. Otherwise the production planning might encounter some serious issues. However it is also possible to see the other relevant buyer codes, which are grouped into initial and 'other', like software, EOL and POU.

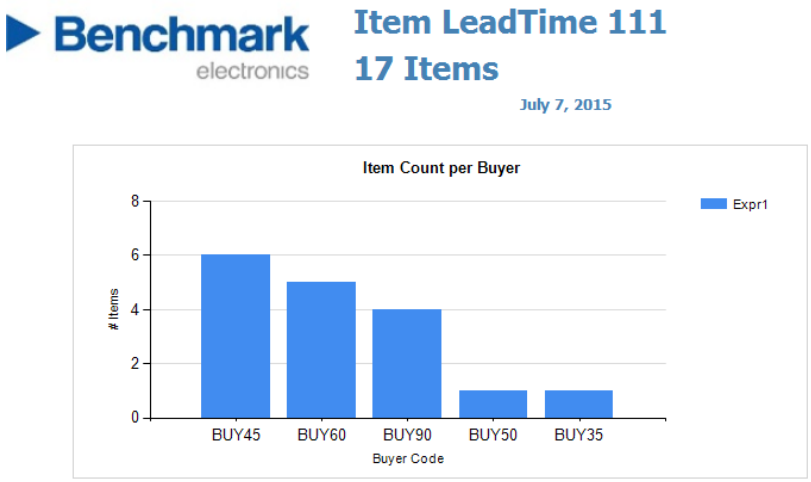
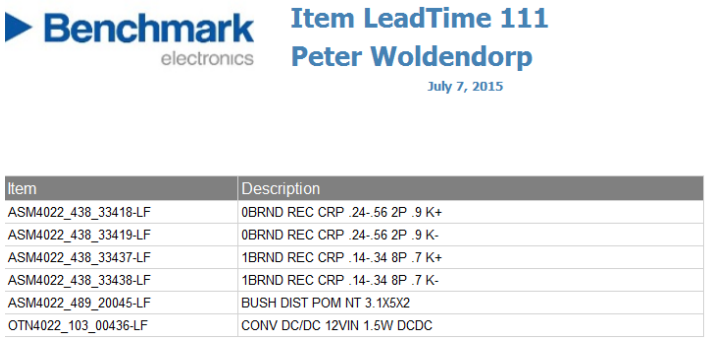



Figure 28 - LT111 Item codes

By clicking on the belonging buyer code a new screen gets opened that looks like in Figure 29. In there is an Nx2-matrix with all the item codes and item descriptions given. These item codes then have to be looked up in BaaN, where the supply time has to be filled in if it becomes known.




| Item | Description |
|---|---|
| ASM4022_438_33418-LF | 0BRND REC CRP .24-.56 2P .9 K+ |
| ASM4022_438_33419-LF | 0BRND REC CRP .24-.56 2P .9 K- |
| ASM4022_438_33437-LF | 1BRND REC CRP .14-.34 8P .7 K+ |
| ASM4022_438_33438-LF | 1BRND REC CRP .14-.34 8P .7 K- |
| ASM4022_489_20045-LF | BUSH DIST POM NT 3.1X5X2 |
| OTN4022_103_00436-LF | CONV DC/DC 12VIN 1.5W DCDC |

Figure 29 - LT111 specifications

## 6.3. OTHER DELIVERY FACTORIALS

There are also a few other KPIs regarding delivery which still have to be generated in SPSS. For some of them additional research is needed and for some it isn't. Let's start with those that don't need additional research and then follow it up with the one that needs extra research.

### 6.3.1. ON TIME DELIVERY (TO REQUEST)

In the time I have been at Benchmark quite a discrepancy showed up. At the Tier 3 ASML BAM board the OTD was also measured, but it was a different measure than at the purchasing department. Program Managers like to think on behalf of their client and thus want to measure if the orders have been delivered on time according to the customers wishes. According to Stewart (1995) it's also important to measure according to the requested date. If this score is low, it means fixed supply times are higher than the customer expects from you. If it's a key customer, you might want to improve its supply times first to keep the customer as your customer. Delivery speed is an market winner after all (Gunasekaran et al., 2001). At customer level BAM this will be discussed, but it's most certainly relevant for the purchasing department, since the purchasing department is responsible for managing the suppliers. The only thing that needs to be done in order to generate the report is that the deliveries must be measured against the requested date instead of the latest confirmation date.

### 6.3.2. OPEN ORDERS/EXPEDITING LIST

As stated by Terwiesch et al. (2005) it is important not to shift your orders too much. At the moment lots of signals are generated to expedite or delay an order. This process needs researching, since not all buyers want to follow these signals because they have the feeling it influences their delivery reliability. The literature gives reasons to assume this is true, so the KPI needs reviewing with the actual data.

## 6.4. SUMMARY

In this section it has been explained why the option of making a data warehouse was not chosen. The alternative best suited for the Benchmark environment was to use the current reporting tool available, namely SSRS. In SSRS three new reports have been built that don't require manual handling, are robust and are ready to use for BAM purposes.

# 7. DATA ANALYSIS

## 7.1. DEFINING THE DATA SET

For the data analysis, we are going to use the data set that consists of the past deliveries in the last 13 months. To make a data analysis that can be used for future predictions, the current data set needs to be filtered in several ways. Within the delivery sheet, there is a place for three different types of orders, namely: RTV (Return to Vendor), MRO (Maintenance, Repair & Operational Supplies) and PROJECT (belonging to a customer project line).

