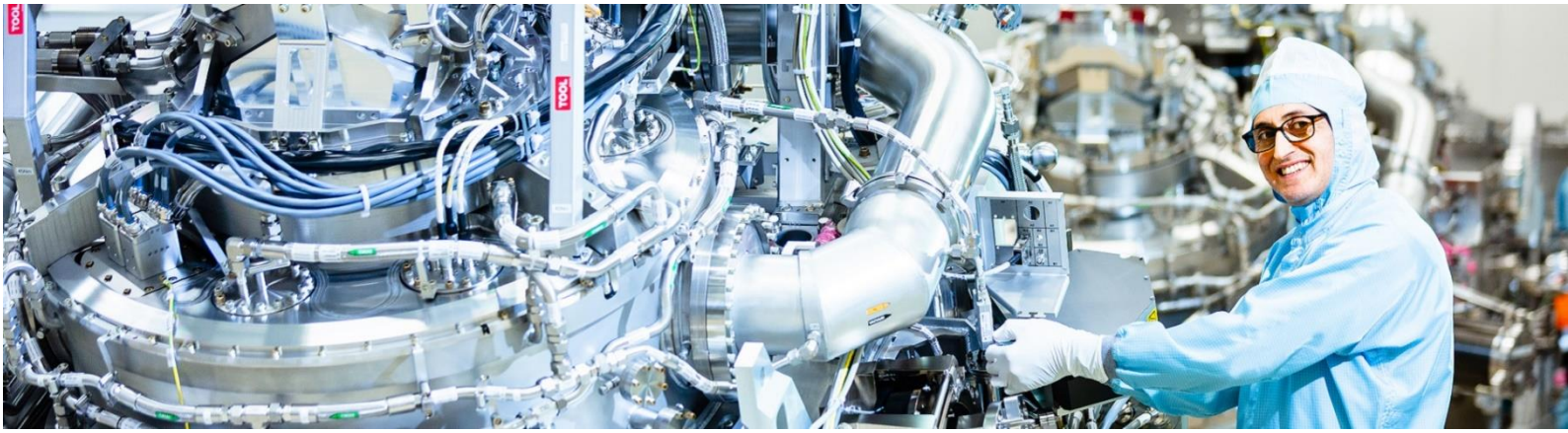
EXPANDING VDL ETG ALMELO'S SUPPLIER BASE IN THE IBERIAN PENINSULA TO ENHANCE SUPPLY CHAIN RESILIENCE



GRADUATION THESIS

MASTER INDUSTRIAL ENGINEERING AND MANAGEMENT

JAN-HEIN KLOPPENBERG

JANUARY 2024

UNIVERSITY OF TWENTE.

Master thesis Industrial Engineering and Management

Specialisation: Production and Logistics Management

Expanding VDL ETG Almelo's supplier base in the Iberian Peninsula to enhance supply chain resilience

This is a publicly available version of this thesis. For this reason, all confidential data are replaced by an X. Moreover, all company names are replaced by 'Supplier A', 'Cleaning company A', 'Laboratory A', etc. Finally, the names of company representatives are left out.

Author:

J.B Kloppenberg (Jan-Hein)

VDL ETG Almelo

Bornsestraat 345

7601 PB Almelo

0546 540 000

University of Twente

Drienerlolaan 5

7522 NB Enschede

053 489 9111

Supervisor VDL ETG Almelo

A. Rusch (Andries)

Supervisors University of Twente

Dr. P.B. Rogetzer (Patricia)

Dr. Ir. N.J. Pulles (Niels)

Preface

Dear reader,

You are about to read the master thesis 'Expanding VDL ETG Almelo's supplier base in the Iberian Peninsula to enhance supply chain resilience'. This research is executed at VDL ETG in Almelo as the final assignment for my master Industrial Engineering and Management at the University of Twente.

I am grateful for the opportunities provided by VDL ETG Almelo, in which I could visit potential suppliers in Spain. They have given me full responsibility and freedom, which is something that I truly appreciate. I want to thank everyone who was involved in this research from VDL ETG Almelo for their help and input. Without the help and expertise of everyone, I would not have been able to execute the project in this way.

A special thanks to my supervisor Andries Rusch, who guided me through the research. I want to thank him for the trust that was given to me, as no colleague from VDL ETG Almelo accompanied me on the trip to Spain, besides the other colleague graduation student. Andries was always available for questions and helped me a lot through the research. Since VDL ETG Almelo is such a large organisation, Andries was always able to identify the relevant stakeholders in the process. A big thanks to Harmen Nijboer, who is the other graduation student. It was great to visit the companies with him and we enjoyed the three weeks in Spain well. It was also valuable for the outcome of the research to have visited all of the suppliers together, as we could benchmark these suppliers accordingly. Also, thanks to Arno, Peter, Ronald and Richelle for providing me with extensive information and feedback regarding the relevant (technical) aspects of supplier visits. I also enjoyed the visits to the reference suppliers with them.

Unquestionably, I would like to thank my UT supervisor Patricia Rogetzer. Due to her enthusiasm and positive mindset regarding the possible graduation assignment in the beginning, I was persuaded that this research could be executed to meet all requirements. I enjoyed our meetings and could have nice talks with her, not only about the research. Without all her feedback and insights, I could not have finished my thesis in such manner, so thanks a lot! I would also like to thank my second supervisor Niels Pulles for his refreshing view on my thesis.

At this point, my student time in Enschede comes to an end. It has been an eventful period of 6,5 years with a board year, a minor in Madrid and endless activities, besides all of the studying of course. I want to thank my family, friends, girlfriend and roommates for their support, during my whole study period. Together with everyone involved, I enjoyed my time at the University of Twente well.

As a reader, I hope you enjoy reading this master thesis!

Jan-Hein Kloppenberg

Enschede, January 2024

Management summary

This research has been performed at the Projects department at VDL ETG Almelo, in the Netherlands. The research is part of a broader research project named 'Next Gen Resilience'. A collaboration is set up, consisting of Windesheim University of Applied Sciences, University of Groningen and consultancy firm Involvation. The following companies (besides VDL ETG Almelo) are also involved in the research: Avebe, Bosch, Broshuis, Corbion, Diversey, DSV, Evofenedex, Koopmans, Scania and Vreugdenhil.

VDL ETG is a tier-one design & contract manufacturing partner with global operations, with its customers being Original Equipment Manufacturing (OEM) companies that have a leading role in high-tech manufacturing equipment, in sectors like semiconductor, medical, defence and aerospace. The turnover of VDL ETG Almelo has been increasing significantly the last years, with the expectation that the turnover will have doubled in a couple of years. This growth potential, combined with the existing geopolitical tensions concerning China, leads to the desire of establishing an additional supplier base of MEC-02 commodity mechanical products closer to VDL ETG Almelo than an already existing supplier base in Malaysia. Already two Portuguese suppliers of VDL ETG Almelo exist and relevant mechanical production clusters should exist in the Basque Country. For this reason, the full potential of the Iberian Peninsula as a supplier base for the high-tech market is being investigated. The main research question in this thesis is formulated as follows:

How can VDL ETG Almelo make a thoughtful decision on which suppliers to select for sourcing mechanical products in the mechanisation market segment from the Iberian Peninsula?

A supplier selection tool is developed in this research, which is designed specifically for first time visits to potential mechanical suppliers of the Projects department. The basis of the tool is the Analytic Hierarchy Process (AHP), which follows three steps. The first step concerns the selection of categories of Key Performance Indicators (KPIs), as well as the KPIs per category. This is done with the use of literature and interviews with the four employees with a tactical purchasing function at the Projects department at VDL ETG Almelo. The eight determined categories of KPIs, relevant for first time supplier visits, are General, Quality, Logistics, Technology, Cost, Service, Sustainability and Resilience. In total, 30 KPIs are found to be relevant and measurable. In the second step of the development of the tool, the range in scores is determined. This has been done with the relevant stakeholders that have previously been described. In this way, objective judgement of KPIs is made possible. The weights of the categories and KPIs are determined in the third step, with the use of pairwise comparison between categories and/or KPIs, which is executed by the four described stakeholders. The average values of the individually filled in pairwise comparison matrices lead to the weights of the categories and KPIs. These steps combined lead to the supplier selection tool, illustrated in Table 1 below.

The tool has been applied during the field research period. Ten potential mechanical suppliers, a cleanroom and a laboratory have been visited in Spain. These suppliers are graded during the company visits, with a score of 5.00 to be acquired maximally. The top three suppliers consist of Supplier G (score 4.51), Supplier J (4.22) and Supplier C (4.09). Supplier F also scores high with a score of 4.06. Since Supplier F is in the middle of a merger process from two facility locations into one, they are not ready to do business with VDL ETG Almelo at this moment.

Supplier G, Supplier J and Supplier C are all capable of high precision machining, because they have Japanese machines that are top of the class, with high accuracy. Examples of technical product drawings containing difficult mechanical requirements have been shown to them and these suppliers all mentioned that they are capable of producing these products. Supplier G has ISO class 8 cleanrooms in house, whereas Supplier J has space available for a cleanroom, which they want to have operational in 2025. All three suppliers have experience in relevant comparable sectors, like medical and

aerospace. Also, small batch sizes of shoebox sized products are possible. Capacity is available at all suppliers, in terms of planned capacity at machines, available manpower and space to grow.

The visited cleanroom is Cleaning company A. Cleaning company A is not officially certified according to ISO Class 7, as this is not required by their customers and the certificate is expensive. Laboratory A is the laboratory in Barcelona that verifies if the cleaning process has been executed correctly. In order to certify cleaning, Laboratory A has a laboratory with a cleanroom accredited according to ISO Class 8. Since the certification of ISO Class 7 is expensive and not required by their customers, they do not officially have this certification. Still, they work according to the requirements of ISO Class 7.

The investigated supply chain in the Iberian Peninsula does have potential to become a steady supply chain of MEC-02 products in the Iberian Peninsula, worth of approximately €10 million spend annually and fulfilling the increase in demand by 2027. All relevant companies in the supply chain are willing to set up partnerships and have capacity left, both in terms of planned capacity at machines and available personnel, as well as the available space to realise more machines and/or cleanroom facilities. Also, Cleaning company A is willing to investigate the cleanliness requirements of VDL ETG Almelo in order to become the main cleanroom facility in the Iberian Peninsula, possibly also for VDL ETG Eindhoven.

By setting up a supplier base in the Iberian Peninsula, supply chain resilience can improve. This is caused by increased flexibility across locations and suppliers, reducing dependency on one supplier, establishment of inventory buffers to safeguard against supply swings and supply disruptions, and the ability to circumvent trade barriers by operating within 'trade walls'.

The first and most important advice is to research the exact requirements regarding cleanliness for Cleaning company A and Laboratory A, as this is the most important requirement for VDL ETG Almelo. This is caused by Dutch cleanrooms being saturated with demand and having no more capacity anymore.

It is advised to continue with the potential partnerships on a short notice and to further implement the supplier selection process and supplier qualification process flowcharts that VDL ETG Almelo has in place. It is best to start the partnerships with these suppliers slowly. This means that a relatively low number of orders is placed at the suppliers, for which the First Article Inspection (FAI) process is carried out. When this is achieved and all parties are familiar with each other and its requirements, VDL ETG Almelo can use its position in the market well. This is a sound position in which the own profit can be improved.

Next, it is wise to keep the relationship with Supplier F warm, as they have high potential in the near future and because they are also required for their available capacity. Also, it is advised to analyse the possibilities at Supplier K in Vigo (Spain), because they could not be visited this time due to logistical reasons.

For future first time supplier visits related to the Projects department, it is advised to use the supplier selection tool that has been developed in this research.

Table 1: Supplier selection tool

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7				
KPIs	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**
GENERAL	**15.81%**			
Management commitment for doing business with VDL (ETG)	6.22%			Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%			Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.
Experience on a comparable market / customer segments	2.37%			Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.
High mix low volume willingness & capabillities	2.15%			Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%			NDA and GPA are hard requirements
		Total		
QUALITY	**24.48%**			
Certification ISO 9001 or equivalent or achievable within one year	7.43%			Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1
RoHs, REACH compliant	4.86%			Ask for evidence that supplier does comply for our products. This is a European requirement.
Culture of continuous improvement	2.89%			Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.
Quality Management System (KPI/Calibration/deployment)	2.53%			Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5
Operational Quality Performance	2.56%			Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1
Measurement equipment and tooling	4.21%			Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is
		Total		
LOGISTICS	**17.46%**			
Leadtime	4.90%			What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1
Delivery performance for orders placed according to agreed leadtime	8.08%			Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5
Delivery conditions	2.33%			Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5
Barcoding on product and shipping documents possible	2.15%			Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5
		Total		
TECHNOLOGY	**17.00%**			
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%			No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5
Capable of wire EDM / spark machining	1.94%			No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5
Capable of cylindrical or surface grinding	1.99%			No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%			Dimensions of machining
Shape and position tolerances (0.1 - 0.001)	2.49%			Accuracy of turning and milling machines. What is the supplier's sweet spot? >0.1 = score 1, 0.1 = score 2, 0.01 = score 3, 0.001 = score 4, <0.001 = score 5
Local surface treatment company	3.62%			Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5
		Total		
COST	**7.65%**			
Open book calculation	7.65%			Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5
		Total		
SERVICE	**9.74%**			
Timely responsiveness on request for questions	4.20%			Responsiveness based on our experience. In general response time <5 working days.
Multiple English speaking sales employees	3.69%			Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5
Pro-active communication and information	1.85%			Up-front and pro-active information regarding order book. Based on our experience with the supplier.
		Total		
SUSTAINABILITY	**3.28%**			
Policy on environment, health, safety and ethics	3.28%			What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5
		Total		
RESILIENCE	**4.58%**			
Financial stability	2.14%			Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant
Flexible in volume changes / ramp-up or ramp-down	1.19%			Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).
Back-up possibilities for supplier's partners	0.67%			Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5
Recovery time objectives (RTOs)	0.58%			Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5
		Total		
Totals	**100.00%**			
		Total		
Extra information, no weight	**0%**			
Size of organisation (office / work floor)	0%			Size of the company
Capable of processing materials: (stainless) steel / aluminium / titanium	0%			Can supplier machine / process multiple types of material?
Fully automated machining stations (turning and milling	0%			Supplier has automated machining stations to reduce costs
Viewpoint supplier on customer	0%			Focussed on communication aspects, what is required from your side for a beneficial cooperation?

List of Tables

List of Figures

Table of Contents

1. Introduction

This master thesis is conducted at VDL ETG in Almelo, the Netherlands. The focus of the research is on extending the supplier base in Spain and Portugal, in order the improve the resilience of the global supply chain. Section 1.1 introduces the reader to the company. The motivation for the research is given in Section 1.2. The description of the research problem is given in Section 1.3. Section 1.4 describes the research design. At last, Section 1.5 gives the outline of this thesis.

1.1 Company description

VDL Enabling Technologies Group (ETG) is an international company with offices in nine locations, operating in five different countries. These are the Netherlands, Switzerland, Singapore, China and the United States of America. This research is executed at VDL ETG in Almelo, the Netherlands. VDL ETG is part of the VDL Groep, which is an international industrial family business group of more than 100 companies, spread over 19 countries and with over 16,000 employees. Its combined annual turnover in 2022 was €5.752 billion. The activities of these companies can be clustered in the 'five worlds of VDL', which are Science Technology & Health, Mobility, Energy & Sustainability, Infratech and Foodtech. The VDL companies are divided into four divisions, which are Subcontracting, Car Assembly, Buses & Coaches and Finished products. Figure 27 in Appendix A illustrates the organisational structure of the VDL Groep, with the companies per division (VDL Groep, n.d.).

VDL ETG is a tier-one design & contract manufacturing partner with global operations, with its customers being Original Equipment Manufacturing (OEM) companies that have a leading role in high-tech manufacturing equipment and users of advanced production lines (VDL ETG, n.d.). Six market segments exist within VDL ETG. The first one is the semiconductor market. This includes the production of parts/assemblies for semiconductor machines. The output of these machines is called Integrated Circuits (ICs). ICs are used in almost all smart devices, like laptops, phones and other communication devices like smart cards, sensors and monitoring devices. The solar market segment is the second market segment. It contains production resources to produce silicon and thin-film solar cells to generate renewable energy. The next market segment is the medical segment, which includes professional equipment for diagnosis and treatment of diseases in hospital care. Another market segment is Science & Technology, which contains equipment for "Big Science" projects of research organisations in Europe and worldwide, for example parts and modules for a particle accelerator. The fifth market segment is the mechanisation segment. It includes the mechanisation and automation of unique and complex production processes, from design to realisation of the means of production. VDL ETG Projects mainly focuses on this fifth market segment, which is of relevance later. The last market segment contains analysis equipment for material research and life sciences, which is grouped in the analytical market segment.

VDL ETG Almelo offers diverse services, which range from product development and prototyping to series manufacturing of products which are featured by high complexity and low volume. In-house activities include machining, precision grinding, sheet metal working, laser cutting, mechanical and electrical (clean room) assembly, testing, product certification and on-site installation.

1.2 Motivation for research

Within VDL ETG Almelo, the urge exists to develop a new supplier base, because the supplier base in the Netherlands is saturated, with lead times exceeding acceptable targets for its customers. The Purchasing Director has the desire to enhance VDL ETG Almelo's global supply chain resilience by setting up a new supplier base (*Purchasing Director*, 2023). It is described as being able to 'steer to supplier bases when required' (*Purchasing Director*, 2023). To be able to select potential suppliers, a supplier selection tool for first time supplier visits is required. VDL ETG Almelo already has some sort

of supplier selection tool in place, but this tool is not based on first time visits and the determination in range of scores is vague, leading to the tool not being used. Employees of the Projects department were not aware of the existence of the tool as well.

It is expected that the demand for VDL ETG Almelo will only increase, worsening the problem even more. The products that are produced for VDL ETG Almelo often require a cleaning and packaging finishing in a cleanroom, which is the last step of the production process. These cleaning facilities are the bottleneck in the Dutch supplier base, due to the lack of available capacity. This new supplier base should be closer to the Netherlands than currently is the case, with political tensions arising around Taiwan and China, and VDL ETG Almelo having a supplier base in Malaysia, which is in that same region. As a result, the desire exists to develop a new supplier base in Europe.

The motivation for this research is clarified by doing interviews with internal stakeholders. China believes that Taiwan should be part of China, whereas Taiwan wants to remain independent (Maizland, 2023). Taiwan Semiconductor Manufacturing Company (TSMC) is located in Taiwan and is a multinational semiconductor contract manufacturing and design company. Their market share is more than 50% of the global semiconductor foundry market (Alsop, 2023), which means they have extensive knowledge and know-how to work with the machines with are supplied by a company in the semiconductor industry, which is referred to as 'Company B' in this thesis. Company B is an innovation leader in the semiconductor industry and they provide chipmakers, like TSMC, with hardware, software and services. VDL in turn supplies the parts for the machines of Company B. Since both these machines and the know-how of these Company B machines are located in Taiwan, it is feared that this combination may fall in Chinese hands when China invades Taiwan (Maizland, 2023). So, TSMC is the end-customer, with Company B being their supplier, and VDL ETG respectively being the supplier of Company B. This means that these political tensions in Taiwan can also impact VDL ETG in Almelo.

Important suppliers of VDL are located in Malaysia. These suppliers produce, among other components, parts for the machines of Company B. Due to the Chinese aggression in the (South) East Asian region, VDL fears that China might try to acquire classified information (technical drawings of the parts) which are located at these suppliers. This can also be achieved by Chinese investments in foreign markets (*Purchasing Manager Projects Department*, 2023). For example, a Chinese investor could invest significantly in a Malaysian supplier and make it a 'Chinese' supplier, located in Malaysia. China is already by far the top investor in Malaysia, with a value (expressed in the local currency Ringgit Malaysia (RM)) of RM55.4 billion in 2022, compared to a total inbound investments value of RM264 billion according to MIDA (2023).

VDL ETG Almelo already has multiple suppliers in Europe, which are located in the East of Europe (like Romania), Ireland, the South of Europe (Italy) and the Baltic States. These supplier bases are mostly established as low-cost countries (LCC). Recently, Portugal has also been established as a supplier base with two suppliers at the moment. It is internally known that more suitable suppliers must exist on the Iberian Peninsula (which entails Spain and Portugal), with the prices of the current suppliers being competitive (*Purchasing Manager Projects Department*, 2023). For this reason, the focus is laid on the Iberian Peninsula as an LCC. According to Michelman and Sheffi (2007), supply chain resilience refers to the ability of a company to bounce back from a large disruption. The new supplier base is a method to influence the supply chain resilience of VDL ETG Almelo (*Purchasing Director*, 2023).

1.3 The research problem

This section describes how the specific problem has been formulated as such, with the use of the methodology of Heerkens and Van Winden (2017). The relevant aspects of this methodology are the

action problem in Section 1.3.1, the problem cluster in Section 1.3.2 and the development of the core problem in Section 1.3.3.

1.3.1 Action problem

An action problem is a discrepancy between the norm and the reality, as perceived by the problem owner (Heerkens & Van Winden, 2017). The problem owner is VDL ETG Almelo, and it has become clear that VDL ETG Almelo's global supply chain may not be that agile as desired, due to its suppliers in the Netherlands being saturated with orders. Within VDL ETG Almelo, a strategic decision has been made to prioritise customer satisfaction over the feasibility of meeting all demand on time, with a firm commitment to meet customer requirements. Costs can increase as a result of this.

Also, VDL ETG Almelo wants to anticipate losing a large supplier base in Malaysia, due to the geopolitical tensions originating from the Chinese aggression in Asia, and thus not being able to cope with demand anymore. The required purchasing value in the Iberian Peninsula is expected to be between €10 and €15 million per year. In case of a sudden event in Asia, VDL ETG Almelo wants to be prepared to nevertheless meet demand. As a result, the action problem has been described as such:

Purchasing value of €10-15 million yearly in Iberian Peninsula is targeted, with current value being €0.9 million

1.3.2 Problem identification

In order to understand what the cause of the action problem is, a problem cluster has been created. The problem cluster helps to identify the core problem (Heerkens & Van Winden, 2017). This problem cluster can be seen below in Figure 1. An observation study has been executed to understand the underlying problems of the described action problem. This has been done by conducting interviews with internal stakeholders.