The RTV order types are of no relevance to us. These are orders that have been sent by Benchmark with a negative quantity in the delivered order list. This indicates that the order has been sent back to the vendor. The MRO types are also of no relevance to us. These orders do not have a relationship with any customer order. This leaves the orders that are of type PROJECT as possibly relevant.

The second filter that will be used on the data set is based on the item signal codes. Products can have different product life cycle phases and therefore be irrelevant to predict. The relevance of different signal codes is discussed below, those marked *italic* are relevant:

- EOL (End of Life): EOL items are at the end of their product life cycle phase and will not be available for much longer. These are irrelevant for the analysis.
- *NPR (Not Production Released): Items flagged under the code NPR are initial items. There is demand, but the formalities have not been finished yet and the item is not released for production. Since Benchmark is an OEM, this item signal code is quite frequent and it thus might be interesting to analyze.*
- *NPI (New Product Introduction): These are items belonging to new products within the supply chain that have been released for production. These are relevant, but probably do not have a high amount of past deliveries, since they are usually a part of an innovative product.*
- FAI (First Article Inspection): New item codes that need to be inspected, not interesting for analysis.
- INA (Inactive): An inactive item might become relevant if the part becomes active again, but for now, this item signal code is not relevant.
- NCR: I would not exactly know what it means, but this signal code is not being used for current items in the demand sheet and the only item code that was flagged under this signal code is not in the demand sheet either. This will thus be ignored.
- OBS (Obsolete): These items will not be ordered anymore because of obsolescence. Therefore, these are definitely not relevant in any way.
- POU (Phase Out): If an item is phased out, the manufacturer will stop manufacturing the item because it is at the end of its product life cycle. There will not follow many orders with this item signal code, so items that are phased out will not be taken into the analysis.
- *PIN (Phase In): PIN items are items that will replace the phased out items. These items will thus be ordered for a while. They thus are potentially relevant for the analysis.*
- *Blank: It also is a possibility that there is no signal code at all. In this case the items are in volume production, so items without an item signal are possibly relevant.*

Another possible filter to use on the delivery data set is to filter items that have the reconfirmed delivery date filled. These are items that have been shifted in communicated delivery date. It might very well be possible an order is delayed or expedited, because of earlier supply needs or a delay benefit. The analysis of the actual lead-time is therefore very hard to do and extra information is required to say something useful. Therefore, only deliveries

without a reconfirmed delivery date will be considered and deliveries with a reconfirmed delivery date will be filtered out of the analysis.

Another factor to be taken into account is if the FixedLT has changed after a delivery (marked by the column LT last changed in Figure 30). If the FixedLT has been changed after a delivery, the data row is irrelevant for the analysis. Therefore, a column indicating if the delivery was earlier than the latest date the lead-time has changed will be added. If LT last changed is empty, there are two possibilities. The item is marked as LT111 (meaning the FixedLT is unknown), or there is no demand for the item. The items without any remaining demand will not be taken into account, regardless of whether or not the LT last changed is filled or not. The ones with LT111 cannot be classified in terms of supply time expectation, because you don't know the expectation. These will thus also be filtered.

| Supply Time | Supply Time Weeks | Actual Supply Time | LT Category | LT last changed | Order date | Requested date | First committed date | Fullfillment date (Received) |
|---|---|---|---|---|---|---|---|---|
| 14 | 2 | 28 | 1 | | 20-mrt-2014 | 18-apr-2014 | 18-apr-2014 | 17-apr-2014 |

Figure 30 - Delivery stats example

To compare the actual delivery dates with the current date, an extra column is added with the actual supply time minus the FixedLT. It can then be analyzed how much a delivery differs from planning and if there is a high standard deviation.

Another difficulty in analyzing the actual lead-times is that orders are placed earlier than necessary. It could very well be an order has not shifted, but actual supply time is not even near the given FixedLT. In Figure 30 it can be seen that the FixedLT (which is the supply time) is set to 14 days, while the actual supply time is 28 days. However, the order has even been sent a day early compared to the requested date. Therefore, a cell will be added to find out how many days an order has been placed early based on the following comparison:

$$(RequestedDate - OrderDate) - FixedLT = DaysTooEarly$$

Because the supplier cannot be blamed for the seemingly long lead-time, the variable AdjustLT will be computed as follows:

$$(DeliveryDate - OrderDate) - DaysTooEarly = AdjustLT$$

The difference between the dates is expressed a numeric value, so we will end up with numbers. For example, If the RequestedDate is 4-7-2014 and the OrderDate is 4-5-2014, the number value returned is 61, if the FixedLT is 49 days, the order has thus been placed 12 days early. If the OrderDate is 4-6-2014, the difference becomes 30 days and the DaysTooEarly value will then be -19 days, indicating the order has been placed late comparing to the agreed upon FixedLT. The amount of days an order is placed too late will not be taken into account within the AdjustLT since a supplier will then face a penalty time, which it cannot help. The difference between what is the expected FixedLT and the AdjustLT is then given by

$$FixedLT - AdjustLT = FixAdDiff$$

## 7.2. DATA PREPROCESSING

Prematurely to mining data with Weka, some data analysis has to be done and we are going to use IBM SPSS Statistics for that. With the ANOVA (analysis of variance), it is possible to see if different categories within a certain nominal

variable differ in mean for the values of FixAdDiff. The typical way to perform such an ANOVA is to take the one-way ANOVA. However, this ANOVA has some basic assumptions underlying it. These are the six assumptions underlying an ANOVA (One-way ANOVA in SPSS Statistics, 2013):

1. The dependent variable is a continuous variable.
2. The independent variable should consist of two or more categorical, independent groups.
3. There should be independence of observations.
4. There should be no significant outliers within the data set.
5. The dependent variable should be approximately normally distributed for each category of the independent variable.
6. There needs to be homogeneity of variances.

These assumptions were invalid in this case as given in Appendix C.

The alternative for the one-way ANOVA is to take the Kruskal-Wallis test. In addition, at the Kruskal-Wallis test, the same distributions of data are being assumed. This test also failed. Because of the much simpler computations of the one-way ANOVA, the one-way ANOVA will therefore be taken as an indication to cluster values. This will be done with the Welch ANOVA, which can handle the violation in variances. With a Games-Howell post hoc test it can be seen if there are statistically significant differences. Groups that don't show a statistically significant difference will be clustered to reduce the amount of branches and leaves on the classifying trees. Different categorical variables will be examined and tested for a difference in their means. These different categorical variables will be tested:

- ABC Code
- Item Signal
- Lead-time category
- Product Line
- Item Commodity

Within the tests a few interesting groups can be pointed out. If we look at the post hoc test for the comparisons of the ABC-code groups, we see that only A and B do not statistically significantly differ. These will be clustered and three different options remain. This is done for all categorical variables and is found in Appendix D

**Multiple Comparisons**

Dependent Variable: FixAdDiff

Games-Howell

| (I) ABC | (J) ABC | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| A | B | -2,26717 | 1,16450 | ,209 | -5,2648 | ,7305 |
| | C | -8,41305* | 1,02436 | ,000 | -11,0527 | -5,7734 |
| | Null | -46,24108* | 1,79795 | ,000 | -50,8651 | -41,6171 |
| B | A | 2,26717 | 1,16450 | ,209 | -,7305 | 5,2648 |
| | C | -6,14588* | ,80384 | ,000 | -8,2127 | -4,0790 |
| | Null | -43,97391* | 1,68211 | ,000 | -48,2998 | -39,6480 |
| C | A | 8,41305* | 1,02436 | ,000 | 5,7734 | 11,0527 |
| | B | 6,14588* | ,80384 | ,000 | 4,0790 | 8,2127 |
| | Null | -37,82803* | 1,58831 | ,000 | -41,9136 | -33,7425 |
| Null | A | 46,24108* | 1,79795 | ,000 | 41,6171 | 50,8651 |
| | B | 43,97391* | 1,68211 | ,000 | 39,6480 | 48,2998 |
| | C | 37,82803* | 1,58831 | ,000 | 33,7425 | 41,9136 |

*. The mean difference is significant at the 0.05 level.

**Figure 31 - Post Hoc test**

## 7.3. THE DATA MINING STEP

Before progressing to the data mining step it's important to briefly explain what data mining is. Data mining is the computational process of discovering patterns in large data sets. This involves methods at the intersection of artificial intelligence, machine learning, statistics and database systems. The overall goal of data mining is to extract information from a data set and transform it into an understandable structure for further use. At the University of Waikato in New Zealand, a couple of professors have developed a program that is able to assist in data mining, namely Weka (Waikato Environment for Knowledge Analysis) (Witten & Frank, 2005). We will use this program to mine the Benchmark data and to see if we can discover patterns.

Before digging into the actual numbers, it is useful to explain Weka a little bit more. Within the output, a summary is given. This depends on if you want to predict a value or if you want to classify your data and thus if the output is numeric or nominal. Since we want to perform a classification on the data, the output is nominal. There are three possible classifications. The items can be in time (within the -3 to 1 window), be earlier or be later. We want to know if we can predict if a certain combination of attribute values will lead to items coming late.

Within the nominal summary the first two outputs to be found are the amount and percentages of the correctly and incorrectly classifies instances. At the end of the output, a confusion matrix is given. This confusion matrix gives the amount of correctly and incorrectly classified instances in a matrix form. The values given on the main diagonal are the amount of correctly classified instances. If there are values filled outside the main diagonal, these values form the amount of incorrectly classified instances. In a 2x2-matrix of the form $\begin{bmatrix} 4 & 1 \\ 2 & 6 \end{bmatrix}$, there are thus $4 + 6 = 10$ values classified correctly, $2 + 1 = 3$ values classified incorrectly and a percentage of $\frac{10}{13} = 76.9\%$ is classified correctly. This is thus the sample accuracy.

The initial group of data has been brought back to an amount of 7227 rows of the initial 25000 rows of delivery data after the filters had been applied. To be able to make the data available for data mining with Weka, the data set had to be converted in an Attribute-Relation File Format (arff) file. From these rows, the top 1000 rows will be taken in terms of demand value to not overload the Weka capacity. Within this 1000 delivery rows there were a few instances that had a count of 1 on a certain attribute value. Those were removed and 994 values were left.