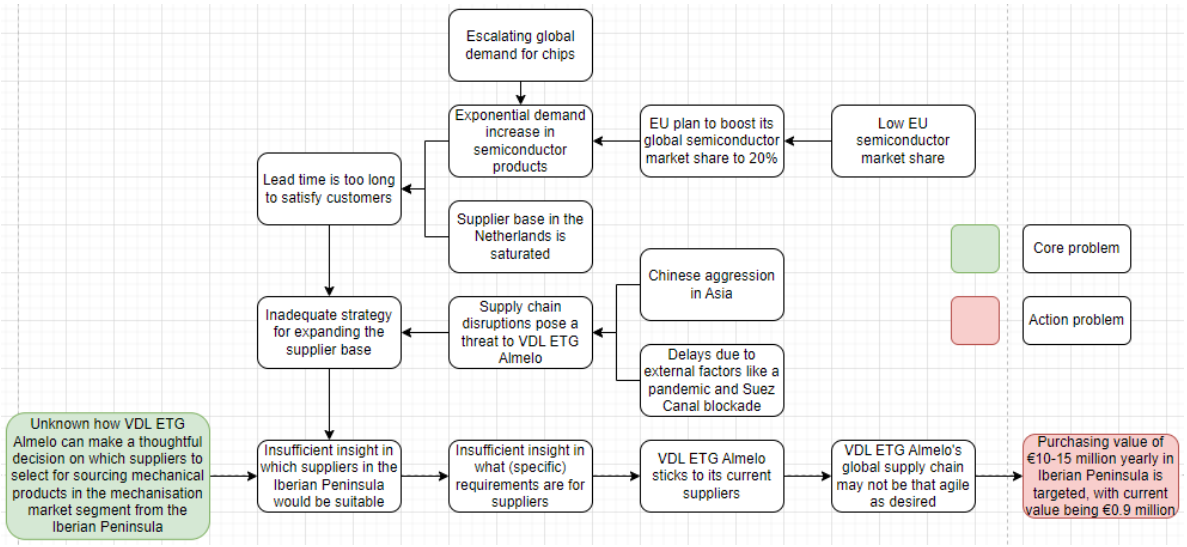


Figure 1: Problem cluster

In Figure 1, one can see the action problem in the red colour, which is caused by other problems. First of all, VDL ETG Almelo's global supply chain may not be that agile as desired. This means that the current supply chain is not flexible enough to cope with varying demand and supply options at suppliers. This in turn is caused by VDL ETG Almelo sticking to its current suppliers, because there is insufficient insight in what specific requirements exist for switching to new suppliers or expanding the supplier base.

There is a continuous worldwide increase in usage of chips on one hand (European Commission, 2022). On the other hand, there exists a global trend to boost internal semiconductor markets (Van Sloun, 2023). For example, the EU has a plan to boost its global semiconductor market share from 10% to 20% (Deutsch, 2023). Together, this leads to an exponential increase in demand for semiconductor products. This in turn, combined with the supplier base in the Netherlands being saturated (also with these semiconductor products), leads to the lead time being too long to satisfy customers. The Dutch supplier base in general is saturated, with VDL ETG Almelo using a lot of regional suppliers' production capacity. Globally, geopolitical tensions exist around Taiwan and China, also impacting the Malaysian supplier base. As a result, VDL ETG Almelo feels the urge to develop a new supplier base region in Europe, which is closer to VDL ETG Almelo than Malaysia.

Currently, VDL ETG Almelo already has two suppliers in Portugal. The experiences with these suppliers are noteworthy, with their product prices being competitive and the quality of products being high for meeting the standards of VDL ETG Almelo. Internally it is known that suitable suppliers must exist in the Iberian Peninsula. This is based on the existence of production clusters, for example in the aerospace industry (*Purchasing Manager Projects Department*, 2023). Other regions like the Baltic States and Eastern Europe are already discovered. For this reason, it is chosen to focus on establishing a new supplier base in the Iberian Peninsula. However, there is insufficient insight in which suppliers in the Iberian Peninsula would be suitable. Also, it is unclear what the effect of this new supplier base is on VDL ETG Almelo's global supply chain resilience.

1.3.3 Core problem and motivation

Problems in the problem cluster which do not have a cause by themselves are potential core problems (Hans Heerkens, Arnold van Winden, 2017). These potential core problems can be found at the start of the cluster in Figure 1, where there is no arrow going to that box. A core problem is selected if it can be influenced.

Various potential core problems exist. The problem 'Escalating global demand for chips' is not a problem which can be influenced. It is impossible to decrease the demand of these chips, the demand will only increase since more and more products require these chips, and more and more people require these products (Casanova, 2023). Casanova (2023) states that a study by SIA and the Boston Consulting Group in 2020 found that global demand for semiconductor manufacturing capacity is projected to increase by 56% by 2030. Also, these worldwide chip shortages exist, because demand for integrated circuits is greater than the supply (Shein, 2023).

The EU has the desire to establish itself as a global leader in the semiconductor market, with a plan to increase the EU's semiconductor market share from 10% today to 20% in 2030 (James, 2023). The related problem 'Low EU semiconductor market share' is not directly influenceable. This problem will continue to be a problem with all the countries globally that want to gain market share in the semiconductor industry.

'Chinese aggression in Asia' is not influenceable and is thus not chosen as the core problem. However, it is a quite significant problem in the global semiconductor industry with its importance and relevance needed to be highlighted. 'Delays due to external factors like a pandemic and the Suez Canal blockade' can occur in global supply chains. Efforts like nearshoring can lead to a decrease in the risk of these factors, but risks will remain. This problem is thus not completely influenceable.

The problem 'Supplier base in the Netherlands is saturated' is a problem with a significant impact. The fact that this supplier base is saturated now and will remain saturated in the coming years as expected,

is not directly influenceable. Nevertheless, the remedy for the overarching issue can be observed in this specific trajectory, as can be seen in the problem cluster.

The last potential core problem is that it is 'Unknown how VDL ETG Almelo can make a thoughtful decision on which suppliers to select for sourcing mechanical products in the mechanisation market segment from the Iberian Peninsula'. Currently, VDL ETG Almelo's supply chain is not as agile as desired, and it is influenceable to research how having a diverse supplier base can influence this. This problem in turn will provide insight in which suppliers in the Iberian Peninsula would be suitable and what the specific requirements are for these suppliers. Concluded, by tackling the core problem, the action problem can be solved. This means that the following problem has been chosen as the core problem of the research:

Unknown how VDL ETG Almelo can make a thoughtful decision on which suppliers to select for sourcing mechanical products in the mechanisation market segment from the Iberian Peninsula

1.4 Research design

This section describes how the research is designed, based on the methodology of Heerkens and Van Winden (2017). Section 1.4.1 gives an overview of the research questions. Secondly, Section 1.4.2 describes the scope of the research. The stakeholders in this research are elaborated on in Section 1.4.3. Lastly, the deliverables are mentioned in Section 1.4.3.

1.4.1 Research questions

The main research question, based on the described core problem, is given below:

How can VDL ETG Almelo make a thoughtful decision on which suppliers to select for sourcing mechanical products in the mechanisation market segment from the Iberian Peninsula?

In order to answer the main research question, research is conducted by answering research questions. The following questions form the common thread through the research:

1. *What is the current state of the global supply chain of VDL ETG Almelo?*
2. *What are suitable tools to select suppliers, taking into account various viewpoints and their relative importance?*
3. *How can suppliers of mechanical products in the mechanisation market segment in the Iberian Peninsula be selected?*
4. *How can the solution method be implemented and evaluated?*
5. *What recommendations and conclusions can be made from conducting the thesis at VDL ETG Almelo?*

1.4.2 Scope

Determining the scope and setting the boundaries of the research is important to get reliable and feasible results within the time frame of an academic semester. In this research, the focus is laid on suppliers of mechanical products in the Iberian Peninsula. The focus is laid on a maximal shoebox size of the products (internal reference), since this is the focus area of the Projects department at VDL ETG Almelo. Since these suppliers potentially make products for VDL ETG Almelo, with VDL ETG Almelo demanding high quality, the focus is on suppliers that can deliver products with this quality. This quality can be measured in terms of the accuracy of machines, and the possibility to work with materials like titanium. These products have the internal commodity reference MEC-02. To illustrate the importance of the MEC-02 commodity, the Product Family portfolio assessment of VDL ETG Almelo is given below in Figure 2. It can be seen that the supply risk (number of capable suppliers) is quite high, but not the highest compared to other products of the MEC product family. However, the purchasing spend (in

terms of volume and/or financial value) is the highest of all commodities of VDL ETG Almelo, indicating the importance of the research to establish a supplier base to cope with this highest purchasing spend.

In the research, the focus is laid on suppliers that are not too small, and where VDL ETG Almelo can have roughly 10-20% of the total turnover of that supplier. A rough estimation is that the supplier has at least an annual turnover of a couple of million euros, which means that VDL ETG Almelo can place orders in the size of hundreds of thousands of euros. As a consumer, one seeks to maintain an equitable balance in the allocation of revenue share from the supplier, avoiding both excessive and insufficient proportions (Purchasing Manager Projects Department, 2023).

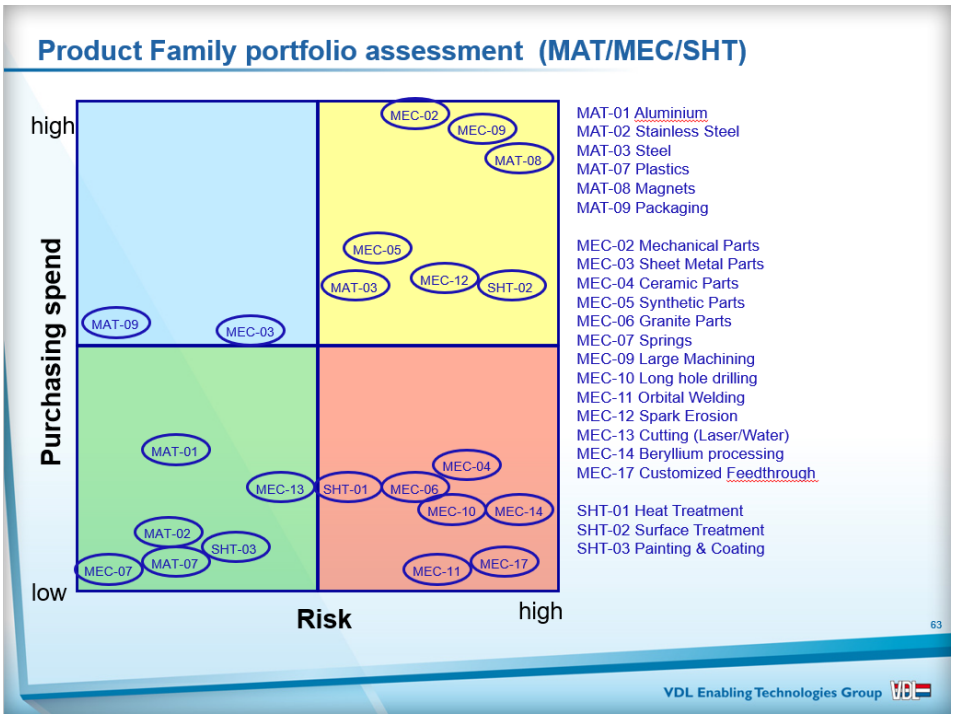


Figure 2: Product Family portfolio assessment
(Source: (Fortuin, 2018))

1.4.3 Stakeholders

The main stakeholder in the research is VDL ETG Almelo and then specifically the Projects Purchasing department. Products at this department can be characterised by the principle of high mix, low volume (Gan et al., 2023). This means that all the 'special' cases are conducted by this department and that it is not just a production line full of one specific product. All stakeholders are employees of VDL ETG Almelo. People with a tactical purchasing function at the Projects department are relevant stakeholders as well, since they have knowledge of supplier selection, and they will be in contact with the possible suppliers after the selection (in VDL ETG Almelo's implementation phase). The purchasing manager of the Projects Department is the supervisor in this research and will thus be updated weekly.

Another stakeholder is the Supply Chain department, which can provide useful figures and information in the research. The Purchasing Manager from department 1 is also relevant, since he supervised previous research in extending the supplier base in Malaysia. Also, the research is applied to the departments 1 and 2, which will be referred to in Section 2.3.

Finally, the Management Team has to be incorporated in the research to keep the strategic vision of the company in place. The Purchasing Director of VDL ETG Almelo is thus important for this vision.

1.4.4 Deliverables

Together with the involved stakeholders, deliverables are defined which are the desired outcomes after having conducted the research. The following deliverables are defined:

- A supplier selection tool to rank suppliers and select them based on KPIs and their weight;
- The results of the supplier visits in the Iberian Peninsula;
- A graphical representation of the partners in the Iberian Peninsula's supply chain;
- Recommendations and conclusions on how VDL ETG Almelo can select potential suppliers;
- This master thesis to illustrate how the research has been executed.

1.5 Outline

Chapter 2 describes the current state of the global supply chain of VDL ETG Almelo. Key players in VDL ETG Almelo's global supply chain are identified and challenges in this global supply chain are elaborated on, indicating the current state of the supply chain resilience. Chapter 3 gives insights in which tools are applicable to use for supplier selection it and gives an explanation for the chosen supplier selection tool. Relevant Key Performance Indicators (KPIs) for this supplier selection tool are given. Chapter 0 describes how suppliers of mechanisation products can be selected with the use of the supplier selection tool. This chapter delivers the supplier selection tool, designed for first time supplier visits of the Projects department at VDL ETG Almelo. Chapter 5 describes the data collection method and gives the results of the field research in the Iberian Peninsula. The thesis concludes with Chapter 6, giving the main conclusions and recommendations. The theoretical and practical contributions of the research are given, and limitations are formulated.

2. Current global supply chain of VDL ETG Almelo

This chapter describes the current global supply chain of VDL ETG Almelo. The following research question is answered in this chapter:

What is the current state of the global supply chain of VDL ETG Almelo?

Section 2.1 describes the current purchasing strategy. Then, Section 2.2 gives the structure of the global supply chain, after which the key players in this global supply chain are given and elaborated on in Section 2.3. Fourth, Section 2.4 describes the challenges in the global supply chain. Finally, Section 2.5 concludes with how VDL ETG Almelo's global supply chain has evolved over time in response to recent global events and trends, and how resilient the global supply chain is. Section 2.7 concludes the chapter.

2.1 VDL ETG Almelo's purchasing strategy

To determine what VDL ETG Almelo's purchasing strategy is, an interview was scheduled with the Purchasing Director. Determining what the current purchasing strategy exactly is, is crucial for fitting this research into the wishes of VDL ETG Almelo. VDL ETG Almelo's purchasing strategy is:

Stable and competitive value chain as business enabler

Figure 3 below translates the purchasing strategy into five objectives, each with the strategy description to reach the 'mission'. 'Stable' concerns controlling potential risks and managing the supply base, to create a consistent inflow of materials and products. 'Competitive' incorporates supplier assessment and continuously focusing on Quality, Logistics, Technology and Costs (QLTC) costs. 'Value Chain' means that who creates value, gets the value in the chain. Lastly, 'Business Enabler' focuses on meeting current and future demand. Also, it concerns anticipating on expectations of VDL ETG's focus market, helping to develop new business. The five pillars with underlying strategies are elaborated on more in

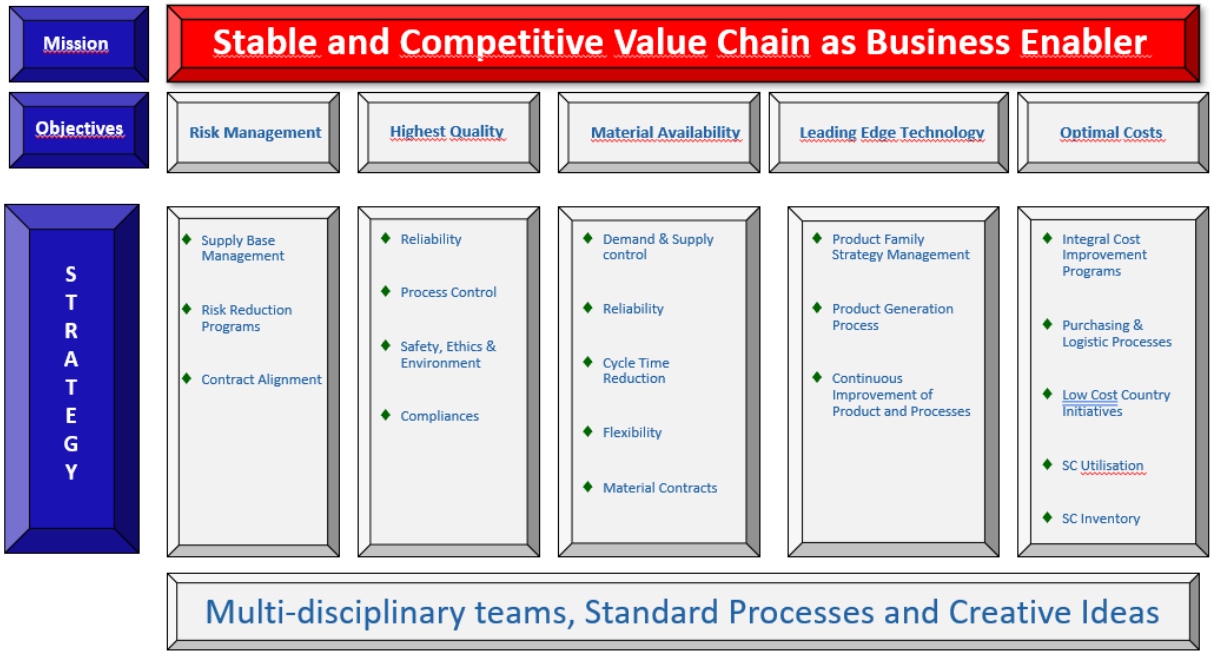


Figure 3: Purchasing strategy VDL ETG Almelo
(Source: (Fortuin, 2018))

2.2 Purchasing volume suppliers VDL ETG Almelo

An interview with a Supply Chain Engineer and the Purchasing Manager of department 1 at VDL ETG Almelo gave insight in the structure of the global supply chain, indicating the purchasing volumes per country, per product commodity and per year. VDL ETG Almelo's purchasing volume in 2023 so far (with future confirmed orders) is approximately €X million. This is divided across multiple countries and continents, with significant differences in these values existing between countries. An overview of the purchasing volume values can be seen in Figure 4. The circles illustrate the size of the purchasing volume, with the large circle covering a big part of Europe being the Netherlands.

As can be seen in Figure 4, the Netherlands is by far the largest supplier market for VDL ETG Almelo with over two-thirds of the total purchasing volume. In the Netherlands, there is a large quantity of suppliers, divided across different segments. These are mostly mechanical, electric and Original Equipment Manufacturer (OEM). The biggest market after that is Germany, followed by the United States of America (USA) and China. In the USA, large aluminium blocks weighing 30 tons and OEM items are produced, which form a substantial portion of the American purchasing portfolio.

Figure 4: Purchasing volume VDL ETG Almelo 2023

Since the scope of the research is specified on suppliers of mechanical products in the mechanisation market segment, another overview is provided in Figure 5 below to illustrate what the purchasing volume of the commodity MEC-02 is in 2023 (including confirmed purchasing orders in 2023). This internal commodity refers to the products that are in the scope of the research.

Figure 5: Purchasing volume VDL ETG Almelo MEC-02 2023

It can already be seen that for this commodity, the Netherlands is also by far the biggest market, with a purchasing volume of almost €X million, of the total €X million purchasing volume of MEC-02 products in 2023. The purchasing volume in Portugal of almost €900,000 comes back in the action problem of the research, described in Section 1.3.1.

Figure 6 below shows the expected growth of the MEC-02 commodity in the next four years. The purchasing value of 2023, which has been shown in Figure 5 already, is the reference value for the expected growth figures of the coming years. These growth figures are applied in accordance with the Supply Chain Engineer, where new projects are taken into account, in addition to the current increasing demand. It can be seen that a large growth is anticipated. The expected purchasing value in 2027 is more than twice as large as the current value in 2023. Assumed that the percentual increase in

purchasing value is the same for each country, the expected purchasing value in 2027 in Malaysia is approximately €X million. To be ready for a transfer of this purchasing volume to the Iberian Peninsula in case of large disruptions and risks concerning the Malaysian supplier base, the Iberian Peninsula supplier base needs to be able to cope with this purchasing volume, in addition to the current purchasing volume in Portugal already. Considered that the purchasing volume in Portugal has also doubled in 2027, twice €900,000 has to be added to the required capacity in a few years. In total, this makes approximately €X million, which explains the research goal in Section 1.3.1 to establish a supplier base in the Iberian Peninsula, capable of a yearly purchasing volume of €10-15 million, taking into account some possible fluctuations.

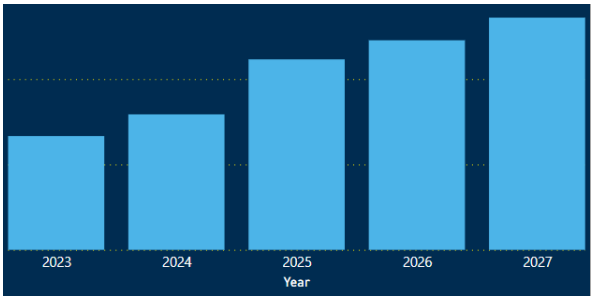


Figure 6: Purchasing volume VDL ETG Almelo expected growth MEC-02

2.3 Key numbers in the global supply chain

The following data is gathered during an interview with the Supply Chain Engineer. VDL ETG Almelo's global turnover is expected to be €X million in 2023. The rough division in turnover volume of the departments within VDL ETG Almelo can be seen in Figure 7, with a total turnover of €X million. The Projects department has a share of 15% of the total global turnover. It is expected that the total global turnover volume in 2024 accounts for €X million, as can be seen in Figure 8. Mainly the departments 1 and 2 are expected to realise a large growth. Still an expected increase of approximately €X million for Projects is quite large. The increase for Projects is caused by the large increase in total turnover volume, despite the percentual decrease of the Projects department in the total turnover volume.