After bringing back the data set to the 994 values, the attribute values are distributed according to the graphs given in the figures below:

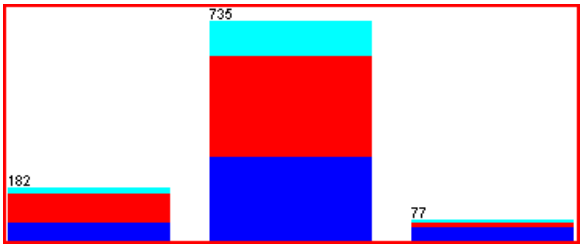



Figure 33 - ABC

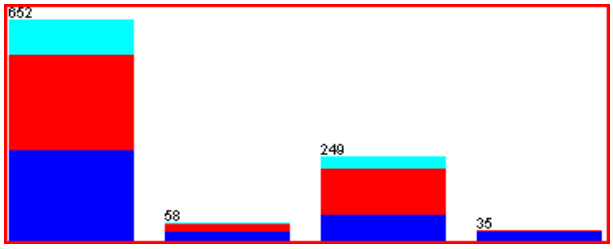



Figure 32 - BEA Status

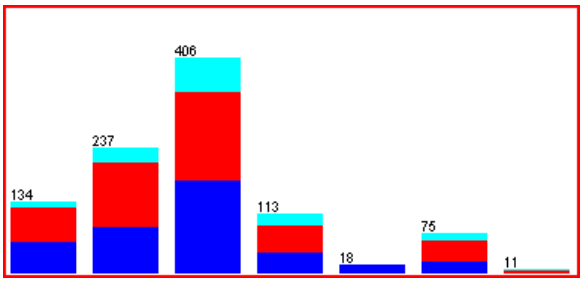



Figure 36 - Item Commodity

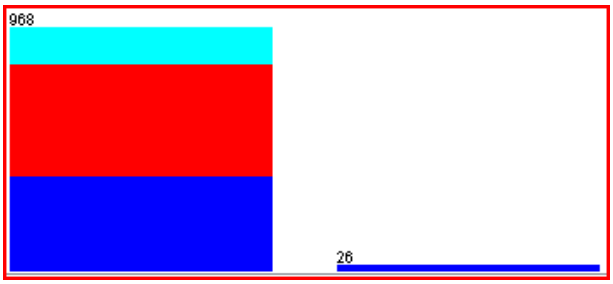



Figure 37 - Signal Code

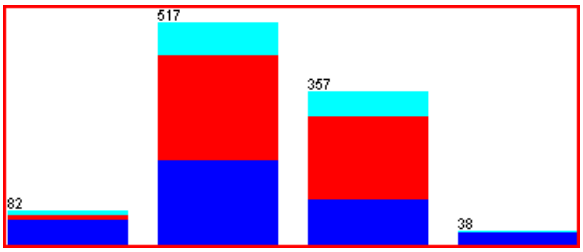



Figure 35 - LT Category

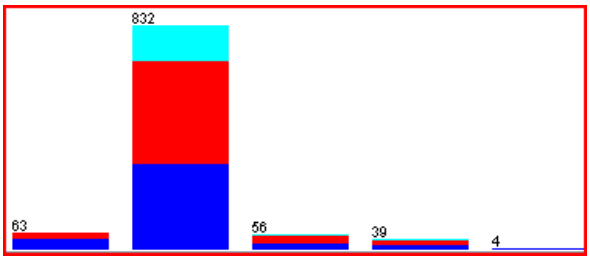



Figure 34 - Product Line

Within this figures, something can be noticed. If you look at the distributions of the different variables, only several small groups might have an approximately homogeneous classification. Most of the categories of the six nominal variables have a distribution in which all three classifications are quite common and there are no distinctive factors to group by. The expectation is thus that it will be hard to classify the data properly.

Let's look at a J48 classification tree. This is a decision tree that makes its decision upon the biggest information gain it can get. It makes branches with a classification based on a combination of different categories. If we run one, the output summary is given in Figure 38. If we look at the results, we can see they are pretty bad for the predictions. If we look at the percentages given in the summary, we can see that in the J48-case only 59.4% of the instances was classified correctly. We can also see that the TP Rate (True Positive Rate) of 'Later' is just 6.2%, which means only 6.2% of the classifications is correct in the 'Later' class. We can also find this back in the confusion matric, where only 9 values are on the main diagonal and 136 of the values are divided between a and b. This is a useless result if we want to predict the classes. In addition, experimenting with different attributes to include in the classifications, results do not seem to improve whatsoever.

```
=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances         590               59.3561 %
Incorrectly Classified Instances       404               40.6439 %
Kappa statistic                          0.2875
Mean absolute error                      0.35
Root mean squared error                  0.4267
Relative absolute error                 85.6252 %
Root relative squared error             94.3911 %
Total Number of Instances              994

=== Detailed Accuracy By Class ===

               TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
                 0.532     0.193      0.652     0.532     0.586      0.716    Earlier
                 0.821     0.516      0.565     0.821     0.67       0.678    InTime
                 0.062     0.009      0.529     0.062     0.111      0.582    Later
Weighted Avg.    0.594     0.311      0.595     0.594     0.554      0.68

=== Confusion Matrix ===

   a   b   c   <-- classified as
 214 182   6 |   a = Earlier
  78 367   2 |   b = InTime
  36 100   9 |   c = Later
```