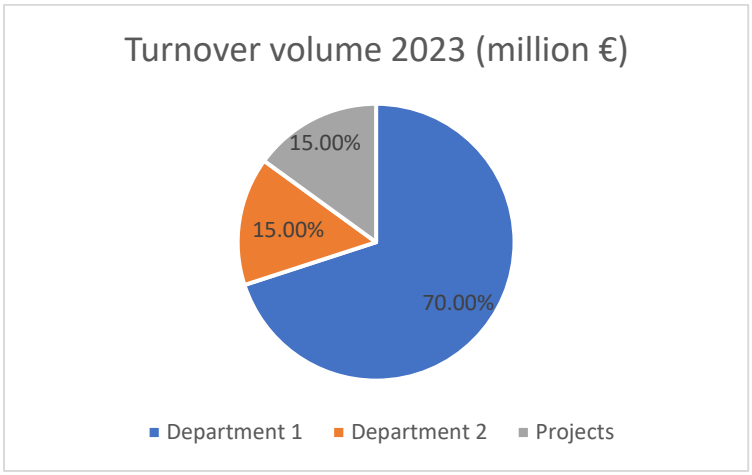


Figure 7: Global turnover division departments VDL ETG Almelo 2023

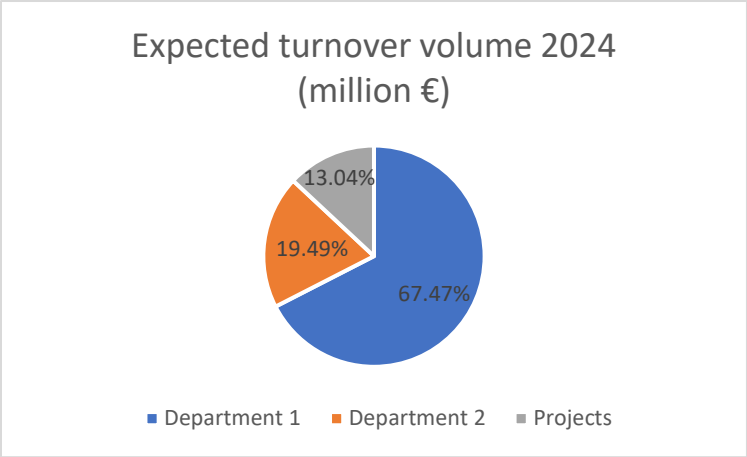


Figure 8: Expected global turnover division departments VDL ETG Almelo 2024

2.4 Challenges in the global supply chain of VDL ETG Almelo

Ambition is growth at VDL ETG Almelo (*Purchasing Director*, 2023). Over the last years, the growth has been established as an increase of 70% in turnover. This means that the purchasing volume also must grow with these numbers. Some current suppliers cannot grow with this increase. As a result, an extension of the supplier base is required. Numerous ways exist in which this can be achieved, based on VDL ETG Almelo's experience. The first one is about exploring new opportunities from the current suppliers; this might include diversifying the products or services sourced from them or building stronger long-term relationships. The second one concerns exploiting new opportunities from new suppliers. It helps to reduce the dependency on the current suppliers and can lead to more competitive pricing, innovation and a broader range of choices. Next, outsourcing within the VDL Groep is an option. Internal outsourcing means exploiting the capabilities of other units within the Groep. It can optimise resource utilisation and expertise, leading to cost savings and improved overall efficiency. The fourth option concerns make-or-buy, in which it is evaluated which products to produce in-house or purchase them externally. This can allow the organisation to focus on core competencies. Another way is the use of higher-level procurement, which involves exploring purchasing at a more strategic level, in which the focus can be laid on long-term agreements that focus on sustainability for example. The last method is cooperation or business takeover, which involves cooperative ventures or even acquisition of suppliers. This method can secure a critical supply chain and enhance control (*Purchasing Director*, 2023).

Focus is laid on establishing a new supplier base. Management believes that establishing a new supplier base is the answer to the problems caused by the growing demand (*Purchasing Director*, 2023).

Risks in the global supply chain exist and they will remain. One can think of examples like the COVID-19 pandemic and the blockade of the Suez Canal. A situation can occur when suddenly, import duties or much higher shipping costs are in place which make the Asian products more expensive than the European products. Nearshoring provides a reduction in these risks (Crowe & Rawdanowicz, 2023).

Currently, geopolitical tensions exist around Taiwan and China (Maizland, 2023). The USA imposes restrictions on the export of Extreme Ultraviolet (EUV) machines to China. These EUV machines are used in semiconductor device fabrication to make integrated circuits. Next, China has a considerable influence on suppliers in Malaysia, where VDL ETG Almelo currently has a supplier base.

Currently, the suppliers in Malaysia are satisfied with the demand provided by VDL ETG Almelo. However, they still have a sizeable portion of their capacity unused, while suppliers in the Netherlands

are largely saturated. VDL ETG Almelo on purpose places just enough orders at the Malaysian supplier base to keep them satisfied, but VDL ETG Almelo does not want to place more orders in Malaysia due to the geopolitical tensions in that region. The question is how long these Malaysian suppliers will remain loyal on the long term. This aspect will be elaborated on in Section 6.5.

Since the Dutch supplier base for high precision products, like parts for the semiconductor industry, was saturated, VDL ETG Almelo and other customers of these suppliers searched for other supplier bases. For this reason, VDL ETG Almelo extended the supplier base to Malaysia. Since all these customers moved production away from the Dutch supplier base, this Dutch supplier base was able to work through the backlog of production jobs and currently has capacity left over (*Purchasing Manager Department 1*, 2023). Nevi PMI (2023) provides insight in the decrease in the production index in Figure 9 below. A production index larger than 50 means that there is an increase in production volume compared to the previous month. The value for October 2023, which is at the datapoint positioned most to the right, is 44.8, indicates that the production volume in the Dutch production sector is decreasing.

Figure 9: Production index
(Source: (Nevi PMI, 2023))

Due to the decrease in production volume, these Dutch suppliers offer discounts right now to get more orders again. When customers place more orders again at the Dutch suppliers, the cycle may repeat itself, which may be a challenge at peak times. In contradiction, Dutch suppliers wanted to increase their prices some months ago to their customers, to cope with the price increase of energy and raw materials (*Purchasing Manager Department 1*, 2023).

Another existing challenge concerns magnets. A specific part of the assemblies for Company B are magnets, which are imported from China, specifically the Ningbo region. VDL ETG Almelo also has a German supplier for these magnets, but this supplier is also dependent on the Ningbo region. If something happens in that region, or sanctions are imposed which make trade (almost) impossible, big challenges arise. The dependency on rare materials and products illustrates the challenges VDL ETG Almelo can experience.

As of the first of October 2023, the Carbon Border Adjustment Mechanism (CBAM) is in place (Taxation and Customs Union, n.d.). The CBAM has the purpose to accelerate the decarbonisation of European industries while preventing carbon leakage, which occurs when businesses shift their production to countries with weaker climate regulations to avoid higher carbon costs (Oropeza, 2023). Since VDL ETG Almelo imports products from outside the EU, VDL ETG Almelo must report what the emissions are, otherwise they will be penalised. By interviewing the Supply Chain Engineer, it became clear that VDL

ETG Almelo is not ready for this transition documentation wise, because carbon emission documentation is not stored accordingly yet.

Transport and social pressure around sustainability is gaining increasingly more attention. A challenge is to arrange the supply chain in such manner that sustainable transport is achieved. This is already getting more attention, but the current global supply chain is not ready for it yet due to the internal focus on cost and quality, rather than sustainability. Soon, it is expected that more sustainability certifications due to regulation are required (European commission, 2023). Also, big customers like Company B may put in place their sustainability requirements (prior to legal requirements) themselves to cope with this social pressure around sustainability.

The main challenges described in this section are how to cope with the growing demand and the geopolitical tensions around Taiwan. The other challenges are also present, but are of lesser importance and relevance at the moment than the other two described challenges.

2.5 Evolved and resilient supply chain

The COVID-19 pandemic and its impact are taken as an example. Suddenly, the pandemic appeared and caused great chaos in the supply chain worldwide, not just that of VDL ETG Almelo (Naseer et al., 2023). VDL ETG Almelo's global supply was not resilient (*Supply Chain Engineer*, 2023). There were a lot of delays, with lead times reaching far too long values. At that point, new supplier bases had to be established to be able to cope with the higher demand and restrictions. The Malaysian supplier base was not established primarily for the lower costs, but for the available capacity and the low lead times, while maintaining high quality. Setting up new supplier bases costs time, which means that VDL ETG Almelo was already too late when the pandemic happened. As a result, VDL ETG Almelo did not grow as hard as it could have done (*Supply Chain Engineer*, 2023). However, due to recent global events and trends, such as the COVID-19 pandemic, their global supply chain has become more resilient. It is expected that VDL ETG Almelo can cope better with unforeseen events now, because the supply chain and supplier base is organised more diversly now, with increased flexibility in production and transport.

2.6 Implementation of potential suppliers in VDL ETG Almelo's global supply chain

This section describes how the selected potential new suppliers can be incorporated into VDL ETG Almelo's global supply chain. VDL ETG Almelo has multiple flowcharts in place, which show relevant steps in the process, to select suppliers and to incorporate these suppliers in the supply chain. These include the supplier selection process (Section 2.6.1) and the supplier qualification process (Section 2.6.2).

2.6.1 Supplier selection process

The flow chart of the supplier selection process can be seen in Figure 28 in Appendix C. Several steps that are present in this flow chart have been executed in this research and they are shortly referenced to in this section. The need for a new supplier has been identified (step 10) in Chapter 1, after which the product family code has been determined (step 20). Market research is executed (30) and a short list of suppliers is made (step 40) in Chapter 0. In step 50, it is checked if other VDL ETG sites already do business with these suppliers. This information is determined partly via the mail, when planning the site visits. These site visits are a way to make initial contact with individual suppliers (step 60), which is executed in this research and elaborated on in Chapter 5. The document 'V-30002 BD03 Supplier selection criteria' is used for filling in the supplier selection criteria overview (scoring + weight factors in step 70). This step has been adjusted in this research, since the supplier selection criteria overview has been adjusted with the supplier selection tool used in this research as a result, which is developed in Chapter 0. Step 80 describes the confidence in the highest scoring potential supplier, which is

executed in Chapter 5. The next step is to perform the supplier selection process for each supplier in Step 90.

2.6.2 Supplier qualification process

The document 'V-30004 Supplier Qualification Process' is used to perform Step 90 of the supplier selection process, described in the previous section. This document contains a flow chart to illustrate the supplier qualification process and can be found in Figure 29 and Figure 30 in Appendix C. Currently, steps 10, 20 and 30 have already been executed. Several aspects for the Supplier Information List (SIL) of step 40 have already been gathered during the site visits, since these aspects are used in the supplier selection tool in this research. However, not all information is gathered and the document 'V-30002 Supplier information list' therefore is not complete. This is where this research stops and where the acquired knowledge is transferred to the relevant stakeholders of the Projects department. To implement the suppliers in VDL ETG Almelo's global supply chain, steps from and including step 40 of the document 'V-30004 Supplier Qualification Process' have to be executed. Further steps include for example the 'Request for Quotation (RFQ) process', the 'Application Form Suppliers' and the 'Framework Agreement', resulting in an archived contract. Responsible officer(s) are indicated per step, which can be the initial buyer or the Purchasing Manager.

2.7 Conclusion

In this chapter, the current global supply chain of VDL ETG Almelo has been described. Section 2.1 describes the purchasing strategy of VDL ETG Almelo '*Stable and competitive value chain as business enabler'*. Section 2.2 gives insight into the purchasing volume of VDL ETG Almelo, which is approximately €X million in 2023. The Netherlands has been found as the country with the largest purchasing value. The research focuses on the internal commodity MEC-02, which has a purchasing volume of €X million in 2023. Consequently, the Netherlands is also the largest supplier base for this commodity, with a purchasing volume of €X million in 2023. Section 2.2 illustrates that the purchasing volume in 2027 is expected to have doubled, compared to 2023.

Section 2.3 gives the division in turnover, divided over the departments within VDL ETG Almelo. Focus is laid on the Projects department, which had a turnover of €X million in 2023. The expected turnover for the Projects department in 2024 is €X million, thus growing with approximately €X million turnover in a year. Section 2.4 focuses on the challenges in the global supply chain of VDL ETG Almelo. The main challenges are how to cope with the growing demand and the geopolitical tensions around Taiwan. Section 2.5 describes how VDL ETG Almelo has coped with the COVID-19 pandemic, indicating that the company has learned from a challenge like the pandemic. The conclusion was that the supply chain and supplier base have to be organised more diversly, in order to be flexible. Section 2.6 describes the flowcharts that VDL ETG Almelo has in place to follow the supplier selection process and supplier qualification process. These document can be found in Appendix C. In this research, all steps up to step 90 in the supplier selection process, which leads to and includes step 30 in the supplier qualification process, are executed.

3. Literature review

In this chapter, a literature review is executed to find the answer to the following knowledge question:

What are suitable tools to select suppliers, taking into account various viewpoints and their relative importance?

First, Section 3.1 describes relevant terminology for the research. Next, motivation for expanding the supplier base is described in Section 3.2. Third, Section 3.3 states the advantages and disadvantages of different methods of expanding the supplier base. Section 3.4 describes which supplier tools exist in literature. Section 3.5 elaborates on which KPIs exist in supplier selection. Also, KPIs specific for the mechanisation market segment are incorporated. Section 3.6 concludes the chapter.

3.1 Relevant terminology

In this section, terminology is explained which is important for this thesis.

According to Michelman and Sheffi (2007), supply chain resilience refers to the ability of a company to bounce back from a large disruption. Supply chain disruptions are unexpected events that could be observed for a prolonged period, and the shock can be propagated to other supply chain echelons (levels) (Olivares-Aguila & ElMaraghy, 2021). In fact, a company can recover from disruptions if they are better positioned than competitors to deal with risks (Michelman & Sheffi, 2007). According to Christopher and Towill (2001), agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace.

Supplier diversification is employed by manufacturers to reduce the risk and dependencies that arise due to reliance on a single supplier (Swaminathan & Shanthikumar, 1999). Reshoring means bringing production back home (Crowe & Rawdanowicz, 2023). Müller-Dauppert (2016) define nearshoring as the geographical relocation of the production function, which entails business functions and processes, in nearby or surrounding countries. Friendshoring refers to the rerouting of supply chains to countries perceived as politically and economically safe or low-risk, to avoid disruption to the flow of business (Ellerbeck, 2023).

3.2 Expanding a company's supplier base

To know about expanding a company's supplier base, it is relevant to provide insight in what actually entails purchasing, which is done in Section 3.2.1. Section 3.2.2 gives the motivation for supplier base expansion. The benefits of getting preferred customer status are described in Section 3.2.3. The viewpoint from the other perspective, supplier satisfaction, is elaborated on in Section 3.2.4

3.2.1 Purchasing process

First, it is important to describe what is included in the term purchasing. Figure 10 below illustrates what the purchasing process entails. Strategic sourcing includes the process of planning supply, selecting suppliers and contracting them to establish the potential for supply. Operative procurement includes the ordering of material and services, ensuring its delivery and, finally, activating the payment, thus executing the order. The research in this thesis focuses on the second step of the purchasing process in strategic sourcing, which is thus the supplier selection step.

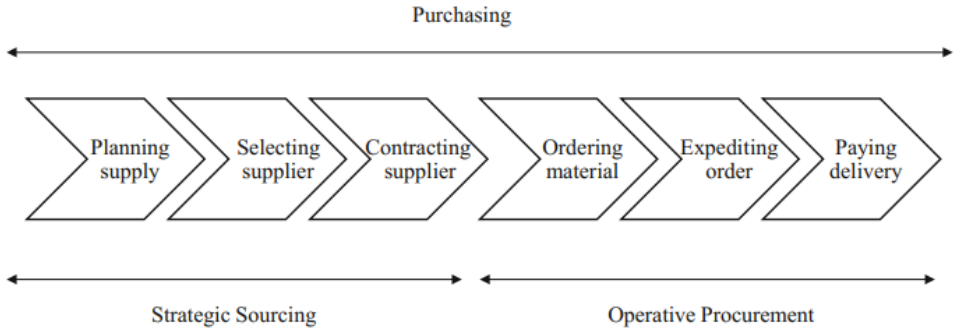


Figure 10: Purchasing process
(Source: (Schiele, 2019))

According to Schiele (2019), purchasing traditionally has three main objectives: (1) ensuring safe, timely and sufficient supply at (2) appropriate quality with (3) the lowest possible costs. Reflecting the growing importance of suppliers for the prosperity of a firm, two novel objectives are added by Schiele (2019), namely, (4) facilitating innovations from and with suppliers and (5) ensuring competitive advantage to the firm by guaranteeing privileged access to sources of supply. These objectives mentioned in Schiele (2019) are elaborated on below. Chand (n.d.) adds the objective to achieve a high degree of co-operation and co-ordination with other departments in the organisation. The five objectives described by Schiele (2019) are also present in the work of Chand (n.d.), illustrating their relevance.

The first objective is safe supply. The most basic objective of purchasing is to provide the materials or services needed on time, at the right time and the right place, as agreed upon between both parties (Schiele, 2019). Stopping an assembly line, for instance, causes substantial costs that far exceed the value of missing components; hence, the emphasis on this objective is a necessary condition (Chand, n.d.).

Quality is the second objective. This is another necessary condition, because a product that does not match required quality criteria cannot be sold. Sustainability of the supply chain has recently been included as a special indication of quality (Schiele, 2019).

The third objective is cost. Traditionally this is the main sufficient condition to make a sourcing project feasible (Schiele, 2019). Regarding the importance of the cost block “supplies” in a modern firm, this criterion gains in importance. Chand (n.d.) illustrates that a one percent saving in materials cost can be equivalent to a 10 percent increase in turnover.

The next objective is innovation. Since the 1990s, there has been a fundamental change in how innovations have occurred (Schiele, 2019). In-house research and development laboratories are no longer responsible for the bulk of novelties. This is often taken over by buyer-supplier networks or specialised suppliers. Hence, a new objective for purchasing was established, namely, (a) to ensure the flow of innovation from suppliers into the buying firm and (b) to establish the conditions and to manage buyer-supplier collaborative innovation processes (Schiele, 2019).

Strategic positioning is the last objective according to Schiele (2019). In a firm where the purchasing volume is of substantial size and where there is a scarcity of suitable suppliers, a further objective for purchasing emerges, namely, to ensure a competitive advantage for the firm by designing and maintaining a performant supply network to which the firm has privileged access. For example, this means better access to the supplier than its competitors in order to achieve competitive advantages. This is illustrated by Chand (n.d.), indicating that purchasing is perceived as a strategic managerial

function at the moment. Achieving preferred customer status, as described by Schiele (2012), is a way to accomplish strategic positioning. This is further elaborated on in Section 3.2.3.

The sixth objective described by Chand (n.d.) is achieving a high degree of co-operation and co-ordination with other departments in the organisation. It is important because it facilitates the achievement of common goals, promotes a comprehensive approach to problem-solving and it enhances efficiency (Chand, n.d.).

3.2.2 Expanding supplier base

Expanding the supplier base is one of the seven core sourcing levers described by Schiele (2019). These sourcing levers form a tailored set of tactics to achieve cost savings, innovation and other performance goals. These seven sourcing levers are given below:

1. 'Volume bundling' to leverage larger purchasing volumes;
2. 'Price evaluation' as a new form of negotiating prices based on cost information;
3. 'Extension of supplier base' to introduce new supply sources;
4. 'Product optimisation' to modify the material or service;
5. 'Process optimisation' to simplify the buyer-seller interface;
6. 'Optimisation of supply relationship' to partner with suppliers;
7. 'Category-spanning optimisation' to consider possible synergies across sourcing categories.

The third lever, the extension of the supplier base, is elaborated on below. The extension of the supply base is described as increasing the number of sources and bidders per request for quotation (Schiele, 2019). The supply base design, and thus the number of suppliers, determines competition in the supply market (Li, 2013). Introducing new suppliers into the supply base, even if not awarded with a contract, may lead to better offers by the established bidders (Gnyawali & Madhavan, 2001). Extension of the supply base may be done through international sourcing and developing local or foreign sources. Competences of potential suppliers may be developed directly (Sillanpää, Shahzad, and Sillanpää, 2015; Sucky and Durst, 2013) or indirectly by gradually awarding business to build their capability and experience for future successful bids (Handfield et al., 2006); (Krause et al., 1998).

In the work of Hesping and Schiele (2016), three indicators for the extension of the supply base are developed. The first one is building up suppliers, which can be done for instance by increasing volumes stepwise. The process can be managed incrementally in this way, which ensures a smoother and more controlled transition in the supply chain (Hesping & Schiele, 2016). Another approach is to drive forward use of suppliers from cost-competitive countries. This can potentially lead to cost savings for the organisation and thus enhance profitability (Hesping & Schiele, 2016). The last approach is to drive forward (deep) localisation, thereby expanding capacities near place of demand. This approach can reduce lead times, lower transportation costs and enhance the supply chain responsiveness (Hesping & Schiele, 2016). Statistical tests have shown that these three indicators highly contribute to supplier base extension, which means that these measures could also be applied in this research (Hesping & Schiele, 2016).

According to Schiele (2019), levers 1–3 are also called 'commercial levers', because they can be applied by purchasers alone and have limited support from other functions, whereas levers 4–7 are known as "cross-functional levers", because their applications require intensive collaboration with other functions. For example, product optimisation links to engineering, whereas process optimisation often links to logistics. The commercial levers try to exploit existing benefits, while the cross-functional levers try to explore new benefits (Schiele, 2019). Given the current need for the supplier base extension, focusing on one of the commercial levers means that the new supplier base might be implemented

quicker since it focuses more on one department, compared to implementing one of the cross-functional levers.

3.2.3 Preferred customer status

Achieving preferred customer status is a way to accomplish strategic positioning, which is relevant in the fifth objective of purchasing, described by Schiele (2019) in Section 3.2.1. When expanding the supplier base, it is beneficial to acquire preferred customer status with a supplier if the supplier offers the customer preferential resource allocation, for example better access to its valuable products or services than it offers to other customers (Schiele, 2019). This can be accomplished in several ways. A supplier may dedicate its best personnel to joint new product development projects, customise its products according to the customer's wishes, offer privileged treatment if bottlenecks in production occur and offer innovations first or even enter into an exclusive agreement (Steinle & Schiele, 2008). The core assumption here is that not all customers are treated equally, because suppliers have to make a choice in view of resource scarcity.

In cases of supply shortage, safe supply is provided to the preferred customers, while other customers may suffer from a supply interruption, thus, preferred customer status reduces supply risk (Schiele, 2019). Further research has found indications that suppliers offer beneficial pricing to their preferred customers, as they appreciate loyalty, expressed in consistent business. Likewise, success in buyer-supplier collaboration for innovation is strongly influenced by the customer's status with the supplier. Finally, with the preferred customer approach, purchasing has a chance to satisfy the novel target of contributing to a firm's competitive advantage. Having exclusive access to a supplier with valuable capabilities creates a strategic advantage for this firm.

According to Schiele (2012), in buyer-supplier relations, buying firms (1) need to be sufficiently attractive for potential suppliers to get a quotation from them. In case a business relation is established, then, (2) the supplier needs to be satisfied with the relation. Finally, (3) the supplier needs to be more satisfied with this customer than with its alternatives so that the buying firm finally becomes a customer of choice and hence get privileged treatment.

In order to assess a buyer's strategic situation with the suppliers, the 'preferred customer matrix' has been developed by Schiele (2012), which can be seen in Figure 11 below. It shows the buyer's status with the supplier against the competitiveness of the supplier. A supplier's competitiveness typically is assessed in a very company-specific way, depending on the strategic direction of the firm. Schiele (2012) suggests various criteria to assess the other axis, which is a firm's status with its supplier. The first one is a technical match, meaning the strategic importance of the customer firm for the supplier due to a conformance of technological roadmaps. The next criterium is commercial importance, which can be measured by the significance of purchasing volume in supplier's overall business. Third, the cultural fit plays a role. In here, existence of similar cultural values in buyer and supplier firms can have significant impact. Lastly, key account status is relevant, which means awarding of key account status with the supplier's sales, R&D, quality, and production departments.