Figure 38 - J48 classification output

It will be interesting to take a look if there might be other classifiers that perform better than the J48-classifier. To look for that, we use the Weka Experimenter instead of the Explorer. This is capable of comparing different classifiers. If we take the J48 decision tree as base classifier we can compare with multiple classifiers. We do so by cross-validating for 10 different runs of each classifier. We can see the output in Figure 39. If we look, we can see that only two of the classifiers perform significantly better than the J48 decision tree. These are the RandomTree and the IBk. However, these accuracy values also are disappointingly low. If we combine this with the expectations, we conclude that the data is too random in its classes to properly mine.

```
Dataset                   (1) trees.J4 | (2) trees (3) trees (4) rules (5) rules (6) bayes (7) funct (8) lazy.
-------------------------------------------------------------------------------------------------------------
'whatever-weka.filters.un(100)   59.93 |   61.04     61.83 v   53.12 *   44.97 *   55.68 *   55.76 *   61.84 v
-------------------------------------------------------------------------------------------------------------
                            (v/ /*) |   (0/1/0)   (1/0/0)   (0/0/1)   (0/0/1)   (0/0/1)   (0/0/1)   (1/0/0)


Key:
(1) trees.J48 '-C 0.25 -M 2' -217733168393644444
(2) trees.RandomForest '-I 100 -K 0 -S 1' -2260823972777004705
(3) trees.RandomTree '-K 0 -M 1.0 -S 1' 8934314652175299374
(4) rules.OneR '-B 6' -3459427003147861443
(5) rules.ZeroR '' 48055541465867954
(6) bayes.NaiveBayes '' 5995231201785697655
(7) functions.Logistic '-R 1.0E-8 -M -1' 3932117032546553727
(8) lazy.IBk '-K 1 -W 0 -A \"weka.core.neighboursearch.LinearNNSearch -A \\\"weka.core.EuclideanDistance -R first-last\\\"\"' -3080186098777067172
```

Figure 39 - Experimenter output

## 7.4. SUMMARY

In this section, we set up a data analysis with the goal of predicting which combination of categories would come in later than expected. After some data preprocessing and converting into the right data formats is was found that the data was too random to mine properly for different combinations of categorical variables.

# 8. CONCLUSIONS AND RECOMMENDATIONS

## 8.1. CONCLUSIONS

A few conclusions can be drawn from this research. These conclusions can be put into a few different categories, since this research had two major components. These were;

1. How Benchmark should design their performance measurement system to enable performance improvement.
2. How to increase supply chain flexibility by reducing supply times.

### 8.1.1. CONCLUSIONS REGARDING ENABLING PERFORMANCE MEASUREMENT SYSTEM DESIGN

Benchmark actually has a very good system setup with BAM. However, this is not being lived by for the fullest. It could very well be seen that the employees had not received their BAM training yet and where thus inexperienced with the system, while Wouters (2009) states this is a key to success. The setup as it is, with the SQDIC-metrics, the DAT-tracker, the A3-board and the CI-section is good. Now it needs to be lived by. The DAT-tracker is barely used, the CI-section neither and the A3-trackers is being used for very different purposes than intended. This combined with the reporting mess that was left behind at the SQDIC-section made that the BAM sessions at the purchasing department did not work out really well. To make this work out better, the protocols should be taken into use after the training session, which needs to be facilitated soon.

For the SQDIC-section, improvements have been made within this research. Three of the performance measures have been generated in a robust way and furthermore the data is or directly actionable, the causes of underperformance are directly made clear and the improvement opportunities are presented. For some of the other performance measure extra research will have to be done. These are presented in section 9. The ones that aren't mentioned there and are not yet generated will have to made by the BI department as soon as possible.

### 8.1.2. CONCLUSIONS REGARDING SUPPLY TIME REDUCTION

For the increase of supply chain flexibility more research is needed. The current supply time reduction strategies can however be assessed. The current efforts to reduce supply times are the ones they should use, like VMI. This is good for stock levels and shorter supply times. In addition, the Logistic Forecast Agreements (LFAs) that are currently being used are good. However, the supply times chosen to reduce are not really based on the real priorities. These will have to follow from further research regarding the supplier flexibility portfolio, since the data mining did not achieve useful results for Benchmark in terms of priorities.

## 8.2. RECOMMENDATIONS

Based on this research, recommendations can be made on what to do for now. In addition, there are some recommendations for future research directions. These will be found in section 9, the recommendations that can already be made based on this research will be found below.

### 8.2.1. ALIGNING PERFORMANCE MEASURES

Within the delivery performance of Benchmark, a lot of different elements are being evaluated. Within for example Tier 3 at the ASML BAM board the OTDR is being presented, while the purchasing department does not evaluate the OTDR. It is being measured, but it is not discussed during BAM sessions. This is weird and it creates unnecessary discussions within the company. Moreover, what do you want as a company like Benchmark? You want to be able

to respond to customer demand, because customer service level is regarded as a market winner (Gunasekaran et al., 2001) within this type of market. Therefore, you want to be able to deliver your products according to the customer's wishes. If request dates for a certain product are not being met, you might have your target for reducing the supply times in order to be more flexible and achieve rapid response. As mentioned earlier the OTDR should thus be added to the BAM board.

### 8.2.2. INVOLVE PURCHASERS IN AUTOMATING PERFORMANCE MEASURES

Within Benchmark's purchasing department, as a result of this thesis, some transformations have been made in the reporting structure. However, it has not finished yet. Not all of the performance measures have been built in SSRS yet. The BI department is responsible for maintaining and integrating all data in a database, but do not necessarily know everything about every business process.

In order to adequately develop the performance, IT tools should be made available for the non-specialists. They feel safe with using Excel, but for reporting purposes a bunch of things might go wrong. The IT tools should be monkey proof! The possibilities of the robust reporting are in place with the implementation of SSRS, but with only one person responsible for managing the data system in SSRS the full potential is not being met. From what I have seen during my research period, he doesn't have enough time to manage all requests he gets and an awful lot of time he just gets requests of reporting on a business process he's not completely familiar with. If better and renewed IT tools are too expensive, it is thus of utmost importance that there is a good mediator between a department like the purchasing department and the business intelligence department for generating the reports. He will know much better what plays a role within the purchasing department than a BI-coordinator will. And to make sure SSRS will actually be used, it has to have the same user friendliness as a program like Excel when it does work. A pitfall to be definitely avoided is too few people knowing about the data.