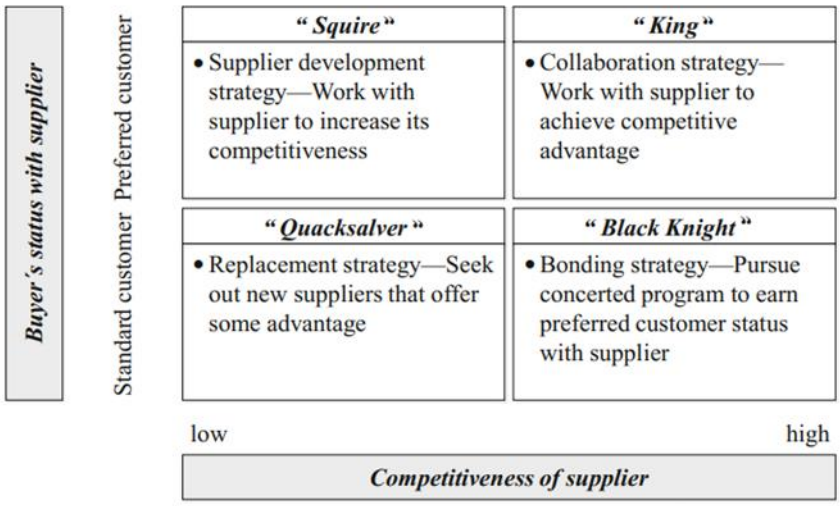


Figure 11: The preferred customer matrix
(Source: (Schiele, 2012))

3.2.4 Supplier satisfaction

Schiele (2019) has revealed several main factors that influence supplier satisfaction. Having a satisfied supplier improves the relationship between supplier and customer, which is thus crucial to take into account when selecting new suppliers (Schiele, 2019). These can be operationalised to understand if suppliers are satisfied with a particular customer. The first aspect is the growth opportunity. For sales personnel, it is more interesting to collaborate with a customer whose turnover is growing, so that in a subsequent period more products can be sold. Another aspect is profitability, because a supplier is more satisfied if a customer is paying fair (Schiele, 2019). The third aspect is relational behaviour. This considers the behaviour of a customer's personnel in terms of reliability, support offered or openness for supplier involvement influences the supplier's satisfaction with this relationship. The last factor to be discussed is operational excellence. Operational excellence like simple processes, prompt responses and accurate forecasts also positively influence the relationship according to Schiele (2019).

3.3 Advantages and disadvantages of supplier base expansion methods

The potential for reducing global value chain (GVC) risks without eroding efficiency gains vary across products and sectors (Crowe & Rawdanowicz, 2023). Diversifying, bringing production home or to closer (friendlier) locations (the so-called re-shoring and near-(friend)-shoring, terminology explained in Section 3.1), and optimising stockpiling are the three most frequently discussed strategies to cope with GVC risks, according to Crowe and Rawdanowicz (2023). For this reason, focus is laid on these three strategies.

Diversifying generally functions better in ensuring resilience and robustness of supply chains, compared to re-shoring (Crowe & Rawdanowicz, 2023). Near-shoring can reduce import fees and delays of long supply chains (Piatanesi & Arauzo-Carod, 2019). Friend-shoring can help to minimise geopolitical risks, involve smaller risks to intellectual property (Banaszyk, 2023). However, defining "friends" based on clear and lasting criteria without adding to business uncertainty is challenging (Crowe & Rawdanowicz, 2023).

Reshaping supply chains can be costly, but diversification could be less expensive than re/near-shoring. The analysis of Tang and Kouvelis (2011) identified a supplier diversification benefit, that is, diversification reduces the output inefficiency caused by random yield and increases the expected market output. It is generally cheaper and easier to diversify production of goods that require simple

technologies, are characterised by small economies of scale and are standardised (Crowe & Rawdanowicz, 2023). Diversifying and re-shoring may be unviable or difficult in sectors with high fixed costs and for many natural resources (Crowe & Rawdanowicz, 2023).

Most actions to improve resilience lie with firms rather than governments, according to Crowe and Rawdanowicz (2023). However, firms have to cope with incentives of governments and incorporate these in their daily practice (Nguyen et al., 2023). Private firms have financial incentives to reduce risks of costly disruptions to production. On the contrary, they could be limited by the sunk costs of investments and the costs of adapting supply chains (Crowe & Rawdanowicz, 2023). Private firms can choose best between the robustness and resilience of their supply chain (Crowe & Rawdanowicz, 2023).

Threats to national security in principle justify insuring against negative geopolitical events or acting to prevent such events. However, geopolitical risks and associated economic costs are difficult to evaluate, as indicated in the case study concerning North and South Korea (Pyo, 2021). Besides, some policy measures may prove ineffective in ensuring security (Crowe & Rawdanowicz, 2023). To minimise risks that such policies will be ineffective and costly for taxpayers and consumers, objective and thorough evaluations are needed (Crowe & Rawdanowicz, 2023).

Concerns over the resilience of supply of manufactured goods that are critical inputs for the economy due to high concentration of production abroad have led some governments to support domestic production. Globally, various countries are already implementing measures to increase resilience by diversifying domestic and international suppliers. The EU has an act to boost the domestic semiconductor market (Deutsch, 2023). The same holds for the USA (Thorbecke, 2022).

Table 2 below from Pedersen and Jensen (2023), illustrates how companies can address disruptions. It shows resilience strategies, their expected impact and associated costs. Resilience strategies 1, 2 and 4 for the local natural disasters fit in the aim of this research, just as resilience strategy 1 for the political conflicts.

Table 2: Ways for companies to address disruptions
(Source: (Pedersen & Jensen, 2023))

External disruptions (examples)	Resilience strategies (examples)	Expected impact of strategies	Costs and Disadvantages
Local natural disasters (e.g., flooding, hurricane and earthquake) Case-illustration: Nissan and Danish electronics company	1. Diversify locations of production in order not to get overexposed to one location 2. Multiple suppliers 3. Safety stocks 4. Back-up sites	1. Reduced exposure to local risks; increased flexibility across locations 2. Increased flexibility across suppliers; reducing lock-in and dependency on one supplier 3. Decreased interdependence between tasks in production process 4. Establishment of buffer to safeguard against supply swings and supply disruption	1. Increased management and coordination costs; differences in output and quality standards 2. Potential loss of benefits gained from close collaboration with single suppliers 3. Tied-up capital due to slack resources (stock and capacity) 4. Similar to 3), due to excess capacity
Political conflicts (e.g., China-US trade conflict, territorial conflicts and Brexit) Case-illustration: Apple and Danish electronics company	1. Local production activities rather than cross border trade 2. Early warning strategies, tracking and monitoring central indicators 3. Tracking and monitoring of supply chain	1. Ability to circumvent trade barriers by operating within "trade walls" 2. Improved readiness to foresee and respond to disruptions in extended supply chain 3. Similar to 2), plus a stronger, integrated relationship and information flow with suppliers	1. Establishment costs (can be significant); reduced economies of scale; fewer synergy effects from globally concentrated activities 2. Costs of design and development of monitoring system 3. Similar to 2)

3.4 Supplier selection tools

Several evaluation tools for supplier selection have been proposed by Sarkis and Talluri (2002). The majority of the tools mentioned in Sarkis and Talluri (2002) are based on multiple-supplier criteria, of which the most relevant tools are described below. More literature research regarding other supplier selection tools is given in Appendix D.

3.4.1 Total cost of ownership (TCO)

TCO is a methodology and philosophy, which looks beyond the price of a purchase to include many other purchase-related costs. According to Ellram (1995), TCO is a complex approach which requires that the buying firm determines which costs it considers most important or significant in the acquisition, possession, use and subsequent disposition of a good or service. In addition to the price paid for the item, TCO may include such elements as order placement, research and qualification of suppliers, transportation, receiving, inspection, rejection, replacement, downtime caused by failure, disposal costs and so on.

3.4.2 Analytic hierarchy process (AHP)

AHP is an approach that can be used in a multifactor decision-making environment, especially when subjective and/or intuitive consideration has to be incorporated (Sarkis & Talluri, 2002). It is a robust technique that allows managers to determine preferences of criteria for selection purposes, quantify those preferences, then aggregate them across diverse criteria. It is a relatively easy approach to understand and apply (Sarkis & Talluri, 2002). AHP provides a structured approach for determining the scores and weights for the multiple criteria used and standardises them, so that they can be compared and decisions made (Barbarosoglu & Yazgac, 1997). A shortcoming of AHP is that it not explicitly considers the interactions among the various factors (for example, cost and quality may impact flexibility) (Sarkis & Talluri, 2002).

3.4.3 Fuzzy AHP

Tools exist to deal with the shortcomings of AHP. In these tools, Fuzzy logic is combined with AHP to combine the advantages of the two methods. In fuzzy logic, everything, including truth, is a matter of degree (Zadeh, 1988). Fuzzy logic does not have the capability to measure the level of consistency in the judgments provided by a decision maker Ishizaka (2014). AHP cannot capture subjectivity (or fuzziness) of human judgments as the verbal assessments are converted into clear values.

Ishizaka (2014) compares Fuzzy logic, AHP, Fuzzy Analytic Hierarchy Process (FAHP) and Hybrid Fuzzy AHP for new supplier selection and its performance analysis. FAHP is a merger of the two methods, Fuzzy logic and the AHP, which inherits the advantages of both and, therefore, addresses the above-mentioned problems. The FAHP method is useful in identifying a suitable supplier and to evaluate its performance as demonstrated in the described case study. It can also be applied in any other selection or ranking problem. The Hybrid Fuzzy AHP can manage direct or pairwise, clear or fuzzy evaluations.

3.4.4 Analytic network process (ANP)

ANP is a more general form of the AHP used in multi-criteria decision analysis (Saaty, 2004). AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the ANP structures it as a network. ANP takes into account that attributes may influence each other, and thus influence the choice. More elaborations on this are given below in Section 3.4.5.2. ANP is an accurate decision support tool for supplier selection (Sarkis & Talluri, 2002).

3.4.5 Differences between tools

The sub-sections below describe various comparisons made between different tools. Since AHP is compared most in literature with Fuzzy AHP, TCO and ANP, the sections below give comparisons between these tools where applicable. After the comparisons, a supplier selection tool is chosen for this research in Section 3.4.6.

3.4.5.1 Difference AHP and Fuzzy AHP

As with the Fuzzy logic method, AHP also formulates the problem in a hierarchical structure. The main difference is the extraction of relative weights (importance) of the criteria and performances of the

alternatives through pairwise comparisons, which are collected in a comparison matrix. Fuzzy AHP exists in order to capture the benefits of both methods (Ishizaka, 2014). The main difference between the two lies in their treatment of uncertainty and imprecision in the decision-making process (Ishizaka, 2014). A comparison per relevant aspect is given below.

Regarding handling uncertainty, AHP is a crisp or deterministic method, meaning it assumes that the input data (such as pairwise comparisons of criteria) and the resulting weights are precise and without uncertainty (Özdağoğlu & Özdağoğlu, 2007). It does not explicitly account for ambiguity or fuzziness in the decision process. Fuzzy AHP on the other hand extends AHP by allowing for the representation of imprecision and uncertainty in the decision data (Özdağoğlu & Özdağoğlu, 2007). It uses fuzzy sets and linguistic terms to describe the vagueness of judgments and criteria. Fuzzy AHP acknowledges that decision-makers may not always have precise information and accommodates this uncertainty in the analysis (Ishizaka, 2014).

The next aspect is about membership functions. In AHP, judgments are typically expressed as crisp, precise values, such as "Criterion A is three times more important than Criterion B." There is no consideration of degrees of membership or uncertainty in these judgments (Özdağoğlu & Özdağoğlu, 2007). Fuzzy AHP uses membership functions to represent the degree of membership of elements (criteria or alternatives) to linguistic terms like "very important," "important," "slightly important," etc. This allows for a more flexible and expressive way to capture imprecise judgments (Ishizaka, 2014).

Third, aggregation of preferences is discussed. AHP uses the eigenvector method to aggregate the pairwise comparison matrices and calculate the final priorities or weights for criteria and alternatives. The result is typically a set of crisp numerical values (Özdağoğlu & Özdağoğlu, 2007). Fuzzy AHP employs fuzzy aggregation techniques, such as the fuzzy weighted geometric mean or fuzzy weighted arithmetic mean, to aggregate the fuzzy judgments and calculate fuzzy priorities, which can be represented as fuzzy numbers or fuzzy sets (Ishizaka, 2014).

Another relevant aspect is the representation of data. AHP uses crisp matrices for pairwise comparisons and crisp values for priorities, which can be straightforward but may not adequately capture real-world imprecision (Özdağoğlu & Özdağoğlu, 2007). Fuzzy AHP represents data using fuzzy matrices and fuzzy numbers, which can better accommodate imprecision and provide a more realistic representation of decision-makers' judgments (Ishizaka, 2014).

In summary, the primary difference between AHP and Fuzzy AHP is the treatment of uncertainty and imprecision. AHP is a deterministic method that assumes precise data, while Fuzzy AHP uses fuzzy logic to model and handle imprecise, uncertain, or vague information in the decision-making process. Fuzzy AHP is particularly useful when decision-makers need to make decisions in situations where data is inherently uncertain or qualitative in nature (Ishizaka, 2014). However, the study of Chan et al. (2019) infers that Fuzzy AHP is in fact not a favourable method over classical AHP, because a sophisticated method is not necessarily better than a simple method.

3.4.5.2 Difference AHP and ANP

Since (Fuzzy) AHP and ANP seem feasible tools for application in this research, it is elaborated further on the differences between AHP and ANP. AHP only considers one-way hierarchical relationships among factors (Saaty, 2004; Sarkis & Talluri, 2002). This simplistic assumption does not consider the many possible relationships among the groups of factors or those within them (Sarkis & Talluri, 2002). For example, for selection of a project, a decision maker may categorize factors into cost, quality and flexibility. A project may be rated on each of these factors separately and aggregated to arrive at an overall score, which is essentially what AHP does. Yet, AHP does not explicitly consider the interactions among the several factors (for example, cost and quality may impact flexibility). ANP can incorporate

this and many other interrelationships of factors into the decision model. In addition, another problem with AHP is that of "rank reversal". Rank reversal can be a concern in decision-making because it suggests that the outcome is sensitive to the criteria weights and can lead to different decisions under different circumstances (Saaty, 1996). To mitigate rank reversal, decision-makers often engage in sensitivity analysis, which involves evaluating the robustness of their decisions by varying criteria weights to understand how they affect the ranking of alternatives.

On the other hand, the ANP approach may have disadvantages in some situations because it can become quite complex as the number of factors and relationships increases, requiring more effort by analysts and decision makers (Saaty, 2004). A summary of AHP versus ANP per different aspect is given below.

The first aspect to be discussed is the hierarchical versus network structure. AHP is based on a hierarchical structure, where the problem is broken down into a hierarchy of criteria and alternatives. It involves pairwise comparisons to establish the relative importance or preference of criteria and sub-criteria (Sarkis & Talluri, 2002). ANP, on the contrary, allows for more complex relationships by using a network structure. In ANP, elements (criteria, sub-criteria, and alternatives) are interconnected in a network, and the relationships between them can be both hierarchical and non-hierarchical. ANP extends the capabilities of AHP by accommodating feedback loops and dependencies between elements (Saaty, 2004).

Differences exist in terms of dependence handling. AHP assumes that the criteria and sub-criteria are independent of each other. It does not explicitly handle dependencies or feedback loops between criteria (Sarkis & Talluri, 2002). ANP is designed to handle dependencies and feedback loops among criteria and sub-criteria. It allows for a more realistic representation of complex decision problems where elements may influence each other directly or indirectly (Saaty, 2004).

Thirdly, the aspect of pairwise comparisons is elaborated on. AHP relies heavily on pairwise comparisons to determine the relative importance of criteria and alternatives. The consistency of these comparisons is also checked using mathematical consistency indices (Sarkis & Talluri, 2002). ANP extends pairwise comparisons to include not only the comparison of criteria but also the relationships between criteria and sub-criteria within the network. This can make the evaluation process more complex (Saaty, 2004).

Both tools apply a different mathematical formulation. AHP uses a mathematical formulation based on eigenvector methods to calculate the weights of criteria and alternatives (Sarkis & Talluri, 2002). ANP uses a more complex mathematical formulation based on the super matrix approach, which considers both the inner and outer dependencies within the network (Saaty, 2004).

Lastly, it is compared when the tool is applied in practice. AHP is often used for decision problems with a relatively simpler hierarchical structure, where the interactions between criteria are limited and can be adequately captured through pairwise comparisons (Sarkis & Talluri, 2002). ANP is employed when decision problems have a more complex network structure with interdependencies and feedback loops. It is suitable for problems where the relationships between elements are crucial and cannot be simplified (Saaty, 2004).

3.4.5.3 Difference AHP and TCO

According to Bhutta and Huq (2002), AHP is more of a selection tool and is appropriate in decision-making situations, where both quantitative and qualitative factors have to be considered, whereas TCO is difficult to use in an environment where subjective assessments and judgements have to be used in comparing factors. AHP provides a framework to cope with multiple criteria situations involving

supplier selection, while the total cost of ownership is a methodology and philosophy, which looks beyond just the price of a purchase to better understand and manage costs in selecting and maintaining suppliers (Ramanathan, 2007). According to Bhutta and Huq (2002), both approaches can be used in negotiations and in helping to optimise and concentrate resources where they are most needed. However, AHP can help evaluate and compare suppliers on different evaluation criteria, and, if cost data are included as they are in TCO, AHP can provide a more robust tool for managers to select and evaluate suppliers across the board, enabling them to make sound selections based on both qualitative and quantitative criteria (Bhutta & Huq, 2002).

3.4.6 Conclusion from comparison

The analytic hierarchy process (AHP) has been selected as the supplier selection tool used in this research. It is assumed that the stakeholders in the research who will execute the pairwise comparisons deliver precise data. For this reason, the Fuzzy logic of Fuzzy AHP is not required. Also, research has shown that Fuzzy AHP is in fact not a favourable method over classical AHP, because a sophisticated method is not necessarily better than a simple method. ANP is not preferred, compared to AHP, because the rank reversal disadvantage of AHP is not considered to be a problem in this research. The opinion of the stakeholders is considered to be correct, which will lead to the correct criteria weights and thus the 'correct' outcomes. Internally, a tool is preferred which delivers the correct results, without making the reasoning unnecessarily complex. For this reason, ANP is not selected as well. Finally, since the tool considers more factors (AHP) than just factors expressed in costs (TCO), TCO is not deemed to be applicable.

3.5 KPIs for supplier selection

In this section, relevant categories and KPIs for supplier selection are elaborated on. Section 3.5.1 focuses on relevant categories and KPIs for supplier selection, applied in 'mechanical' supplier selection tools. Section 3.5.2 gives more insight into KPIs specifically for the resilience aspect, aiming to tackle risk.

3.5.1 KPIs in the mechanical industry

Three ways of categorising KPIs are described in this section. One way to categorise KPIs for supplier selection, is the scheme introduced in Yücenur et al. (2011). According to Yücenur et al. (2011), four categories exist with different KPIs per category. These categories consist of 'Service Quality', 'Cost', 'Risk Factors' and 'Supplier's Characteristics' (Yücenur et al., 2011). Since each KPI is described in depth by Yücenur et al. (2011), all the 28 KPIs will not be stated and elaborated on here. The summary of this hierarchy, existing of the categories with KPIs, can be seen below in Figure 12. In the figure, the numbers in the boxes indicate the KPI numbers that are clustered per category. For example, 'Reliability' (number 1) until and including 'Communication easiness' (number 8), are clustered under the category 'Service Quality'. The overview indicates an exemplary global supplier selection, consisting of three suppliers. Since eight KPIs exist in the category 'Service Quality', eight lines go from the first box to each of the three suppliers. The same holds for each category, indicating that the categories with its KPIs influence the supplier selection process for each supplier.

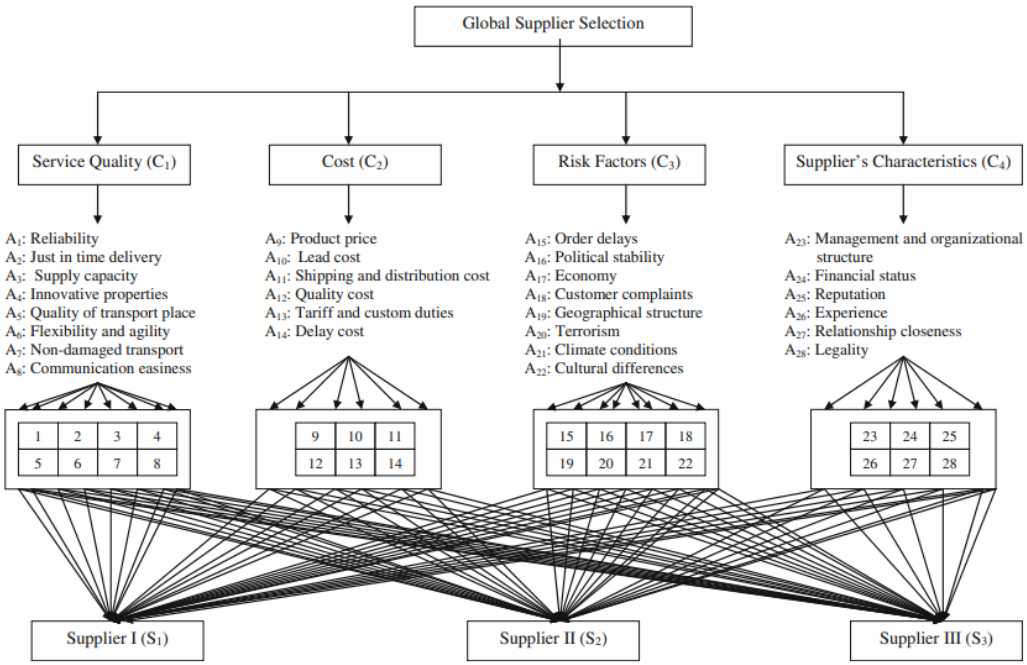


Figure 12: The categorisation of the supplier selection problem (Source: (Yücenur et al., 2011))

Ishizaka (2014) proposes another overview of KPIs for supplier selection. This overview is given below in Figure 13. Four categories exist which are composed of multiple KPIs. These categories are 'Quality', 'Delivery', Service' and 'Costs'. To illustrate, 'Quality' is composed of the KPIs 'Quality control rejection rate' and 'Customer rejection rate'. Behind these KPIs, Ishizaka (2014) gives a linguistic importance scale (different scores in words). To cope with the difference in words for people, the fuzzy aspect provides clarity in terms of judgement. These scores are low importance (L), moderate importance (M), high importance (H) and very high importance (VH). The weights assigned to the criteria in Figure 13 exist for a specific case in the work of Ishizaka (2014) and thus are not representative of a general supplier selection process, they are merely given as an indication for what a weight distribution could entail. 'w_1' up to and including 'w_{10}' are the weights of the KPIs. The overview shows which KPIs are used as indicators for the categories and how their importance is considered by the different weights. In the end, a score is given for a supplier by taking into account the scores and the weights given.

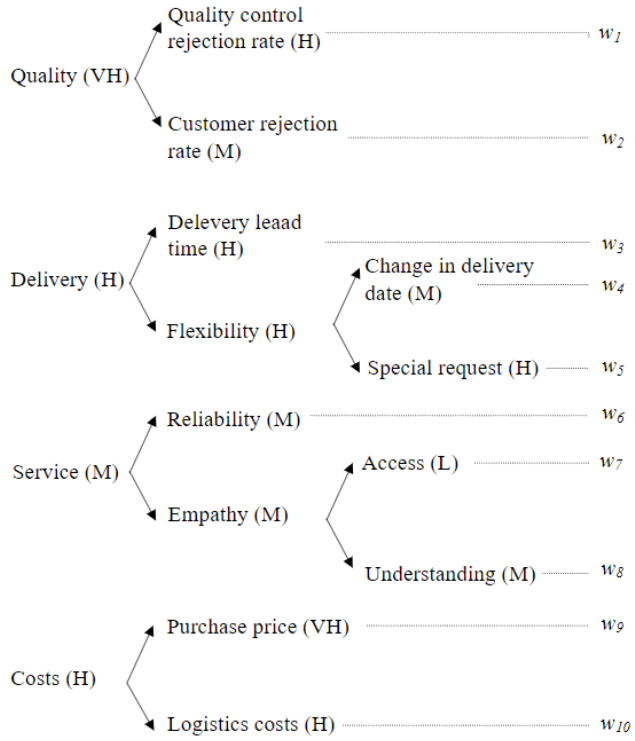


Figure 13: Supplier selection overview
(Source: (Ishizaka, 2014))

Sarkis and Talluri (2002) describe ANP for strategic supplier selection and elaborate on a range of factors and their components. Figure 14 below gives the summary of these factors and components that are described and elaborated on by Sarkis and Talluri (2002). These factors and components are divided in two fields, namely strategic performance metrics and organisational factors. Four categories are described, which are 'Cost', 'Quality', 'Time' and 'Flexibility'. These categories are made up of KPIs to measure how well these categories score. These four categories together make up the strategic performance metrics, which can be seen on the left side in Figure 14. On the right side in this figure, the organizational factors can be found. These organizational factors are composed of 'Culture', 'Technology' and 'Relationship'. Each of these three categories is composed of KPIs to measure the specific categories. The overview of Sarkis and Talluri (2002) is given as input in this research for KPIs that exist per category, and to get acquainted with which categories actually exist in the supplier selection process.

SUMMARY OF FACTORS AND COMPONENTS OF THE STRATEGIC PERFORMANCE METRICS AND ORGANIZATIONAL FACTORS CLUSTERS

Strategic Performance Metrics	Organizational Factors
Cost (Barb. and Yazgac 1997)	**Culture (Ellram 1990)**
Low initial price (LIP)	Feeling of trust (FOT)
Compliance with cost analysis system (CCA)	Management attitude/outlook for the future (ATT)
Cost reduction activities (CRA)	Strategic fit (SF)
Compliance with sectoral price behavior (CSP)	Top management compatibility (TMC)
Quality (Choi 1996)	Compatibility among levels and functions (CALF)
Conformance quality (CQ)	Supplier's organizational structure and personnel (SOSP)
Consistent delivery (CD)	**Technology (Ellram 1990; Barb. and Yazgac 1997)**
Quality philosophy (QP)	Technological compatibility (TCOMP)
Prompt response (PR)	Assessment of future manufacturing capabilities (FMC)
Time (Choi 1996)	Supplier's speed in development (SSD)
Delivery speed (DS)	Supplier's design capability (SDC)
Product development time (PDT)	Technical capability (TCAP)
Partnership formation time (PFT)	Current manufacturing facilities/capabilities (CFC)
Flexibility (Choi 1996)	**Relationship (Choi 1996)**
Product volume changes (PVC)	Long-term relationship (LTR)
Short setup time (SST)	Relationship closeness (RC)
Conflict resolution (CR)	Communication openness (CO)
Service capability (SCAP)	Reputation for integrity (RFI)

Figure 14: Summary of factors and components of the strategic performance metrics and organisational factor clusters (Source: (Sarkis & Talluri, 2002))

Figure 12, Figure 13 and Figure 14 provide insights in what relevant KPIs are, divided over categories, in the strategic supplier selection process in general. It may be assumed that KPIs that are present in more than one source seem to be viable KPIs in the supplier selection process. More specific KPIs applied to the mechanisation market segment are elaborated on in Section 3.5.2.

3.5.2 KPIS regarding risk

Company B has implemented a Business Continuity Management (BCM) System, which is a sort of risk management approach, to ensure that Company B and its supply chain are adequately prepared for disruptive events, manifesting from internal and external events, and threats. It is capable to continue the delivery of products and services at acceptable predefined levels (following a disruptive event) (Company B, 2023). It minimises the likelihood of disruptive events and effectively prepares the organisation to manage the impact of a disruptive event, should any occur. For this reason, an impact/likelihood matrix is in place, which can be seen in Figure 15 below. The value of risk is calculated by the estimated recovery time (RT) in weeks, multiplied by the sales margin per platform/product. This means the loss of revenue for the weeks that production is not possible. The likelihood is gathered via the supplier self-assessment and is validated by an independent risk engineer.

The goal of the loss prevention control assessment in the likelihood aspect is to detect possible risks on the manufacturing premises and gain better insights including mitigation actions to prevent the chances of an accident to occur (Company B, 2023). The supplier shares its report (which is verified by an independent third party) with Company B, after which Company B translates the results into internal scores with a C, B, A or AA rating. There is a mutual aim to score at least "A" or create a roadmap to further improve the risk profile until "A" is achieved. The arrows in Figure 15 represent a potential roadmap.

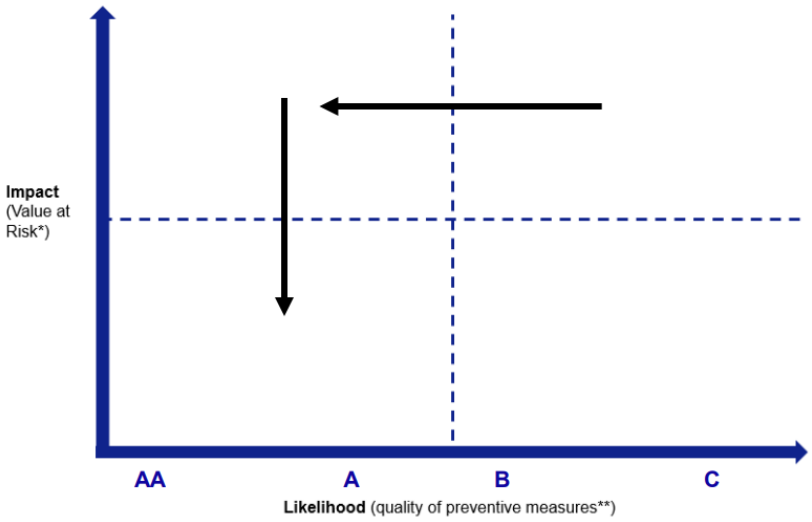


Figure 15: Impact/likelihood matrix
(Source: (Company B, 2023))

Company B requires its suppliers to score an AA (above standard) or A (standard) rating. Measures to accomplish this are summarised below. These measures can also be applied in this research, to cope with risk and rephrase risk into a KPI for the supplier selection tool.

The first measure is about transparency. Company B (2023) states that there is transparency about the supplier's risks. A supplier and Company B agree on required improvements needed to meet or reduce recovery time (RT). A KPI can measure the reduction in recovery time. Next, suppliers shall implement and maintain loss prevention control and preventive maintenance standards for (critical) assets, in line with industry standards and best practices. Control measures shall be well-maintained and regularly tested. A KPI can measure the presence of these systems. Lastly, loss prevention control assessment should be executed by an independent risk engineer during supplier selection, every three years and in case of major changes / extensions to the manufacturing sites. This can also be a binary KPI to measure if it is available.

Company B has defined recovery time objectives (RTOs) to resume the supply chain operations after a disruptive incident. These RTOs per operation in Company B's supply chain can be found below in Table 3. The last column illustrates the RTOs per type of products. This can be transformed into a KPI to measure if the requirements regarding RTO are met when disruptions occur.

Table 3: Company B's approved RTOs
(Source: (Company B, 2023))

Type of products	Visually	Supply chain	Recovery time objectives
DUV Products		Manufacturing	max. 16 weeks
EUV Products		Manufacturing	max. 26 weeks
APPS Products		Manufacturing	max. 26 weeks
Parts delivery on stock		Service / parts	max. 2 weeks

3.6 Conclusion

Schiele (2019) describes seven core sourcing levers to achieve cost savings, innovation and other performance goals. The extension of the supplier base is one of these levers and this is where the

research focuses on. Diversifying, bringing production home or to closer (friendlier) locations (the so-called re-shoring and near-(friend)-shoring), and optimising stockpiling are the three most frequently discussed strategies according to Crowe and Rawdanowicz (2023). Since VDL ETG Almelo has the desire to enhance their global supply chain resilience by expanding the supplier base, the focus is laid on the diversification of suppliers in a nearshoring environment (thus finding new suppliers in a nearby country). Achieving preferred customer status is a way to accomplish strategic positioning, which is relevant when extending the supplier base, described by Schiele (2019), and illustrated in Section 3.2.1. According to Pedersen and Jensen (2023), the expected impact of this strategy is reduced exposure to local risks and increased flexibility across locations. However, this strategy leads to increased management and coordination costs, and leads to differences in output and quality standards.

Several evaluation tools for supplier selection have been proposed by Sarkis and Talluri (2002), of which the Total cost of ownership (TCO), Analytic hierarchy process (AHP), Fuzzy AHP and the Analytic network process (ANP) are described in Section 3.4. Comparisons between these tools are made, after which the AHP is selected in Section 3.4.6, as the supplier selection tool to be applied in this research. VDL ETG Almelo has stated that the focus of the research should not be on incorporating the most complex model. However, they prefer to see a capable model implemented with KPIs that are well chosen, based on the expert opinions of the relevant stakeholders, leading to AHP.

Yücenur et al. (2011), Ishizaka (2014) and Sarkis and Talluri (2002) provide overviews of categories with KPIs for global supplier selection. Categories described in their work include the following: (Service) Quality, Cost, Risk Factors, Delivery, Flexibility, Culture, Technology, Relationship and Supplier's Characteristics. These categories consist of KPIs, which are KPIs that are relevant for this research. Since these three overviews together form an extensive list of KPIs, they will not be elaborated on here, but can be found in Figure 12, Figure 13 and Figure 14 in Section 3.5.1. Company B (2023) illustrates Company B's Business Continuity Management (BCM) System in Section 3.5.2 to ensure that Company B and its supply chain are adequately prepared for disruptive events. Recovery time objectives (RTOs) are proposed, which improve the global supply chain of Company B. This can be relevant for VDL ETG Almelo.

In Chapter 0, AHP is used to develop a supplier selection tool for first time visits to potential suppliers, which consists of categories and KPIs, based on the outcome of literature research in this Chapter.

4. Supplier selection

This chapter describes how the AHP supplier selection tool is developed, how it is applied in the research, what the steps are in the preparation phase before the data can be gathered and it answers the following question:

How can suppliers of mechanical products in the mechanisation market segment in the Iberian Peninsula be selected?

The supplier selection tool for first time supplier visits is developed in this Chapter. Section 4.1 describes how the shortlist of suppliers (that are to be contacted for supplier visits) is developed, leading to a list of suppliers that are visited. To illustrate the development process of the supplier selection tool with the use of the AHP method, a part of the developed supplier selection tool is given below in Table 4. The orange blocks in the left column show categories of KPIs, with the KPIs per category being in the yellow blocks in the left column. The selection of these categories and KPIs is described in Section 4.2. The weights for these categories and KPIs are shown in the second-left column, and are elaborated on in Section 4.3. Section 4.4 explains how gathering of data with the use of supplier visits is executed in a verified and validated manner. Section 4.5 concludes the chapter.

Table 4: Illustration developed supplier selection tool

KPIs	Weight	Score (scale 1-5)	Weighted score	Determination of range in scores
GENERAL	**15.81%**			
Management commitment for doing business with VDL (ETG)	6.22%			Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%			Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.
Experience on a comparable market / customer segments	2.37%			Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.
High mix low volume willingness & capabillities	2.15%			Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%			NDA and GPA are hard requirements
		Total		
QUALITY	**24.48%**			
Certification ISO 9001 or equivalent or achievable within one year	7.43%			Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1
RoHs, REACH compliant	4.86%			Ask for evidence that supplier does comply for our products. This is a European requirement.
Culture of continuous improvement	2.89%			Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.
Quality Management System (KPI/Calibration/deployment)	2.53%			Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5
Operational Quality Performance	2.56%			Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1
Measurement equipment and tooling	4.21%			Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is
		Total		

4.1 Longlist and shortlist of suppliers

To determine what VDL Almelo is exactly looking for regarding capabilities of suppliers, interviews have been held with tactical purchasers of the Projects department. Also, contact has been made with a strategic purchaser from VDL ETG Eindhoven to investigate what they see as opportunities in the Iberian Peninsula and to determine what their requirements are.

A longlist of potential suppliers in the Iberian Peninsula has been developed, with suppliers being identified via various methods. Some potential suppliers were selected, based on research executed by a former purchaser at VDL ETG Almelo in 2011, concerning potential suppliers in the Iberian Peninsula. In the same documentation, also a folder of the Hannover Messe in 2011 provided additional information about potential companies (Reliance, 2011). Next, access to a database concerning companies in various sectors was acquired by having a Teams meeting with a representative of Moody's (2023). In this database, specific search strings were used to find companies. An example is the usage of a certain annual turnover, in a certain sector, with a certain

minimum number of employees, etc. This database helped to search suppliers of mechanical products, with a certain minimal turnover in Spain and Portugal.

A prerequisite in supplier selection is that the supplier facilitates cleanroom activities, since this part of the production process is a bottleneck in the current supplier base. With facilitated, it is meant that this is done in-house, or that the supplier has a partner (nearby) that is responsible for these cleanroom activities. These cleanroom activities involve surface treatment and cleaning which enable the product to be used in a cleanroom. A cleanroom is a controlled environment that filters pollutants like dust, airborne microbes and aerosol particles to provide the cleanest area possible (Angstrom Technology, 2023). At VDL ETG Almelo, cleanrooms are classified into different classes depending on the number of particles allowed. Two cleanroom grades are considered (which are Company B standards), namely grade 2 and 4. Grade 4 allows more particles per cubic meter than grade 2. Regarding the suppliers, at least grade 4 is required. It can be assumed that the Company B grade 4 is the equivalent of ISO7, which is an international standard (Cleanliness expert VDL ETG Almelo, 2023).

A Teams meeting with Malagon (2023) clarified the presence of a cluster of mechanical products in the Basque Country in the North of Spain. A Teams meeting with Egaña (2023) gave insight into some potentially relevant suppliers and described the probable lack of a cleanroom at a potential supplier. It was illustrated that mostly universities and technological centres, like Tekniker, had these facilities. Other potential suppliers were found by using Google in both English and Spanish. All these methods combined lead to a longlist of 56 potential suppliers, which can be found in Table 15 in Appendix A.

To determine which suppliers of the longlist can be selected for the shortlist, the suppliers are graded binary on a couple of aspects that can be determined based on their website. These measurable aspects are determined together with the relevant stakeholders with a tactical purchasing function at the Projects department and can be seen below.

- Capable of processing materials: (stainless) steel/aluminium/titanium (all required)
- Fully automated machining stations (turning and milling)
- Measurement equipment and tooling available (quality control department)
- Capable of cylindrical or surface grinding
- Small machine possible <1000&1000&1000mm
- High mix low volume willingness & capabilities
- Certification ISO 9001 or equivalent or achievable within one year
- At least clean room ISO 7 facilitated (in-house or at an external partner)
- Surface treatment possible i.e., NIP, anodizing
- Temperature and humidity-controlled production environment
- Enough capacity/turnover, can be based on Google Maps to get an impression
- Customer segments
- Other remarks, like site only in Spanish for example

Together with the stakeholders from the Projects department, it has been determined that the first five criteria are hard requirements. The cleanroom is found to be relevant as well, however this is not present on websites of suppliers, as already indicated by Egaña (2023). For this reason, the hard requirement for the cleanroom is left out here. The longlist with scores on the first five criteria can be found in Table 15 in Appendix E. In total, 32 out of the 56 suppliers score a ‘Yes’ on all of these five criteria, which is shown in Table 16 in Appendix E.

Then, the other KPIs are taken into account. The focus is laid on the capacity/turnover and other remarks. These other remarks take for example into account if the site is only in Spanish and the

location link leading to an odd location in Google Maps. In case a supplier is not found to be relevant enough, it is marked in red and the reason for it is given in the 'Remarks' column. The current state of the list of suppliers can be found in Table 17 and Table 18 in Appendix E. 23 suppliers out of the 32 suppliers are left.

At last, the location is taken into account. As can be seen in Figure 16 below, most suppliers are located in the Basque Country, which is around the number '15' in the figure. Cantabria and Navarra are regions adjacent to Basque Country. Summarised, there is one supplier in Aragon, 14 in Basque Country, one in Cantabria, three in Catalonia, one in Galicia, one in Madrid, one in Navarra and one in Portugal. The locations that are far away from the cluster and not completely relevant are one of the three in Catalonia, the one in Madrid and the one in Portugal. The other two in Catalonia are relevant enough (even though the distance to the other suppliers is longer). These three suppliers are excluded from the list, which leads to the shortlist of potential suppliers, consisting of 20 suppliers in total. The final shortlist can be found in Table 19 in Appendix E. Future research can alter the location scope of the suppliers.

Figure 16: Location potential suppliers
(Source: (Sourcemap, 2018))

4.2 KPIs with boundary values

First, categories of KPIs are determined here, after which more specific KPIs are clustered under these categories. Literature has given insight into relevant categories of KPIs which are essential in the supplier selection process. As described in Section 3.6, the most common categories of KPIs found in literature are (Service) Quality, Cost, Risk Factors, Delivery, Flexibility, Culture, Technology, Relationship and Supplier's Characteristics. Some of these categories are already present in the supplier selection tool that VDL ETG Almelo has in place (but which is not being used). The categories of KPIs are taken into account and are discussed with the relevant stakeholders of the Projects department. With their expert opinions, the previously mentioned collection of categories has been adjusted slightly into a set of eight categories of KPIs. These are General, Quality, Logistics, Technology, Cost, Service, Sustainability and Resilience. The Resilience category takes into account the four main

drivers of resilience, which are redundancy, flexibility, transparency and agility. The basis for this category is the Supply Chain Resilience QuickScan (2023).

A second session with the stakeholders of the Projects department functioned for determining the more specific KPIs per category, which the stakeholders find relevant for a first time visit to a potential supplier. The panel of the stakeholders consisted of four employees with a tactical purchasing function, with extensive experience in this field. In total, 30 KPIs have been determined which are to be graded at a potential supplier. In addition to that, four KPIs have been determined to provide more information about the company but without receiving a grade for that specific KPI. The categories of the KPIs (in orange) made up of the specific KPIs (in yellow) can be found in Table 20 in Appendix E.

To make sure that the supplier selection process is executed in an objective manner, the range in scores is determined where applicable. To give an example, the determination of range in scores for delivery performance for orders placed according to agreed lead time is given here. This is based on integer values. If required, values are rounded up or down accordingly. <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5. Where applicable, the KPIs have received these kind of range in scores. This has been done together with the relevant stakeholders of the Projects department. All these ranges in scores per KPI are given in Table 21 and Table 22 in Appendix E.

4.3 Weight distribution of KPIs

The weights of the categories of the KPIs and specific KPIs per category have been determined with the use of the AHP pairwise comparison. All four relevant stakeholders of the Projects department have filled in the pairwise comparison matrix. The cells in green require to be filled in, the cells in red will fill itself automatically. In here, their intensity of importance of KPI A in favour of KPI B is filled in, and so forth. The fundamental scale of absolute numbers of Saaty (2004) is used for this and is given below in Figure 17. In the pairwise comparison matrix, the KPI on the horizontal level is compared to the KPI on the vertical level. The process of the weight determination by the AHP pairwise comparison method is described and shown in this section. The four individual pairwise comparison matrices of the stakeholders are combined, and the average values are taken, which can be seen in Table 5 below. With these values, the rest of the computations are executed.

Intensity of Importance	*Definition*	*Explanation*
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix

Figure 17: The Fundamental scale of absolute numbers
(Source: (Saaty, 2004))

Table 5: Pairwise comparison matrix average values

Pairwise comparison matrix	GENERAL	QUALITY	LOGISTICS	TECHNOLOGY	COST	SERVICE	SUSTAINABILITY	RESILIENCE
GENERAL	1.000	1.369	1.119	0.844	3.125	1.365	3.583	1.750
QUALITY	0.730	1.000	2.750	2.500	5.000	2.250	7.000	3.500
LOGISTICS	0.894	0.364	1.000	2.583	3.750	1.833	5.250	3.000
TECHNOLOGY	1.185	0.400	0.387	1.000	4.250	2.750	5.750	4.500
COST	0.320	0.200	0.267	0.235	1.000	1.417	4.250	2.583
SERVICE	0.733	0.444	0.545	0.364	0.706	1.000	4.250	3.250
SUSTAINABILITY	0.279	0.143	0.190	0.174	0.235	0.235	1.000	1.333
RESILIENCE	0.571	0.286	0.333	0.222	0.387	0.308	0.750	1.000

To illustrate how to read this matrix, the following example is given. When 'General' is taken on the horizontal level and 'Quality' on the vertical level, a value of 1.369 can be read. This means that 'General' is considered 1.369 times more important than 'Quality' when selecting a new supplier, according to the four stakeholders. These scales can range from a value of 1/9 (when the vertical level is considered more important than the horizontal level) to a value of 9. This means that 'General' and 'Quality' are considered roughly as important as the other. However, when looking at 'Quality' compared to 'Sustainability', a value of 7 can be read in Table 5. This means that 'Quality' is favoured very strongly over 'Sustainability'. When analysing the table, it can be seen that 'Quality' is favoured quite strongly over almost all other categories, except for 'General'. Also, 'General', 'Logistics' and 'Technology' are often favoured over the other remaining categories, which are 'Cost', 'Service', Sustainability' and 'Resilience'. 'Sustainability' scores the worst, with its pairwise comparison values being around 0.20.

Next, the pairwise comparison matrix is normalised, leading to the normalised pairwise comparison matrix with the criteria weights in Table 6 below. To illustrate, an example is given. A value of 0.175 can be seen in the top left corner of the matrix in Table 6. This is calculated by dividing the value in that location in Table 5 by the sum of the column of that location in Table 5. Thus, 1.000 / (1.000+0.730+0.894+1.185+0.320+0.733+0.279+0.571) is 0.175. This procedure is executed for all values. When taking the average of all values per row, the criteria weights for the categories of the KPIs are obtained.