### 8.2.3. DATA ORGANIZATION

The current organization of data within Benchmark is not quite so good. The report building structure is ok, but it needs to be built on a different data format in the future. Benchmark Corporate is already busy with building a data warehouse and that's the direction Benchmark should go. This data warehouse can then be used to build a standard reporting format for all Benchmark Sites. Since Benchmark Almelo is Benchmark's frontrunner in the reporting services, it should actively cooperate in the development of this. Good report building is a follow up of building the data warehouse. When the data is properly organized this should not become a big problem at all.

# 9. DISCUSSION AND FURTHER RESEARCH DIRECTIONS

## 9.1. SUPPLIER FLEXIBILITY PORTFOLIO

The strategic goal of reducing the supply times is a way of achieving something bigger, namely supply chain flexibility at the supply side of the chain. Das & Abdel-Malek (2003), which have been cited multiple times, defined a model in which flexibility can be quantified and used as a parameter of supplier selection within supply contract negotiation. Since it's also a goal of Benchmark to reduce the supply base, it might be good if someone took the time to model flexibility and determine the flexibility level of suppliers for supplier selection. Also different sources (Shin et al., 2000, Chen & Paulraj, 2004) find that reduction of the supplier base significantly contributes to the performance of a buying company. Gosling et al. (2010) and Purvis et al. (2014) underline that and state an optimal supply base portfolio exist in terms of flexibility. Therefore I think it would be useful to let someone research the optimal supplier portfolio for Benchmark, given different flexibility needs and different item commodities. This could then be compared to Benchmark's own portfolio system as was already stated in section 3.5.

## 9.2. FORECAST ACCURACY

Studies of several researchers (Gunasekaran et al., 2004; Terwiesch et al., 2005), address the need of measurements of forecasting accuracy. Gunasekaran et al. (2004) recognize the need of measuring it before being able to improve the accuracy. Terwiesch et al. (2005) show the impacts bad forecasting can have on the company's result and show the forecasting benefits can disappear if they are not accurate. This is an interesting issue, since Benchmark operates in a business environment with a high rate of NPI and also a lot of demand uncertainty. Currently the only forecasting measurement is considering the changes in the forecast and this is sent to the planning department. It doesn't measure the accuracy and it also doesn't test the supplier's performance given the forecasting inaccuracies.

Different buyers have also addressed the issue of forecast inaccuracy. At the BAM-board, an operational KPI generates the purchasing signals. Multiple buyers have addressed the issue of overly proportional delay, cancellation and expediting signals. In addition, the feeling lives that after a few times of expediting and delaying, the order is actually needed at the initial date of the forecast. Another student should research what the impact of the forecast inaccuracies (forecast volatility and forecast inflation) is on the supplier's performance and what kind of impact is has on the buying firm's performance.

## 9.3. PLANNING

Another problem raised within my research period is the amount of 'All Required Now'-signals for planned purchase orders. The fact that it's being signaled is not the problem, because you want to know if you really need an item. What however does form a problem is the fact that they come in a too high amount of orders. The percentages of orders that were planned on a later day than the simulations said orders had to be placed varied between 5-14% of the planned orders. There are some serious planning issues if a planned purchase order is planned after the day it should be ordered. These have also been addressed earlier by some other students, but maybe recent developments in researching literature might be interesting to improve the planning performance. This would also ease the purchasers.

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# APPENDICES

## A. ACRONYMS

- BAM – Benchmark Accountability Management
- CI – Continuous Improvement
- DAT – Daily Accountability Tracker
- ERP – Enterprise Resource Planning
- KPI – Key Performance Indicator
- LFA – Logistic Forecast Agreement
- LT – Lead-time
- NCM – Non-Conforming Material
- OTD – On Time Delivery
- OTDC – On Time Delivery to Confirmed
- OTDR – On Time Delivery to Requested
- PO – Purchase Order
- SCA – Supply Chain Architect
- SDE – Supplier Development Engineer
- SQDIC – Safety, Quality, Delivery, Inventory, Cost
- VBA – Visual Basic for Applications
- ViPeR – Vendor Indicative Performance Rating

## B. LEAD-TIME EXPLAINED

In this appendix it can be seen how different elements of lead-time within Benchmark are built up. This can be seen in Figure 40. The manufactured parts are out of discussion, since they don't fall within the purchasing responsibility. For the purchased parts, it can be shortly explained what is relevant and what is not. The Safety Lead-time is a planning lead-time, which is meant as a buffer for the system. This safety lead-time is never measured, but it is taken into account by the RapidResponse simulation. To lower this, planning methodology has to be reviewed and this is not being reviewed within this research. It has also been done earlier for Benchmark by another student.

The Dock to Stock Lead-time is defaulted to zero within BaaN. This is not really the case in practice. The Dock to Stock Lead-time gets a safety buffer within Benchmark's measurement systems. The dates entering the BaaN system are the to Stock dates, not the to Dock dates. However, since a few months another student has introduced a KPI at the receiving goods inspection department measuring the time from dock to stock for items that had a waybill on the packing slip. It is now measured when items reach the dock and when they reach the stock. The recommendation of the other student is to adjust the delivery measurements at the purchasing department to the to dock date when possible. Not all suppliers add a waybill, so it has to be clear against which delivery time a delivery is being evaluated.