Table 6: Normalised pairwise comparison matrix

	Normalised pairwise comparison matrix								Criteria weights
GENERAL	0.175	0.326	0.170	0.107	0.169	0.122	0.113	0.084	0.158
QUALITY	0.128	0.238	0.417	0.316	0.271	0.202	0.220	0.167	0.245
LOGISTICS	0.156	0.086	0.152	0.326	0.203	0.164	0.165	0.143	0.175
TECHNOLOGY	0.207	0.095	0.059	0.126	0.230	0.246	0.181	0.215	0.170
COST	0.056	0.048	0.040	0.030	0.054	0.127	0.134	0.124	0.076
SERVICE	0.128	0.106	0.083	0.046	0.038	0.090	0.134	0.155	0.097
SUSTAINABILITY	0.049	0.034	0.029	0.022	0.013	0.021	0.031	0.064	0.033
RESILIENCE	0.100	0.068	0.051	0.028	0.021	0.028	0.024	0.048	0.046

To validate if the pairwise comparison matrix has been filled in correctly with regards to consistency, the steps of the AHP method are executed to be able to verify this and to obtain the consistency ratio. These steps are described below. For example, this means that if A is more important than B, with B being more important than C, it would be inconsistent if C is considered more important than A. According to Saaty (2004), inconsistency must be at most one order of magnitude less important than consistency, or simply at most 10% of the total concern with consistent measurement. As a result, a consistency ratio exceeding 0.10 is considered too large and solutions must be found to adapt the matrix in such a way that the measurements become sufficiently consistent.

First, a matrix for the weighted value calculation is calculated. In here, the value of a specific cell in Table 5 is multiplied by the value of that cell in Table 6. These values are added per row and then divided by the criteria weight of that row in Table 6. This matrix can be seen in Table 7 below. The values that are used for the next part of the calculation are in the last column.

Table 7: Weighted value calculation

	Weighted value calculation								Weighted sum value	Ratio weighted sum value / criteria weights
GENERAL	0.158	0.335	0.195	0.143	0.239	0.133	0.118	0.080	1.402	8.867
QUALITY	0.115	0.245	0.480	0.425	0.382	0.219	0.230	0.160	2.257	9.221
LOGISTICS	0.141	0.089	0.175	0.439	0.287	0.179	0.172	0.137	1.619	9.276
TECHNOLOGY	0.187	0.098	0.068	0.170	0.325	0.268	0.189	0.206	1.511	8.886
COST	0.051	0.049	0.047	0.040	0.076	0.138	0.140	0.118	0.658	8.609
SERVICE	0.116	0.109	0.095	0.062	0.054	0.097	0.140	0.149	0.822	8.433
SUSTAINABILITY	0.044	0.035	0.033	0.030	0.018	0.023	0.033	0.061	0.277	8.429
RESILIENCE	0.090	0.070	0.058	0.038	0.030	0.030	0.025	0.046	0.386	8.431

The final steps for the calculation are shown in Table 9 below. λ_{max} is the average of the values in the last column of Table 7. n gives the number of KPIs that are compared, which is relevant for the value of the Random Index (RI) (Saaty, 2004). The value of the RI depends on n, as can be seen in Table 8 below. The Consistency Index (CI) is calculated in the following way:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI}$$

When the CR is less than or equal to 0.10, the pairwise comparison matrix is found to be consistent. If this is not the case, the pairwise comparison matrix is inconsistent. Since the CR in Table 9 is 0.078, the average pairwise comparison matrix is consistent.

Table 8: Random index
(Source: (Saaty, 2004))

n	1	2	3	4	5	6	7	8	9	10
Random Index	0	0	.52	.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 9: Consistency ratio calculation

Conclusion	
λ_{max}	8.769
n	8
Consistency Index (CI)	0.110
Consistency ratio CR = CI/RI	0.078
Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	

The second step is applying the pairwise comparison method for the categories of KPIs that contain multiple KPIs. This means that this method is not applied to the categories 'Cost' and 'Sustainability'. The four stakeholders filled in the pairwise comparison matrices for the specific KPIs of the six remaining categories. These pairwise comparison matrices are averaged in the same way as previously described. Also, the computations are executed in the same manner. The averaged pairwise comparison matrices, the criteria weights, together with its conclusions regarding consistency, are given in Table 23, Table 24, Table 25, Table 26, Table 27 and Table 28 in Appendix E for each of these six categories. The normalised pairwise comparison matrix and the weighted value calculation are not given, as the procedure is the same as previously described. The conclusion regarding the consistency ratios is given below in Table 10.

Table 10: Conclusion CR

Category	Consistency ratio
GENERAL	0.031
QUALITY	0.012
LOGISTICS	0.011
TECHNOLOGY	0.005
SERVICE	0.111
RESILIENCE	0.035

The CR for 'Service' is more than 0.10, resulting in receiving the red colour due to its inconsistency. This is caused by one of the stakeholder's individual pairwise comparison matrix. The consistency ratio of that individual matrix is more than 0.216. The other categories are all found to be consistent, as indicated by the green colour. Saaty (2004) states the following concerning inconsistencies:

"If the C.R. is larger than desired, we do three things: 1) Find the most inconsistent judgment in the matrix, 2) Determine the range of values to which that judgment can be changed corresponding to which the inconsistency would be improved, 3) Ask the decision maker to consider, if he can, changing his judgment to a plausible value in that range."

The steps above have been applied and two pairwise comparisons made by that specific stakeholders have been altered slightly within the range. As a result, the consistency ratio of that specific matrix is found to be consistent, just like the consistency ratio of the average of the pairwise comparison

matrices. The updated matrix with its underlying conclusion is given in Table 29 in Appendix E. The updated version of Table 10 is given below in Table 13, showing all green conclusions.

Table 11: Updated conclusion CR

Category	Consistency ratio
GENERAL	0.031
QUALITY	0.012
LOGISTICS	0.011
TECHNOLOGY	0.005
SERVICE	0.090
RESILIENCE	0.035

The eventual criteria weights for the specific KPIs are calculated by multiplying the weight of that category by the weight of the specific KPI. So, the value in Table 6 is multiplied by the specific value in Table 23, Table 24, Table 25, Table 26, Table 28 or Table 29. To illustrate, the weight calculation of the specific KPI 'Management commitment for doing business with VDL (ETG)' is shown. This is 0.1581 * 0.394 = 0.0622. The final weights for the specific KPIs can be found in Table 30 in Appendix E. Combining the categories and KPIs, with their specific determination in range of scores, and their weights, leads to the supplier selection tool in Table 12 below.

Table 12: Supplier selection tool

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7				
KPIs	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**
GENERAL	**15.81%**			
Management commitment for doing business with VDL (ETG)	6.22%			Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%			Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.
Experience on a comparable market / customer segments	2.37%			Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.
High mix low volume willingness & capabillities	2.15%			Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%			NDA and GPA are hard requirements
		Total		
QUALITY	**24.48%**			
Certification ISO 9001 or equivalent or achievable within one year	7.43%			Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1
RoHs, REACH compliant	4.86%			Ask for evidence that supplier does comply for our products. This is a European requirement.
Culture of continuous improvement	2.89%			Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.
Quality Management System (KPI/Calibration/deployment)	2.53%			Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5
Operational Quality Performance	2.56%			Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1
Measurement equipment and tooling	4.21%			Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is
		Total		
LOGISTICS	**17.46%**			
Leadtime	4.90%			What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1
Delivery performance for orders placed according to agreed leadtime	8.08%			Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5
Delivery conditions	2.33%			Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5
Barcoding on product and shipping documents possible	2.15%			Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5
		Total		
TECHNOLOGY	**17.00%**			
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%			No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5
Capable of wire EDM / spark machining	1.94%			No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5
Capable of cylindrical or surface grinding	1.99%			No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%			Dimensions of machining
Shape and position tolerances (0.1 - 0.001)	2.49%			Accuracy of turning and milling machines. What is the supplier's sweet spot? >0.1 = score 1, 0.1 = score 2, 0.01 = score 3, 0.001 = score 4, <0.001 = score 5
Local surface treatment company	3.62%			Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5
		Total		
COST	**7.65%**			
Open book calculation	7.65%			Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5
		Total		
SERVICE	**9.74%**			
Timely responsiveness on request for questions	4.20%			Responsiveness based on our experience. In general response time <5 working days.
Multiple English speaking sales employees	3.69%			Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5
Pro-active communication and information	1.85%			Up-front and pro-active information regarding order book. Based on our experience with the supplier.
		Total		
SUSTAINABILITY	**3.28%**			
Policy on environment, health, safety and ethics	3.28%			What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5
		Total		
RESILIENCE	**4.58%**			
Financial stability	2.14%			Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant
Flexible in volume changes / ramp-up or ramp-down	1.19%			Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).
Back-up possibilities for supplier's partners	0.67%			Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5
Recovery time objectives (RTOs)	0.58%			Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5
		Total		
Totals	**100.00%**			
		Total		
Extra information, no weight	**0%**			
Size of organisation (office / work floor)	0%			Size of the company
Capable of processing materials: (stainless) steel / aluminium / titanium	0%			Can supplier machine / process multiple types of material?
Fully automated machining stations (turning and milling	0%			Supplier has automated machining stations to reduce costs
Viewpoint supplier on customer	0%			Focussed on communication aspects, what is required from your side for a beneficial cooperation?

4.4 Gathering of verified and validated data

Before the company visits in Spain, two already existing mechanical suppliers in the Netherlands have been visited to verify the applicability of the determined KPIs. This was done together with two stakeholders from the Projects department. They gave insights into relevant aspects to look at during a visit of a potential supplier. Also, they showed which questions are useful to ask. After this, the researchers knew which questions had to be asked to grade a KPI effectively, which is used during the company visits in Spain. The determined KPIs proved to be the correct set of KPIs, as all relevant aspects during the visit of the reference suppliers were covered.

In total, ten potential suppliers, a cleanroom and a laboratory are visited during the data collection period in Spain. Their location is given below in Figure 18. From this figure, the presence of a cluster of mechanical suppliers in the Basque Country in the North of Spain can easily be noticed. This proves the feeling of an existence of such a cluster, as indicated by the Purchasing Manager of the Projects department in Section 1.3.2. The supplier selection tool which is described in Section 4.2 and Section 4.3, is used during the visits of the potential suppliers. Interviews have been conducted with the suppliers during the visit. Also, the production facilities and the offices have been visited to get a feeling for, amongst others, the production capabilities, cleanliness of the production plant, the company atmosphere and the level of English of various employees. Data for filling in the supplier selection tool is gathered during the visit. If certain aspects for filling in the tool were unclear or absent during the visit, information about these aspects is acquired via email after the visit. The visits have been done together with a colleague graduate student. After a visit, the supplier selection tool is filled in separately. After having done this, all given scores plus argumentation are discussed to verify that both researchers are on the same page. Next, consensus about the given scores is to be reached. This proves helpful, since benchmarking can be done by two researchers. The data is validated in this way, so the given scores give an accurate representation of the suppliers.

Figure 18: Location visited companies
(Source: (Sourcemap, 2018))

After the trip, the first findings were presented to all of the relevant stakeholders, which are the four employees with a tactical purchasing function at the Projects department, the Purchasing Manager of the Projects department and the Purchasing Director. The feedback was positive, indicating that the suppliers seem appropriate in terms of their capabilities (for example, the type and number of machines capable of high-precision machining, raw materials, cleanliness). In this way, it proved the

usefulness of the research and the company visits. It emphasized that the steps taken in this research are the correct ones. Also, it proved that the data is gathered in a feasible way, because the given scores in the supplier selection tool immediately indicate why a certain score has been awarded. The results of the company visits are discussed in Chapter 5.

4.5 Conclusion

Section 4.1 describes the process of going from the longlist of potential suppliers (56 suppliers) to the shortlist of potential suppliers (20 suppliers). These suppliers are graded on certain KPIs that can be found on their websites, which are graded binary. The most important ones are: 'Capable of processing materials: (stainless) steel/aluminium/titanium', 'Fully automated machining stations (turning and milling)', 'Measurement equipment and tooling (quality control department) present', 'Capable of cylindrical or surface grinding' and 'Small machine possible <1000&1000&1000mm'. Secondly, the capacity, other remarks (like the website being only in Spanish) and the location of the facility are taken into account.

The categories with specific KPIs are determined in Section 4.2. Combining literature with the opinions of the stakeholders leads to eight categories, consisting of in total 30 KPIs. These categories are General, Quality, Logistics, Technology, Cost, Service, Sustainability and Resilience. The range in scores per KPI is determined in another feedback session with the stakeholders. In this way, suppliers can be graded objectively.

The weights for the categories and their specific KPIs are determined in Section 4.3. The consistency ratio of the categories and their KPIs has been calculated. All categories, except for the Service category, were found to be consistent. The pairwise comparison matrix of the Service category is adjusted slightly, according to the AHP method of Saaty (2004), in order to provide a consistent pairwise comparison matrix for all categories.

The range in scores of the KPIs is determined together with the relevant stakeholders, in order to grade KPIs objectively. Combining the categories and KPIs, with their specific determination in range of scores, and their weights, leads to the supplier selection tool in Table 12 in Section 4.3. When doing the field research and getting the data from the company visits, the supplier selection tool has been filled in individually by both a colleague graduate student and the researcher. Afterwards, the scores plus motivation are compared and consensus is reached, enabling the benchmarking of suppliers. This data validation process is described in Section 4.4. Chapter 5 discusses the results of the supplier visits.

5. Results

This chapter focuses on the results of the research. First, the scores of the potential suppliers are given in Section 5.1.1, then the Spanish supply chain of mechanical products which require cleanroom cleaning + packaging is described in Section 5.1.2. An overview of the potential supply chain in the Iberian Peninsula is given in Section 5.1.3. Section 5.2 illustrates the importance of the establishment of long-term partnerships for potential suppliers. Finally, Section 5.3 answers the following research question:

How can the solution method be implemented and evaluated?

5.1 Results of field research

Since the field research consisted of both supplier visits, as well as visits to a cleanroom and laboratory, this section is divided into two subsections, with its conclusion being given in the third subsection. The supplier visits are elaborated on in Section 5.1.1, whereas the cleanroom and laboratory are elaborated on in Section 5.1.2. The second subsection describes the whole supply chain in Spain of high precision mechanical products that require cleanroom activities. An overview of the potential supply chain in the Iberian Peninsula is given in Section 5.1.3.

5.1.1 Suppliers

The suppliers that have been visited are graded with the use of the supplier selection tool, which is developed in Chapter 0. At the beginning of a company visit, company presentations were given by both companies (so the supplier and VDL ETG Almelo). During the company visit, the production facilities have been visited and questions have been asked to the relevant people there. People on the work floor explained how they work, and illustrated for example how tools are calibrated and who is responsible for determining the correct machine settings when producing a mechanical part. After having visited the production facilities, the remainder of the questions were asked which were not yet answered in the earlier company presentations or during the production facilities visit. Some questions required some additional information and illustration. As a result, these questions were posed via email after the company visit. When all information was gathered, a supplier could receive a final score. The findings of all the suppliers can be found in Table 31, Table 32, Table 33, Table 34, Table 35, Table 36, Table 37, Table 38, Table 39 and Table 40 in Appendix F.

To summarize the findings, Table 13 is given below. In here, the absolute scores of the categories can be seen. The last row gives the final score per supplier. The best scoring supplier is Supplier G (score 4.51), after that Supplier J (score 4.22) and the third best supplier is Supplier C (score 4.09). Supplier F (score 4.06) is close to Supplier C, this is caused by the high potential of Supplier F due to its growth plans. Since Supplier F is in the middle of a moving process of one facility to the other, they are not ready yet to be a consistent supplier of VDL ETG Almelo. When their moving process is finished, they could be. For this reason, the focus is laid on the top three of potential suppliers. They are elaborated on below. Supplier D has received a significantly lower score, because this supplier apparently has a different focus area than expected. The focus area of Supplier D is investment casting and metal injection moulding. They also have a machining department, but this is only used for the finishing of the parts made by these processes. Supplier A, Supplier H and Supplier I did not respond to the questions on the email anymore, which is why they have received scores of 1 on KPIs that had not been graded yet and for which extra information was required. For this reason, these companies score quite low as well.

Table 13: Absolute scores categories KPIs

			Supplier									
Category of KPIs	Weight	Maximum	Supplier G	Supplier J	Supplier C	Supplier F	Supplier E	Supplier B	Supplier A	Supplier I	Supplier H	Supplier D
GENERAL	15.81%	0.79	0.67	0.63	0.72	0.65	0.58	0.49	0.65	0.61	0.38	0.32
QUALITY	24.48%	1.22	1.22	1.22	1.14	1.06	1.01	1.05	0.75	0.85	0.78	0.77
LOGISTICS	17.46%	0.87	0.79	0.59	0.74	0.67	0.71	0.65	0.54	0.29	0.46	0.17
TECHNOLOGY	17.00%	0.85	0.69	0.59	0.54	0.49	0.44	0.52	0.56	0.40	0.43	0.39
COST	7.65%	0.38	0.38	0.38	0.23	0.38	0.38	0.08	0.08	0.08	0.08	0.08
SERVICE	9.74%	0.49	0.49	0.49	0.41	0.45	0.43	0.41	0.19	0.31	0.25	0.29
SUSTAINABILITY	3.28%	0.16	0.07	0.10	0.10	0.16	0.10	0.16	0.07	0.03	0.07	0.10
RESILIENCE	4.58%	0.23	0.20	0.22	0.21	0.20	0.22	0.18	0.21	0.15	0.19	0.13
Totals	100.00%	5.00	4.51	4.22	4.09	4.06	3.88	3.55	3.06	2.71	2.63	2.24

Since each category has a different weight, the relative scores of the categories are given in Table 14 below. This gives a better indication of the performance of a supplier in terms of the categories, relative to the maximum possible score per category. Suppliers can also be compared more clearly in this way.

Table 14: Relative scores categories KPIs

			Supplier									
Category of KPIs	Weight	Maximum	Supplier G	Supplier J	Supplier C	Supplier F	Supplier E	Supplier B	Supplier A	Supplier I	Supplier H	Supplier D
GENERAL	15.81%	0.79	84.26%	80.24%	90.55%	81.83%	73.40%	62.59%	82.45%	76.68%	47.97%	40.62%
QUALITY	24.48%	1.22	100.00%	100.00%	93.20%	86.58%	82.89%	85.86%	61.68%	69.71%	63.45%	62.75%
LOGISTICS	17.46%	0.87	90.74%	67.30%	85.13%	76.56%	81.48%	74.10%	62.38%	33.15%	53.12%	20.00%
TECHNOLOGY	17.00%	0.85	81.25%	68.91%	63.46%	57.56%	52.29%	60.96%	66.17%	46.78%	51.06%	45.42%
COST	7.65%	0.38	100.00%	100.00%	60.00%	100.00%	100.00%	20.00%	20.00%	20.00%	20.00%	20.00%
SERVICE	9.74%	0.49	100.00%	100.00%	84.85%	92.42%	88.62%	84.85%	38.95%	62.73%	50.30%	58.92%
SUSTAINABILITY	3.28%	0.16	40.00%	60.00%	60.00%	100.00%	60.00%	100.00%	40.00%	20.00%	40.00%	60.00%
RESILIENCE	4.58%	0.23	86.85%	94.98%	89.79%	86.85%	94.98%	80.42%	91.87%	65.40%	84.76%	57.45%
Totals	100.00%	5.00	90.14%	84.34%	81.72%	81.20%	77.61%	70.97%	61.12%	54.22%	52.69%	44.87%

To illustrate how well suppliers perform relatively with regards to the categories of KPIs, Figure 19 is given below. Here, it can be seen how well suppliers perform compared to each other, per category.

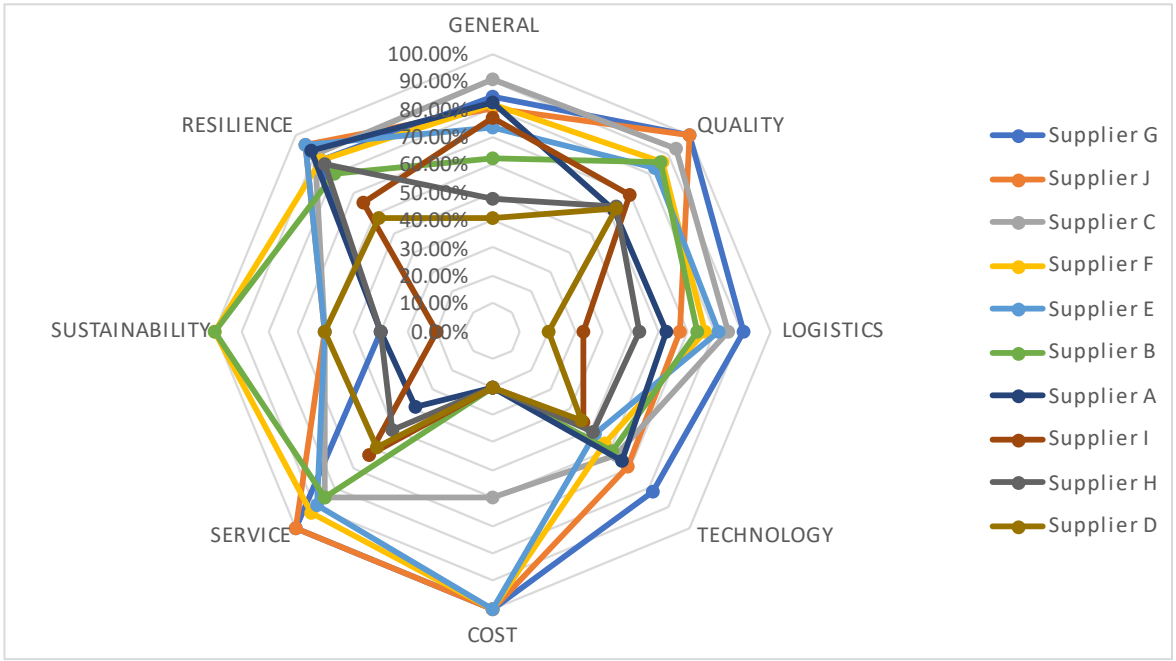


Figure 19: Spider chart relative scores

It can be seen that Supplier G scores the highest on almost all categories, except for sustainability and resilience. Since these categories are not found to be particularly important according to the stakeholders of the Projects department, this does not influence the score of Supplier G significantly.

What is also interesting, is that at least one out of the ten suppliers almost reaches the maximum score per category, except for 'Technology', where the maximum acquired score of all suppliers 'only' is around 80%. Only Supplier G scores relatively high on this category compared to the other suppliers, with the other suppliers scoring almost 20% less. This emphasises the technological competences of Supplier G (next to the other competences of Supplier G of course). Figure 20 provides the spider charts of the suppliers, per category. The charts provide a clear insight into suppliers performing quite differently on the categories Logistics, Cost, Service and Sustainability, whereas the other categories more or less show a coherent circle (compared to the odd shapes).

Figure 20: Overview relative scores suppliers per category

To illustrate why Supplier G, Supplier J and Supplier C have received such high scores, the main findings from the visits, together with the machine lists and pictures of example products, are illustrated in Appendix G. Since the argumentation for each comment is given in Appendix G, the focus here is laid on the most important aspects and they are thus summarised shortly.

Supplier G, Supplier J and Supplier C are all capable of high precision machining. They have Japanese machines that are top of the class, with high accuracy. Technical drawings of example products of VDL ETG Almelo have been shown to them and these suppliers all mentioned that they are capable of producing these products (of which some have difficult mechanical requirements). For Supplier G, the accuracy of their machining is up to five microns, calibration is up to two microns. For Supplier J, the accuracy of turning is up to three microns, for milling five microns. For Supplier C, the accuracy of milling is up to four microns, for the turning machines this is eight microns. Supplier G has ISO class 8 cleanrooms in house, whereas Supplier J has space available for a cleanroom, which they want to have operational in 2025. All three suppliers have experience in relevant comparable sectors, like medical and aerospace. Also, small batch sizes are possible. Next, shoebox sized products are their focus area. Capacity is available at all suppliers, in terms of planned capacity at machines, available manpower and space to grow.

5.1.2 Cleanroom and laboratory

Cleaning company A is a cleanroom partner of suppliers that have been visited. This company is also in contact with VDL ETG Eindhoven, which is a sister company of VDL ETG Almelo. In Spain, a cleanroom is often called a white room due to the lack of certification (OnePointe Solutions, 2023).

This cleanroom partner has been visited in order to see the cleaning process in Spain and to understand how the supply chain regarding cleaning and packaging of mechanical products functions. Also, its cleanliness, processes and protocols are taken into account regarding the requirements from VDL ETG Almelo. Figure 21, Figure 22 and Figure 23 below illustrate the cleanroom present and the cleaning system that is located in the cleanroom.

When products arrive at the cleanroom company to be treated, first they are cleaned by degreasing of contaminants in metal surface parts and components of all kinds. Secondly, they are cleaned by the water-based precision ultrasonic cleaning system which can be seen in Figure 21. Products are placed into metallic baskets (which can be seen in the front in Figure 21). These baskets are then placed into the machine where multiple filters are present. These filters are selected according to the requirements of the customer. For example, if a customer requires a very thorough cleaning process, the most precise filters are placed in the machine. The baskets with products pass through three water baths with filters. After having received treatment in this machine, products are dried and packaged in the cleanroom which can be seen in Figure 23. The recognizable pink bags are used for this. The products are also vacuumed in here. Also, the company is certified according to the ISO 9001:2015 standard.

Figure 21: Water-based precision ultrasonic cleaning system

Figure 22: Cleanroom

Figure 23: Packaging in cleanroom

During the visit, it became clear that this cleanroom partner is not officially certified regarding the ISO norms for cleanliness. Apparently, the system functions differently in Spain compared to the Netherlands. The cleanroom partner indicated that a laboratory exists in Barcelona (in Spain) that verifies if the cleaning process has been executed correctly by cleaning companies and thus if not too much (large) particles are present on the cleaned products. The name of this laboratory is Laboratory A. This laboratory is also visited by the researchers and is elaborated on here.

In order to certify cleaning, Laboratory A has a laboratory with a clean room accredited according to ISO 14644 – Class 8, with independent areas to carry out the extraction and analysis processes of the filters according to VDA 19.1 / ISO 16232. Since the certification of ISO Class 7 is expensive and not required by their customers, they do not have this certification officially. Still, they work according to the requirements of ISO Class 7. In this way, products cannot be contaminated internally at Laboratory A, thus in case a product is contaminated, it must have happened at the external company. In addition to gravimetric and particle counting/classification analysis performed by light microscopy, the laboratory is equipped with an EDX SEM electron microscope. This equipment allows the analysis of the chemical composition of the particles, being especially useful to establish the origin of the contamination of the analysed components. This step is mostly executed if the product cleanliness is declined in the first test. The results of the second test can help to improve a specific step in the production process in terms of cleanliness and contamination. For VDL ETG Almelo, this certainly is a useful piece of equipment for a laboratory to possess.

Laboratory A is an official licensee of VDA QMC since 2014 and is the only official trainer in the VDA 19.1 and VDA 19.2 standards in Spain. Laboratory A has been asked if Cleaning company A generally meets all cleaning requirements and this has been confirmed by Laboratory A. Laboratory A has stated that Cleaning company A is the most capable cleaning company in Spain that they know. Since Laboratory A is the only official credited company in Spain for this process, they are essential for the potential global supply chain of mechanical products in Spain.

5.1.3 Overview potential supply chain Iberian Peninsula

All relevant companies related to MEC-02 products in the Iberian Peninsula are illustrated in the map in Figure 24 below. Currently, there is one supplier of the MEC-02 products commodity, located in Lisbon, Portugal (blue circle). Based on the outcome of the analysis, three suppliers are advised to cooperate with in this research (red circles). Next, Supplier F and Supplier K (yellow circle) are suppliers which have potential in the future. Supplier F has potential, because they have all relevant machines and quality control systems, but they are currently in the process of merging facilities. Supplier K has potential, because it seems that they are capable of producing high precision parts, despite the researchers not being able to visit them due to a tight schedule. The cleanroom (purple circle) is located in Basque Country, with the laboratory in Barcelona (green circle) checking products of some production batches to verify if the cleaning process has been executed as required.

As can be seen in the map, the location of the cleanroom is positioned relatively close to most of the companies in the Iberian Peninsula. Cleaning company A has capacity left and is open to becoming a main cleaning partner for suppliers that deliver to VDL ETG Almelo. Since the cleanroom has a favourable location, the lead time can be reduced in case of rejects. Visited suppliers are willing to take responsibility of the process regarding cleaning of the products. During the company visits, it became clear that an extensive cluster of facilitated surface treatment activities is present in Basque Country. Products that require surface treatment and cleaning in a cleanroom can thus be accommodated in this combined cluster.

A rough calculation of 20% of potential spend at the three advised suppliers combined leads to a yearly spend of €4.62 million, given the current annual turnover figures.

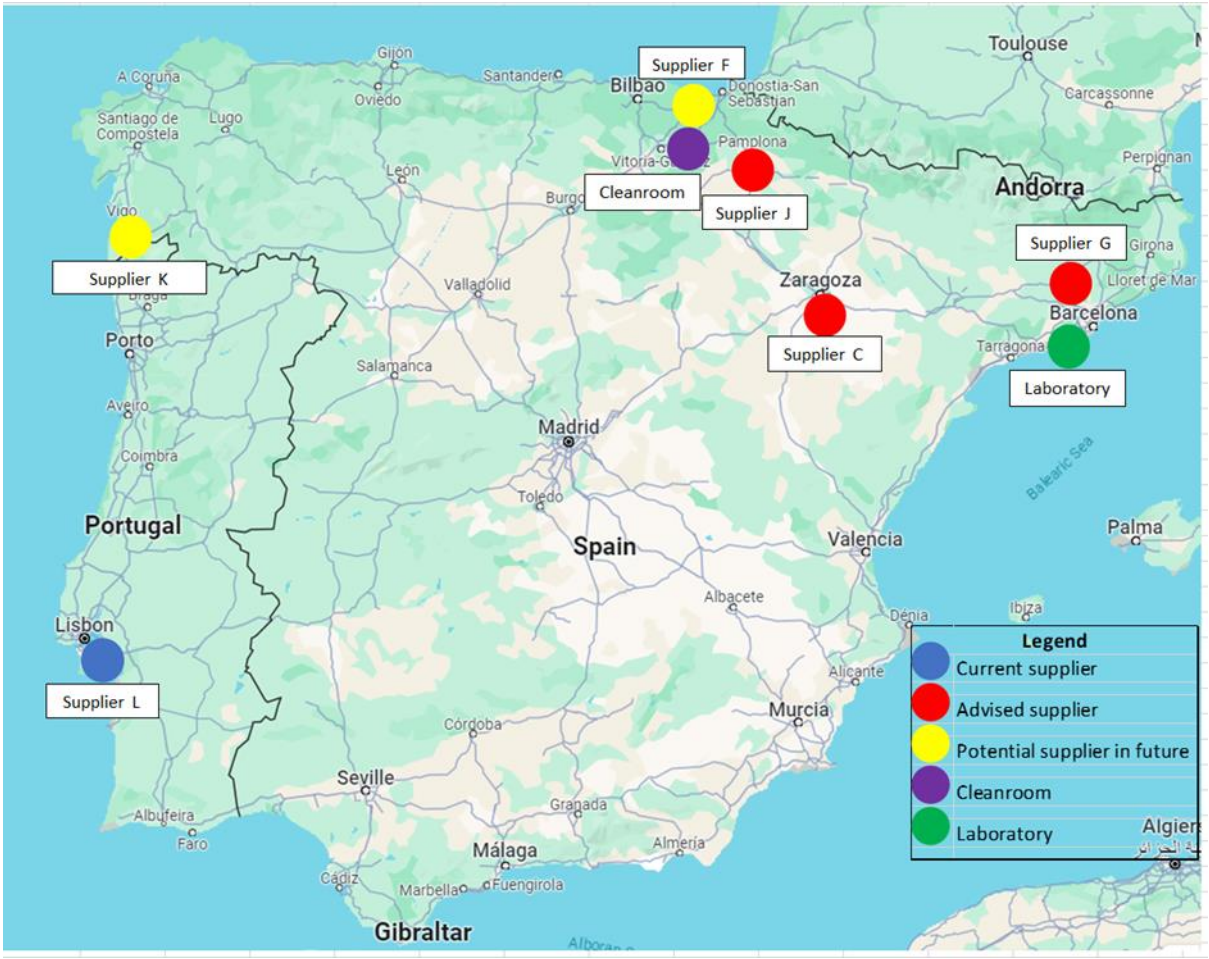


Figure 24: Partners in the supply chain on the Iberian Peninsula

5.2 Establishment of long-term partnerships

During the interviews with the suppliers, the question was posed what the supplier needs from VDL ETG Almelo and how they see a potential cooperation. What is interesting, is that almost all suppliers gave the same answer. Summarised, it entails the focus on a partnership, not a traditional buyer-supplier relationship. They want a win-win relationship that lasts for at least a longer period of time. The suppliers that have been around for some time have partnerships with their customers that last already for more than 40 to 50 years. To achieve this long-term partnership, the suppliers want to start slowly. In this way, they can get acquainted with the requirements of VDL ETG Almelo and get to know each other. VDL ETG Almelo has the same approach to starting a partnership (*Purchasing Manager Projects Department*, 2023).

When the basis is laid for the partnership, and VDL ETG Almelo and the supplier are on the same page with regards to, for instance, technical requirements, the focus is laid on extending the partnership to a stable partnership. Most suppliers do not want to rely too much on one customer (as does VDL ETG Almelo vice versa), so the growth can be realised to a level of approximately 20% of the supplier's yearly turnover. However, the supplier can grow with the growth plans of VDL ETG Almelo, as capacity is available at suppliers. This is both in terms of planned capacity at machines, as well as the available space to realise more machines and/or cleanroom facilities.

It is important for VDL ETG Almelo to realise how they see potential suppliers of the MEC-02 commodity. For this reason, the Kraljic matrix of Kraljic (1983) is given in Figure 25 below. According to the Purchasing Manager of the Projects department, the strategic importance is high. This is not caused by the strategic importance of one part, but by the difficulty and number of products in the package of MEC-02 commodity products, leading to a high (financial) volume purchased. For this commodity, the supply risk is low. As can be seen already during the company visits, multiple suitable and capable suppliers have been found in the area that has been visited. Probably, more suitable suppliers are available, but their existence is (still) unknown. This leads to the leverage categories in the Kraljic matrix, meaning the exploitation of full purchasing power at suppliers by VDL ETG Almelo.

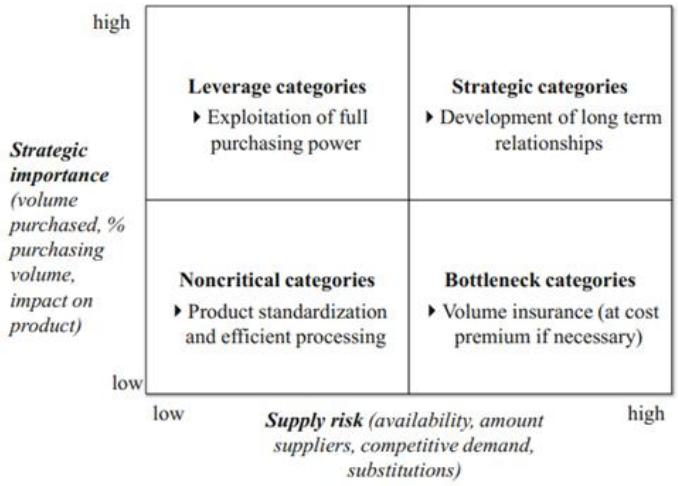


Figure 25: Kraljic matrix
(Source: (Kraljic, 1983))

To illustrate how the potential suppliers see VDL ETG Almelo as a potential customer, the Dutch Windmill model is given in Figure 26 below. In here, the purchaser-seller interdependence can be analysed. The potential suppliers that responded well and on time see VDL ETG Almelo as an essential sales item (Core) when the partnership is stable. This can be illustrated by the description just given concerning the desire for long-term partnerships. According to the matrix in Figure 26, this is a sound position in which the own profit of VDL ETG Almelo can be improved. This confirms that VDL ETG Almelo indeed is in an advantageous position in the market. The nuisance items in the top left corner can be the three suppliers that do not respond anymore after the company visits, where there is a mismatch apparently. As a result, the supplier is changed (or in this case, not selected for a partnership).

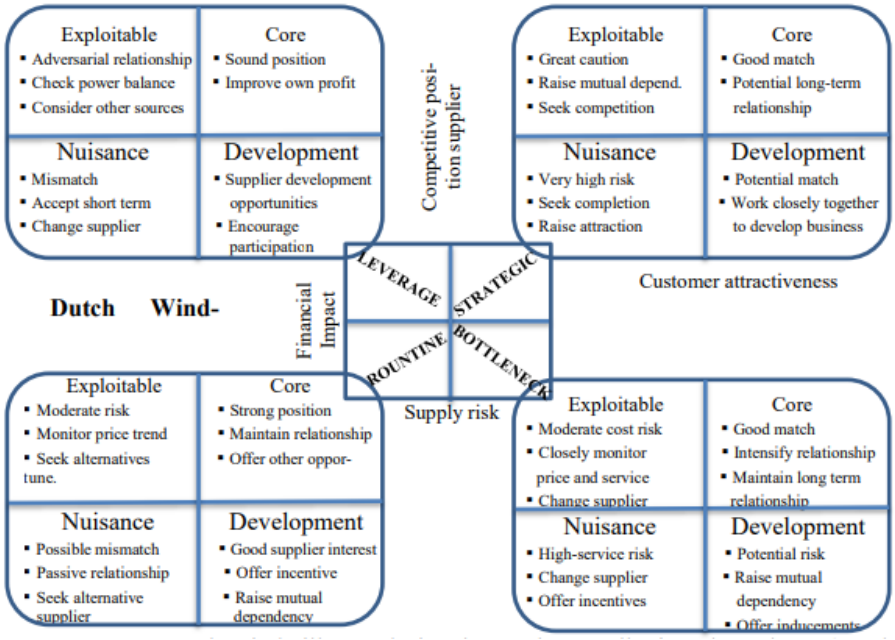


Figure 26: Dutch Windmill model
(Source: (Van Weele, 2018))

5.3 Conclusion

The results of the research are given in this chapter. Section 5.1.1 gives the absolute and relative scores of the suppliers. The top three of the suppliers are Supplier G (score 4.51), Supplier J (4.22) and Supplier C (4.09). The maximum score to be acquired is 5.00. Supplier F also scores high with a score of 4.06. Since this company is in the middle of a merger process from two facility locations into one, they are not ready now to do business with VDL ETG Almelo. However, Supplier F could be ready after this merger. Supplier D has received a significantly lower score, because this supplier apparently has a different focus area than expected, which is investment casting and metal injection moulding. Supplier A, Supplier H and Supplier I did not respond accordingly to the questions on the email anymore, which is why they have received scores of 1 on KPIs that had not been graded yet and for which extra information was required. For this reason, these companies score quite low as well. To illustrate how well suppliers perform relatively with regards to the categories of KPIs, Figure 19 is given in Section 5.1.1. Here, it can be seen how well suppliers perform compared to each other.

Supplier G scores the highest on almost all categories, except for Sustainability and Resilience. Since these categories are not found to be particularly important according to the stakeholders of the Projects department, this does not influence the score of Supplier G significantly. Furthermore, only Supplier G scores relatively high on the category Technology, compared to the other suppliers, with the other suppliers scoring almost 20% less. This emphasises the technological competences of Supplier G.

Supplier G, Supplier J and Supplier C are all capable of high precision machining, because they have Japanese machines that are top of the class, with high accuracy. Examples of technical product drawings containing difficult mechanical requirements have been shown to them and these suppliers all mentioned that they are capable of producing these products. Supplier G has ISO class 8 cleanrooms in house, whereas Supplier J has space available for a cleanroom, which they want to have operational in 2025. All three suppliers have experience in relevant comparable sectors, like medical and

aerospace. Also, small batch sizes of shoebox sized products are possible. Capacity is available at all suppliers, in terms of planned capacity at machines, available manpower and space to grow.

The cleanroom of Cleaning company A and the laboratory of Laboratory A to check the cleaning process have been visited, with their capabilities illustrated in Section 5.1.2. Cleaning company A uses a water-based precision ultrasonic cleaning system to clean mechanical products. Cleaning company A is not officially credited according to the ISO Class 7 norms, but to the ISO Class 8 norms (Class 8 has less requirements than Class 7). Laboratory A verifies if the cleaning process has been executed correctly by cleaning companies and thus if not too much (large) particles are present on the cleaned products. Since the certification of ISO Class 7 is expensive and not required by the customers of Laboratory A, they do not have this certification officially. Still, they work according to the requirements of ISO Class 7, to exclude possible contamination of products at Laboratory A.

Figure 24 in Section 5.1.3 illustrates the potential supply chain of VDL ETG Almelo in the Iberian Peninsula, with the locations of all relevant companies. 20% of the combined yearly turnover of the three advised suppliers account for €4.62 million yearly spend now, given the current figures.

During the company visits, all potential suppliers described what they would require from VDL ETG Almelo as a new customer and how they see a potential cooperation. The findings are summarised in Section 5.2. The recurring aspect is the establishment of a long-term win-win relationship, which is to be started slowly. Section 5.2 also gives the position of VDL ETG Almelo with regards to the Dutch Windmill model. VDL ETG Almelo is in a sound position, according to the model of Van Weele (2018) in which the own profit can be improved. This is a relevant aspect to be kept in mind when consolidating the partnerships with the potential suppliers.

6. Conclusions and recommendations

Within this thesis, a supplier selection tool has been developed specifically for visits to potential suppliers and it has been applied during the field research in the Iberian Peninsula. Potential suppliers, a cleanroom and a laboratory have been visited in Spain. Section 6.1 gives the conclusions of the research. The recommendations are given in Section 6.2. The theoretical and practical contributions of the research are described in Section 6.3. Section 6.4 provides the limitations of the research and recommendations for future research are given in Section 6.5.

6.1 Conclusions

The main research question to be answered in this thesis is:

How can VDL ETG Almelo make a well thought decision on which suppliers to select for sourcing mechanical products in the mechanisation market segment from the Iberian Peninsula?

Various steps have been taken to get to the answer to this question. A supplier selection tool has been developed for first time company visits, with feedback from the relevant stakeholders of the Projects department. Findings from literature, combined with feedback sessions with the stakeholders, have determined the eight categories of KPIs in the tool, together with the underlying 30 KPIs in total. These categories are General, Quality, Logistics, Technology, Cost, Service, Sustainability and Resilience. The range in scores of the KPIs has been determined in a feedback session with the relevant stakeholders, in order to grade the suppliers objectively. The weights of these KPIs have been determined by using pairwise comparisons according to the AHP method, executed by the four employees with a tactical purchasing function at the Projects department. The consistency ratios of the pairwise comparisons matrices have been calculated, to verify if the pairwise comparison process has been executed accordingly. The supplier selection tool has been verified by two reference supplier visits in the Netherlands. Combining the categories and the KPIs, the determination of the range in scores of the KPIs and the weights of the KPIs, leads to the complete supplier selection tool can be found in the Management summary. The supplier selection tool gives insight into the scores and functioning of suppliers, per category. This indicates which suppliers to select, based on the total score and the score per specific category.

First, a longlist of 56 suppliers has been developed. Of this list, 20 suppliers have been selected for the shortlist, which have been contacted in the research. In total, ten suppliers, a clean room and a laboratory have been visited by a colleague graduation student and the researcher. These suppliers have been graded with the use of the supplier selection tool. Both people filled in the supplier selection tool, after which the results were discussed together and consensus was to be reached. This method also enabled the benchmarking of suppliers.

The top three consists of the following suppliers: Supplier G (score 4.51), Supplier J (4.22) and Supplier C (4.09). The maximum score that could have been acquired is 5.00. Supplier F (score 4.06) has potential but is currently in a facility moving process and does not have all focus on new customers at the moment. Supplier D has received a significantly lower score, because this supplier apparently has a different focus area than expected, which is investment casting and metal injection moulding. Supplier A, Supplier H and Supplier I did not respond (sufficiently well) to questions that have been posed to them via email after the company visits. KPIs that did not have a grade yet, received a grade of 1. For this reason, these three suppliers score quite poorly. Figure 19 and Figure 20 in Section 5.1.1 provide spider charts to illustrate the functioning of suppliers per category, helping to make thoughtful decisions on which suppliers to select.

Supplier G, Supplier J and Supplier C are all capable of high precision machining, because they have Japanese machines that are top of the class, with high accuracy. Examples of technical product drawings containing difficult mechanical requirements have been shown to them and these suppliers all mentioned that they are capable of producing these products. Supplier G has ISO class 8 cleanrooms in house, whereas Supplier J has space available for a cleanroom, which they want to have operational in 2025. All three suppliers have experience in relevant comparable sectors, like medical and aerospace. Also, small batch sizes of shoebox sized products are possible. Capacity is available at all suppliers, in terms of planned capacity at machines, available manpower and space to grow. The filled in supplier selection tools per supplier can be found in Appendix F, providing more information.

20% of the combined yearly turnover of the three advised suppliers accounts for €4.62 million yearly spend now, given the current figures. However, these suppliers can grow with the growth plans of VDL ETG Almelo, as capacity is available at suppliers. This is both in terms of planned capacity at machines, as well as the available space to realise more machines and/or cleanroom facilities. These figures, combined with the yearly spend of the already existing supplier of MEC-02 products in Portugal, would lead to a yearly spend of €5.52 million at the moment. However, this does not take into account the increase of the total yearly turnover of suppliers, if VDL ETG Almelo is added to their customer base. Since these suppliers have capacity left, have space left for investing in new machines and cleanroom facilities, are very eager to do business with VDL ETG Almelo and have manpower available, it is expected that their yearly turnover will increase as well. Also, the cleanroom of Cleaning company A is willing to investigate the cleanliness requirements of VDL ETG Almelo and to become the main cleanroom facility in the Iberian Peninsula. This company also has capacity left over and is willing to do business. The capabilities of the cleanroom in the Basque Country and the laboratory in Barcelona seem to be sufficient enough to cope with the requirements of VDL ETG Almelo, according to stakeholders of the Projects department. When the foundation for the supply chain in the Iberian Peninsula is developed, the required growth of VDL ETG Almelo can be realised:

Purchasing value of €10-15 million yearly in Iberian Peninsula is targeted, with current value being €0.9 million

Assuming that the three Spanish suppliers and the Portuguese supplier increase their yearly turnover with 20%, due to the increase in total demand by VDL ETG Almelo, and taking 20% of the total yearly turnover of suppliers, a spend of €6.62 million can be realised. Adding Supplier F in the supply chain in the future, brings the total spend (with the same method) to €9.30 million. This does not take into account the potential of other suppliers in the Iberian Peninsula. The described supply chain in the Iberian Peninsula does have potential to reach enough purchasing value, leading to a steady supply chain of MEC-02 products in the Iberian Peninsula and fulfilling the increase in demand by 2027.