For purchased parts, the fixed lead-time is the key in this thesis. This is the quoted lead-time that is being taken into simulation and this is the lead-time to focus on reducing for the purchasing department. The Lead-time adjust listed below is not being taken into account. If it is, it's already been transformed into a Fixed Lead-time.

| RapidResponse Field | Description | How Baan Field(s) Are Mapped To It | |
|---|---|---|---|
| **Safety Lead Time** | Offsets due date from need date (acts like you need it early thus bringing the due date in earlier and therefore all other dates move up too). | Purchased Part | SafetyLeadTime + ExtraLeadTime + OutboundLeadTime + InboundLeadTime + Item Supplier SafetyLeadTime (if it exists). |
| | | Manufactured Part | SafetyLeadTime + ExtraLeadTime + OutboundLeadTime |
| **Dock to Stock Lead Time** | Creates a dock date prior to due date which therefore moves up the start date. | | Defaulted to zero. |
| **Fixed Lead Time** | Offsets the start date from the due date | Purchased Part | SupplyTime (from the Item Supplier Record if it exists otherwise from Item Purchase Data). |
| | | Manufactured Part | OrderLeadTime |
| **Lead time adjust** | Acts like Fixed Lead Time so it moves up the start date. | Purchased Part | Purchased Part = InternalProcessingTime from Item Supplier Information if it exists. |
| | | Manufactured Part | Manufactured Part = 0 |

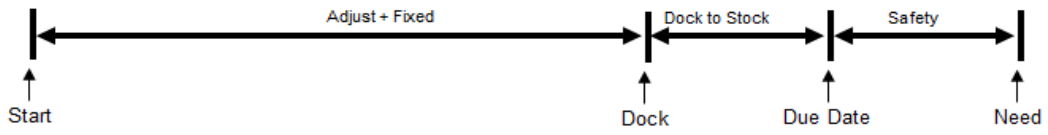


Figure 40 - Lead-time Explanation

## C. ANOVA ASSUMPTION TEST

As stated in section 7, the ANOVA has some basic assumptions underlying it. These are the six assumptions underlying an ANOVA (One-way ANOVA in SPSS Statistics, 2013):

1. The dependent variable is a continuous variable.
2. The independent variable should consist of two or more categorical, independent groups.
3. There should be independence of observations.
4. There should be no significant outliers within the data set.
5. The dependent variable should be approximately normally distributed for each category of the independent variable.
6. There needs to be homogeneity of variances.

To make sure we don't classify data based on invalid data, we need to make sure these assumptions are not being violated or in case of violation find an alternative.

1. The dependent variables are in this case given by the FixAdDiff. This is a continuous numeric variable, so this assumption is being met.
2. There is a bunch of categorical variables on which the test is going to be done, all with at least 4 categorical groups. This assumption thus is also valid.
3. The observations are independent deliveries, so the third assumption is also valid.
4. To make sure no significant outliers lie within the data set, a method prescribed by Hoaglin & Iglewicz (1987) is applied to the data set. The difference between the 75%-value and 25%-value is being taken and weighted and then subtracted from the 25%-value to create a lower bound. For the upper bound the same value is added to the 75%-value. A total of 14 values out of 9220 is being deleted because of being an outlier. These are the values that are lower than -191.04 and greater than 278.40.
5. For checking if the dependent variable is approximately normally distributed within the different categories, a Shapiro Wilk test can be done. This states that the data for this test is not normally distributed. Taking the logarithm of these values by means of transformation also doesn't really normalize the values either.
6. Using the Levene's test it can be seen the variances are heterogeneous and not homogeneous.

It can thus be seen that the assumptions aren't being met.

## D. ANALYSIS CLUSTERS

| Cluster number | Product lines |
|---|---|
| **1** | AIB01, AIB03, AIB05, AIB06, ASM07, ASM08, BEI84, FLU07, GND01, MRO01, RNS01 |
| **2** | AIB02, SIR01, ZEH01 |
| **3** | ASM06, ASM09, OTN01, MRO00 |
| **4** | RNS02, THL04 |
| **5** | SMS_ALL |
| **6** | THL07 |

Table 3 - Product Line cluster

| Cluster number | Item commodities |
|---|---|
| **1** | Batteries, CableAssemblies, Customer, Displays, Documentation, FabricatedPlastic, FabricatedMetal, PCBA, Power, ServiceProvider |
| **2** | Assemblies, CapitalEquipment |
| **3** | Hardware, Labels, MRO, OEMPart |
| **4** | Null |
| **5** | Interconnects |
| **6** | Software, Relays/Switches, PCB |
| **7** | Semiconductors, Passives |
| **8** | Packaging |

Table 4 - Commodity luster

| Cluster number | Benchmark Almelo status |
|---|---|
| **1** | Approved, Customer Prescribed, Restricted, Non-Preferred |
| **2** | Corporate Preferred |
| **3** | Finance Only |
| **4** | Targeted, Null |
| **5** | Intercompany |
| **6** | Preferred |

Table 5 - BEA Status cluster

The other factorials can hardly be clustered. For the ABC-code, the only categories that don't significantly differ are A and B. Some don't have an ABC-code, leaving the AB-cluster, C and Null as possible options. Within the Item Signal tests two clusters can be made out of 4 possible values. Null and PIN don't statistically differ and the same goes for the NPR and NPI codes. Within the fixed LT categories, only two different categories behave the same. The items from 5-9 weeks and the items from 10-12 weeks have approximately the same FixAdDiff.

## E. REFLECTION REPORT

At the 18th of February I started with my bachelor thesis at the University of Twente in collaboration with Benchmark Electronics Almelo. I came in contact with the company through mouth-to-mouth communication, because some of my good friends also performed their bachelor thesis there. After a while I got contacted back and got the opportunity for an application at the company. I applied and got offered two assignments immediately. I could write an implementation plan for the placement of a Kardex system within the warehouse or I could review the purchasing performance measurement system. I chose for the last option, even though it was a little unclear for me. A learning point for a next opportunity is to get those uncertainties away as quickly as possible.

When I took the assignment to the UT, I firstly asked Sandor Löwik to be my examiner, because I thought the key factor within the assignment would be process control. He warned me by doubting if there would be enough research opportunities within this thesis, but nevertheless I went to go and see Chintan Amrit, who did see some opportunities. The supply chain environment was interesting and so was performance measurement, so I went for it and took the challenge.

In the beginning I think I settled quite well within the company. It took a little while to fully comprehend what was playing within the purchasing department, but nevertheless I got along with the employees really well and got a lot of information from them. The start thus wasn't too bad in my opinion and getting familiar with the processes within Benchmark went quite quick. This however changed a lot when I first addressed my research proposal, because Chintan saw an opportunity I didn't really see or knew a lot about, namely data warehousing. At that point I should have aligned Benchmark and the UT, to get a clear vision of where this thesis would be heading for all stakeholders of the project. I failed to deliver on that point. From Benchmark this was stimulated and from the UT perspective this was not found a necessity. I'll know for sure that during my MSc thesis I will make sure this happens in an early stage of the thesis, to avoid misunderstandings and moreover set mutual goals for all stakeholders.

Because of this I didn't bound the research enough and went on doing multiple things, but none of them fully convincing. Due to a lack of communication and a lack of evaluation everything took a lot longer than it should and now I end up having my colloquium at the 25th of August while I started at the 18$^{th}$ of February. That's fairly late. That was not the only cause of this long thesis time. It had also got a lot to do with planning and discipline I think. If you add this up to the lack of evaluation you get a really slow and long process to get an end result.

For the future I think it's necessary to plan from beginning to end, not just separate parts one at a time. When the planning is finished it should be mutually supported and also regularly evaluated. If then the deadlines aren't being met, a bell should ring that a lot of work has to be done!

Another valuable lesson learned during this thesis is that in practice things are way different than in the imaginary world of theory. In theory most of the times things are perfect or what you want it accessible at least. Furthermore it's not being messed with. Especially if we talk about data. The organization of data within Benchmark wasn't even close to the theoretical optimum. Especially in terms of working with data sheets. Every person within the company needed other data sheets for their day-to-day business. These where all separately generated using Crystal Reports, what ended up in 300/400 Excel sheets a day. Ridiculous if you ask me. I'm curious to see how it's organized at other companies.

In terms of skill development the period at Benchmark was really valuable. I think multiple skills have been developed within my few months. First of all in the purchasing function. Even though the sourcing part of a supply chain is an essential part, it is quite overshadowed as far as I'm concerned. You only get one guest lecture of purchasing within the course 'Logistiek Management' and that's it. Also the component of outsourcing is almost only discussed on a

strategic level and in making the decision to outsource or not. It was thus very interesting to be an intern at the purchasing department of an outsourcing partner, a company without an own product.

I've learned about the interaction between the planning and purchasing department for example. In a complex environment like Benchmark's they communicate a lot and the planning department keeps the purchasing department up-to-date. In an outsourcing company it's important to be flexible, so changes in the planning of the customer should be drilled down to Benchmark itself. That's of course also why the purchasing manager finds it important lead times are very short. In an environment like this, that's one of the key competitive priorities, not the money.

Although money plays an interesting role in this which I didn't really know about beforehand. As an outsourcing partner it's important to avoid the risk of obsolescence, because you don't have a product to sell. Therefore, for parts that cannot be returned it's important the customer provides you with liability for the non-cancellable part. Then risk can be shifted to your customer. You don't encounter these type of issues during your courses and I found it very valuable.

Another thing to discuss is the feedback I got and how I handled this. I think I evaluated too little within this process. I'm always looking for solutions myself and form my understanding of a certain point. However, sometimes it's necessary to generate a fresh view on how it's going or a little push to help you (in this case me) get over the edge. During sessions that were used for the feedback, I think I sometimes handled them pretty well and sometimes I didn't. After the feedback session in which Chintan told me to make a data warehouse I think I didn't manage it well at Benchmark. I started drawing star schemas and during the next evaluation the result was very little and moreover not per se really relevant. When Erik and Ronald showed disappointment within that session I think I handled it well and the session after that one I think was really good and they were satisfied. One thing I didn't really evaluate was the complete process to generate an end report and I think I should ask feedback for parts that will end up in the end result, rather than separate sub-project.

I think I have been strong in my social skills within the department, but also in interpreting the issues that I have encountered during this thesis. In addition, I think my performance on the literature study was quite good. I hear a lot of people complaining about performing a literature research, but I actually quite enjoyed it and found the different elements really interesting to put together, which I did quite well in my opinion.

Summarized I think I still have a lot to learn and I will do that during my time a master student. In addition, I did learn a lot and that's nice luggage to take with me during the rest of my time at the university and in my further career.