The literature review has illustrated advantages of diversifying the supplier base nearby. When expanding the supplier base, it is beneficial to acquire preferred customer status with a supplier if the supplier offers the customer preferential resource allocation, for example better access to its valuable products or services than it offers to other customers (Schiele, 2019). Introducing new suppliers into the supply base, even if not awarded with a contract, may lead to better offers by the established bidders (Gnyawali & Madhavan, 2001). The forward use of suppliers from cost-competitive countries has been driven in this research. This can potentially lead to cost savings for the organisation and thus enhance profitability (Hesping & Schiele, 2016). With the establishment of a cluster of required activities in the production process in the Iberian Peninsula, forward localisation is driven, thereby expanding capacities near place of demand. This approach can reduce lead times, lower transportation costs and enhance the supply chain responsiveness (Hesping & Schiele, 2016).

Setting up a supplier base in the Iberian Peninsula combines various resilience strategies, when taking the framework of Pedersen and Jensen (2023) into account. These are diversifying the locations of production in order not to get overexposed to one location (1), establishment of multiple suppliers (2), establishment of back-up sites (3) and local production activities rather than cross border trade (4). The expected impact of these strategies is reduced exposure to local risks; increased flexibility across locations (1), increasing flexibility across suppliers; reducing lock-in and dependency on one supplier (2), establishment of buffer to safeguard against supply swings and supply disruption (3) and the ability to circumvent trade barriers by operating within 'trade walls' (4). The costs and disadvantages of these strategies are increased management and coordination costs; differences in output and quality standards (1), potential loss of benefits gained from close collaboration with single suppliers (2), tied-up capital due to excess capacity (3) and establishment costs can be significant; reduced economies of scale; fewer synergy effects from globally concentrated activities (4). This illustrates the 'steering of production' desire of the Purchasing Director, in which the global supply chain of VDL ETG Almelo becomes more resilient.

6.2 Recommendations

Various recommendations are given based on this research. It is advisable to research the exact requirements regarding cleanliness for Cleaning company A and Laboratory A. When this is clear and achieved, the supply chain for the Iberian Peninsula with Cleaning company A as the cleaner and Laboratory A as the controlling party can be developed. This is possible since capacity is available at all companies in the chain.

For future first time supplier visits related to the Projects department, it is advised to use the supplier selection tool that has been developed in this research. The procedure of data collection as executed by the colleague graduation student and the researcher, and described in Section 4.4, can be applied by employees of the Projects department. Data for filling in the supplier selection tool is gathered during the visit. If certain aspects for filling in the tool (giving integer scores ranging from 1-5) are unclear or absent during the visit, information about these aspects can acquired via email after the visit.

From this research, it followed that both VDL ETG Almelo and the visited suppliers are very eager open in establishing partnerships. Thus, it is advised to start with this on a short notice. Responsible employees can then be assigned to the three selected suppliers, who can also visit the suppliers to get to know them. During the visits, it became evident that this is highly appreciated in Spanish culture, as Spanish people are also open in getting to know work-related people personally. Next, it is wise to keep the relationship with Supplier F warm, as they have high potential in the near future. Also, it is advised to analyse the possibilities at Supplier K in Vigo (Spain).

VDL ETG Almelo has supplier selection process and supplier qualification process flowcharts in place, in order to incorporate potential suppliers into the supply chain. In this research, all steps up to step 90 in the supplier selection process, which leads to and includes step 30 in the supplier qualification process, are executed. This research stops at step 40 in the supplier qualification process, where the knowledge is transferred to the relevant stakeholders of the Projects department. It is recommended to continue the process at this step.

When the basis for the supply chain in the Iberian Peninsula is established, the advice is to slowly start the partnership with the suppliers. This means that a relatively low number of orders is placed at the suppliers, for which the First Article Inspection (FAI) process is carried out. When this is achieved and all parties are familiar with each other and each other's requirements, VDL ETG Almelo can use its position in the market well. This is a sound position in which the own profit can be improved.

6.3 Contribution

The theoretical contribution of the research is given in Section 6.3.1 and the practical contribution of the research is given in Section 6.3.2.

6.3.1 Theoretical contribution

In this research, a literature study has been conducted on supplier selection tools, relevant KPIs for these tools and ways to improve the resilience of a supply chain. Categories of KPIs for supplier selection and specific KPIs related to them are illustrated by Yücenur et al. (2011), Ishizaka (2014) and Sarkis and Talluri (2002). These are incorporated in the AHP supplier selection method, which is described by Sarkis and Talluri (2002), and Barbarosoglu and Yazgac (1997). The Supply Chain Resilience QuickScan (2023) of the research project 'Next Gen Resilience', described by Windesheim (2023) provided insight into relevant KPIs for the category 'Resilience'. Recovery time objectives (RTOs) applied by Company B (Company B, 2023) are incorporated in the 'Resilience' category in the tool as well.

The theoretical contribution implies the merger of different academic sources into one supplier selection tool, grounded by literature. Including resilience aspects into a supplier selection tool is not addressed in the literature (yet). Since the goal of the research is to enhance VDL ETG Almelo's global supply chain resilience by establishing a new supplier base, also previously addressed as the 'steering wheel of production desire' by the Purchasing Director of VDL ETG Almelo, this goal is taken into consideration when selecting new suppliers. Also, a supplier selection tool, which is designed specifically for first time supplier visits, has not been addressed in the literature.

Also, the Kraljic model of Kraljic (1983) and the Dutch Windmill model of Van Weele (2018) provide insights into the position of VDL ETG Almelo with respect to the potential suppliers. This can be used for determining how to approach the potential partnership and to determine which resources to invest in the partnership.

6.3.2 Practical contribution

This research is executed at VDL ETG Almelo, where the opinions of the stakeholders of the Projects department are taken into account to develop the supplier selection tool. With their input, theoretical categories of KPIs and specific KPIs are made measurable and applicable to the Projects department. The practical contribution to the company is the supplier selection tool which can be used by the Projects department for first time supplier visits, but also by other departments if some aspects (for example the dimensions of the products and batch sizes) are adapted slightly. VDL ETG Almelo already has a supplier selection tool in place, however this tool is not used because it is not specified for first time supplier visits and the range in scores for the KPIs is vague. With the new tool, VDL ETG Almelo can select more suppliers than the ones that are advised in this research. Next, it can be applied both in the Netherlands and abroad when current supplier bases are required to expand or when new supplier bases are needed for the 'steering desire'.

With the supplier selection tool, new capable and suitable suppliers are selected. VDL ETG Almelo needs these suppliers to solve the current problem of not being able to meet demand anymore (or meet demand with long lead times) and to be ready to cope with the expected double turnover value in 2027, compared to 2023.

A substantial portion of the data collection phase is done at potential suppliers, where the developed supplier selection tool is applied during the company visits. Pictures of machines and example products are gathered, which are of importance to the stakeholders. Since the colleague graduation student and the researcher have been in extensive contact with the potential suppliers (before and after the visits),

a feeling of understanding of the suppliers has been created, which is also of importance to the stakeholders. VDL ETG Almelo considers the practical contribution of the research to be high, as they are in need of extending the supplier base and they are incredibly eager to continue where the research stops. It is also expected that this is done almost immediately after the research has finished.

6.4 Limitations

The opinions of four stakeholders with a tactical purchasing function at the Projects department are taken into account. The weights of the KPIs could have been different if more people would have given their opinion, perhaps leading to different scores and different conclusions. If employees with another function (for example a strategic purchasing function) would have been taken into account as well, it is likely that the scores would have changed. This can be illustrated by the four tactical purchasers focusing less on costs, while this is one of the reasons why VDL ETG Almelo is willing to investigate the possibilities of a LCC in the Iberian Peninsula. However, this principle might be explained by the cost aspect not differentiating between the suppliers, as all suppliers are in the same LCC region.

The supplier selection tool is developed specifically for the Projects department. Other departments at VDL ETG Almelo cannot immediately use the developed tool, as the ranges of scores might differ (for example the dimensions of products) and the weights of the KPIs might differ (for example a difference in weight for the 'Logistics' category). Also, the selection of KPIs might have a different focus area compared to what other departments require. Since all input fields in the supplier selection tool are connected, changing values in the pairwise comparison matrix and thus changing the weights, can be accomplished easily.

The two reference suppliers have not been graded according to the developed supplier selection tool. It would have been relevant to see how the potential suppliers in the Iberian Peninsula would score compared to the existing reference suppliers in the Netherlands.

The principle of moving (a part of) production to the Iberian Peninsula is also because the Iberian Peninsula is seen as a LCC (*Purchasing Manager Projects Department*, 2023). LCC works best for repeating products, like the products of department 1 at VDL ETG Almelo. This is because of economies of scale and the constant flow of products, resulting in possibly back-up batches arriving earlier than delayed previous batches. This constant flow of products does not exist for the Projects department, as batches are mostly one-time only. It might be that the full potential of the Iberian Peninsula for the Projects department as a LCC is not reached in this way.

6.5 Future research

As described in Section 2.4, currently the suppliers in Malaysia are satisfied with the demand provided by VDL ETG Almelo, even given the low demand that is being given to them, with a large portion of their capacity being unused. The question is how long these Malaysian suppliers will remain loyal on the long term. It is recommended to research this, as the required capacity in the Iberian Peninsula would increase significantly if the whole Malaysian supplier base would fall away.

For future research, it is recommended to apply the same principle in setting up the supplier selection tool for the other departments of VDL ETG Almelo as well. The basis has been established for this and it has to be adapted slightly to function for other specific departments. For example, other departments produce in larger batch sizes or have larger products in terms of dimensions.

Since a large customer in the high-tech mechanical parts is located on the other side of the Pyrenees, it is expected that more relevant companies should be located across the border of the Iberian Peninsula with France, near Toulouse. It is recommended to research the possibilities in that area, as there should be more relevant companies.

Cleaning company A is not officially certified according to the ISO class 7 norms, as this is not required by their customers and the certificate is expensive. It has to be researched if this might be a risk, or that applying the correct cleaning procedures suffices.

References

Alsop, T. (2023). *Leading semiconductor foundries revenue share worldwide 2019-2022, by quarter.* Retrieved October 17, 2023, from https://www.statista.com/statistics/867223/worldwide-semiconductor-foundries-by-market-share/

Banaszyk, P. (2023). Reshoring and friendshoring as factors in changing the geography of international supply chains. *Engineering Management in Production and Services, 15*(4), 25-33.

Barbarosoglu, G., & Yazgac, T. (1997). An application of the analytic hierarchy process to the supplier selection problem. *Production and inventory management journal, 38*(1), 14.

Bhole, G. P., & Deshmukh, T. (2018). Multi-criteria decision making (MCDM) methods and its applications. *International Journal for Research in Applied Science & Engineering Technology (IJRASET), 6*(5), 899-915.

Bhutta, K. S., & Huq, F. (2002). Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches. *Supply Chain Management: an international journal, 7*(3), 126-135.

Casanova, R. (2023). Despite Short-Term Cyclical Downturn, Global Semiconductor Market's Long-Term Outlook is Strong. Retrieved February 8, 2023, from https://www.semiconductors.org/despite-short-term-cyclical-downturn-global-semiconductor-markets-long-term-outlook-is-strong/

Çelikbilek, Y., & Tüysüz, F. (2020). An in-depth review of theory of the TOPSIS method: An experimental analysis. *Journal of Management Analytics, 7*(2), 281-300.

Chan, H. K., Sun, X., & Chung, S.-H. (2019). When should fuzzy analytic hierarchy process be used instead of analytic hierarchy process? *Decision Support Systems, 125*, 113114.

Chand, S. (n.d.). *Purchasing: it's Meaning, Definition, Importance and Objectives | Material Management.* Retrieved October 9, 2023, from https://www.yourarticlelibrary.com/material-management/purchasing-its-meaning-definition-importance-and-objectives-material-management/27936

Christopher, M., & Towill, D. (2001). An integrated model for the design of agile supply chains. *International Journal of Physical Distribution & Logistics Management, 31*(4), 235-246.

Company B (Producer). (2023). Managing BSM system within your Supply Chain. [Powerpoint slides]

Crowe, D., & Rawdanowicz, Ł. (2023). *Risks and opportunities of reshaping global value chains.* Retrieved September 28, 2023, from https://www.oecd-ilibrary.org/content/paper/f758afe8-en

Deutsch, J. (2023). *EU Enacts €43 Billion Chips Act in Bid to Boost Production.* Retrieved September 20, 2023, from https://www.bloomberg.com/news/articles/2023-07-25/eu-enacts-43-billion-chips-act-in-bid-to-boost-production

Egaña, F. (2023). Head of mechanical engineering unit of Tekniker Technological Centre. Retrieved from https://www.tekniker.es/en

Ellerbeck, S. (2023). *What's the difference between 'friendshoring'and other global trade buzzwords?* Paper presented at the Geneva, World Economic Forum (WEF).

Ellram, L. M. (1995). Total cost of ownership: an analysis approach for purchasing. *International Journal of Physical Distribution & Logistics Management, 25*(8), 4-23.

European Commission. (2022). *European Chips Report.* Retrieved September 20, 2023, from https://single-market-economy.ec.europa.eu/industry/strategy/digital-transformation/european-chips-report_en#:~:text=Chip%20demand%20is%20expected%20to,increase%20in%20demand%20for%20wafers.

European commission. (2023). Commision delegated regualtion (EU) 2023/2772. Retrieved, from https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32023R2772

Fortuin, J. (Producer). (2018). Supply Base Management VDL ETG Almelo. [PowerPoint slides]

Gan, Z. L., Musa, S. N., & Yap, H. J. (2023). A Review of the High-Mix, Low-Volume Manufacturing Industry. *Applied Sciences, 13*(3), 1687.
Gnyawali, D. R., & Madhavan, R. (2001). Cooperative networks and competitive dynamics: A structural embeddedness perspective. *Academy of Management review, 26*(3), 431-445.
Handfield, R. B., Krause, D. R., Scannell, T. V., & Monczka, R. M. (2006). Avoid the pitfalls in supplier development. *Supply chains and total product systems: A reader, 58*, 25-44.
Heerkens, H., & Van Winden, A. (2017). *Solving Managerial Problems Systematically*: Noordhoff Uitgevers.
Hesping, F. H., & Schiele, H. (2016). Sourcing tactics to achieve cost savings: developing a formative method of measurement. *International journal of procurement management, 9*(4), 473-504.
Iqbal, M. (2023). *PROBABILITY AND IMPACT MATRIX : PMP/CAPM.* Retrieved September 30, 2023, from https://mudassiriqbal.net/probability-and-impact-matrix/#:~:text=A%20probability%20and%20impact%20matrix,to%20mitigate%20or%20manage%20them.
Ishizaka, A. (2014). Comparison of fuzzy logic, AHP, FAHP and hybrid fuzzy AHP for new supplier selection and its performance analysis. *International Journal of Integrated Supply Management, 9*(1-2), 1-22.
James, L. (2023, August 25). *The EU's plan to address the semiconductor shortage.* Retrieved September 18, 2023, from https://www.power-and-beyond.com/the-eus-plan-to-address-the-semiconductor-shortage-a-6af6b854d8430ad623bd8a1eabcc1154/#:~:text=The%20overall%20goal%20is%20to,the%20'Chips%20Joint%20Undertaking
Kraljic, P. (1983). HBR. *Harvard business review*.
Krause, D. R., Handfield, R. B., & Scannell, T. V. (1998). An empirical investigation of supplier development: reactive and strategic processes. *Journal of operations management, 17*(1), 39-58.
Li, C. (2013). Sourcing for supplier effort and competition: Design of the supply base and pricing mechanism. *Management Science, 59*(6), 1389-1406.
Liu, J., Ding, F. Y., & Lall, V. (2000). Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. *Supply Chain Management: an international journal, 5*(3), 143-150.
Maizland, L. (2023). *Why China-Taiwan Relations Are So Tense.* Retrieved September 20, 2023, from https://www.cfr.org/backgrounder/china-taiwan-relations-tension-us-policy-biden
Malagon, E. (2023, October 5, 2023) *University of the Basque Country*.
Michelman, P., & Sheffi, Y. (2007). Building a resilient supply chain. *Business Review*.
MIDA. (2023). Chinese investment in Malaysia will be 3 pct to 5 pct higher in 2023: Juwai IQI. Retrieved July 11, 2023, from https://www.mida.gov.my/mida-news/chinese-investment-in-malaysia-will-be-3-pct-to-5-pct-higher-in-2023-juwai-iqi/#:~:text=%E2%80%9CApprovals%20for%20inbound%20investments%20from,said%20in%20a%20statement%20today.
Moody's. (2023). Retrieved October 19, 2023, from https://www.moodys.com/
Müller-Dauppert, B. (2016). Production nearshoring in Europe and their consequences to the supply chain. *Gazdaság és Társadalom, 8*(2), 5-25.
Naseer, S., Khalid, S., Parveen, S., Abbass, K., Song, H., & Achim, M. V. (2023). COVID-19 outbreak: Impact on global economy. *Frontiers in public health, 10*, 1009393.
Nevi PMI. (2023). Nevi PMI Productiesector Nederland. *ABN AMRO*.
Nguyen, H., Pham, A. V., Pham, M. D. M., & Pham, M. H. (2023). Business resilience: lessons from government responses to the global COVID-19 crisis. *International Business Review, 32*(5), 102166.
Olivares-Aguila, J., & ElMaraghy, W. (2021). System dynamics modelling for supply chain disruptions. *International Journal of Production Research, 59*(6), 1757-1775.

OnePointe Solutions. (2023). White Rooms vs Clean Rooms in Manufacturing. Retrieved June 24, 2022, from https://www.onepointesolutions.com/blog/white-rooms-vs-clean-rooms-in-manufacturing/

Oropeza, J. C. (2023). *The Implications of the EU Carbon Border Adjustment Mechanism on the Environment and Global Trade.* Retrieved October 5, 2023, from https://earth.org/the-implications-of-the-eu-carbon-border-adjustment-mechanism-and-for-the-environment-and-global-trade/#:~:text=The%20CBAM%27s%20purpose%20is%20to,to%20avoid%20higher%20carbon%20costs

Özdağoğlu, A., & Özdağoğlu, G. (2007). Comparison of AHP and fuzzy AHP for the multi-criteria decision making processes with linguistic evaluations. *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi, 6*(11), 65-85.

Pedersen, T., & Jensen, P. D. Ø. (2023). Resilience: Easier Said than Done–But it Can be Done! *AIB Insights*.

Piatanesi, B., & Arauzo-Carod, J. M. (2019). Backshoring and nearshoring: An overview. *Growth and Change, 50*(3), 806-823.

Purchasing Director. (2023).

Purchasing Manager Projects Department. (2023).

Purchasing Manager Department 1. (2023).

Pyo, D.-J. (2021). Does geopolitical risk matter? Evidence from South Korea. *Defence and Peace Economics, 32*(1), 87-106.

Ramanathan, R. (2007). Supplier selection problem: integrating DEA with the approaches of total cost of ownership and AHP. *Supply Chain Management: an international journal, 12*(4), 258-261.

Reliance. (2011). Hannover Messe 2011 Review. Retrieved, from https://www.reliance-scada.com/en/news-and-events/events/hannover-messe-2011-review

Saaty, T. L. (1996). *Decision making with dependence and feedback: The analytic network process* (Vol. 4922): RWS publications Pittsburgh.

Saaty, T. L. (2004). Decision making—the analytic hierarchy and network processes (AHP/ANP). *Journal of systems science and systems engineering, 13*, 1-35.

Sarkis, J., & Talluri, S. (2002). A model for strategic supplier selection. *Journal of supply chain management, 38*(4), 18-28.

Schiele, H. (2012). Accessing supplier innovation by being their preferred customer. *Research-Technology Management, 55*(1), 44-50.

Schiele, H. (2019). Purchasing and Supply Management. In *Operations, Logistics and Supply Chain Management* (pp. Chapter 4).

Shein, E. (2023). *Global Chip Shortage: Everything You Need to Know.* Retrieved September 18, 2023, from https://www.techrepublic.com/article/global-chip-shortage-cheat-sheet/

Sourcemap. (2018). The platform for Open Supply Chains. Retrieved, from https://open.sourcemap.com/

Steinle, C., & Schiele, H. (2008). Limits to global sourcing?: Strategic consequences of dependency on international suppliers: Cluster theory, resource-based view and case studies. *Journal of purchasing and supply management, 14*(1), 3-14.

Supply Chain Engineer. (2023).

Supply Chain Resilience QuickScan. (2023). Retrieved, from https://resiliencescan.org/?l=nl

Swaminathan, J. M., & Shanthikumar, J. G. (1999). Supplier diversification: Effect of discrete demand. *Operations research letters, 24*(5), 213-221.

Tang, S. Y., & Kouvelis, P. (2011). Supplier diversification strategies in the presence of yield uncertainty and buyer competition. *Manufacturing & service operations management, 13*(4), 439-451.

Taxation and Customs Union. (n.d.). *Carbon Border Adjustment Mechanism.* Retrieved October 10, 2023, from https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

Thorbecke, C. (Producer). (2022). The US is spending billions to boost chip manufacturing. Will it be enough? Retrieved from https://edition.cnn.com/2022/10/18/tech/us-chip-manufacturing-semiconductors/index.html

Van Sloun, S. (2023). U.S. Investment in Semiconductor Manufacturing: Building the Talent Pipeline. Retrieved September 18, 2023, from https://www.cfr.org/blog/us-investment-semiconductor-manufacturing-building-talent-pipeline

Van Weele, A. (2018). *Purchasing and supply chain management*: UK. Cengage Learning EMEA.

VDL ETG. (n.d.). *Company information.* Retrieved September 12, 2023, from https://www.vdletg.com/nl/het-bedrijf/locaties/almelo/vdl-etg-almelo

VDL Groep. (n.d.). *Organization chart.* Retrieved October 20, 2023, from https://www.vdlgroep.com/nl/vdl-groep/management

Weber, C. A., & Ellram, L. M. (1993). Supplier selection using multi-objective programming: a decision support system approach. *International Journal of Physical Distribution & Logistics Management, 23*(2), 3-14.

Windesheim. (2023). Windesheim gaat door met onderzoek naar een veerkrachtige supply chain. Retrieved September 11, 2023, from https://www.windesheim.nl/nieuws/2023/september/veerkrachtige-supply-chain

Yücenur, G. N., Vayvay, Ö., & Demirel, N. Ç. (2011). Supplier selection problem in global supply chains by AHP and ANP approaches under fuzzy environment. *The International Journal of Advanced Manufacturing Technology, 56*, 823-833.

Zadeh, L. A. (1988). Fuzzy logic. *Computer, 21*(4), 83-93.

Appendix A

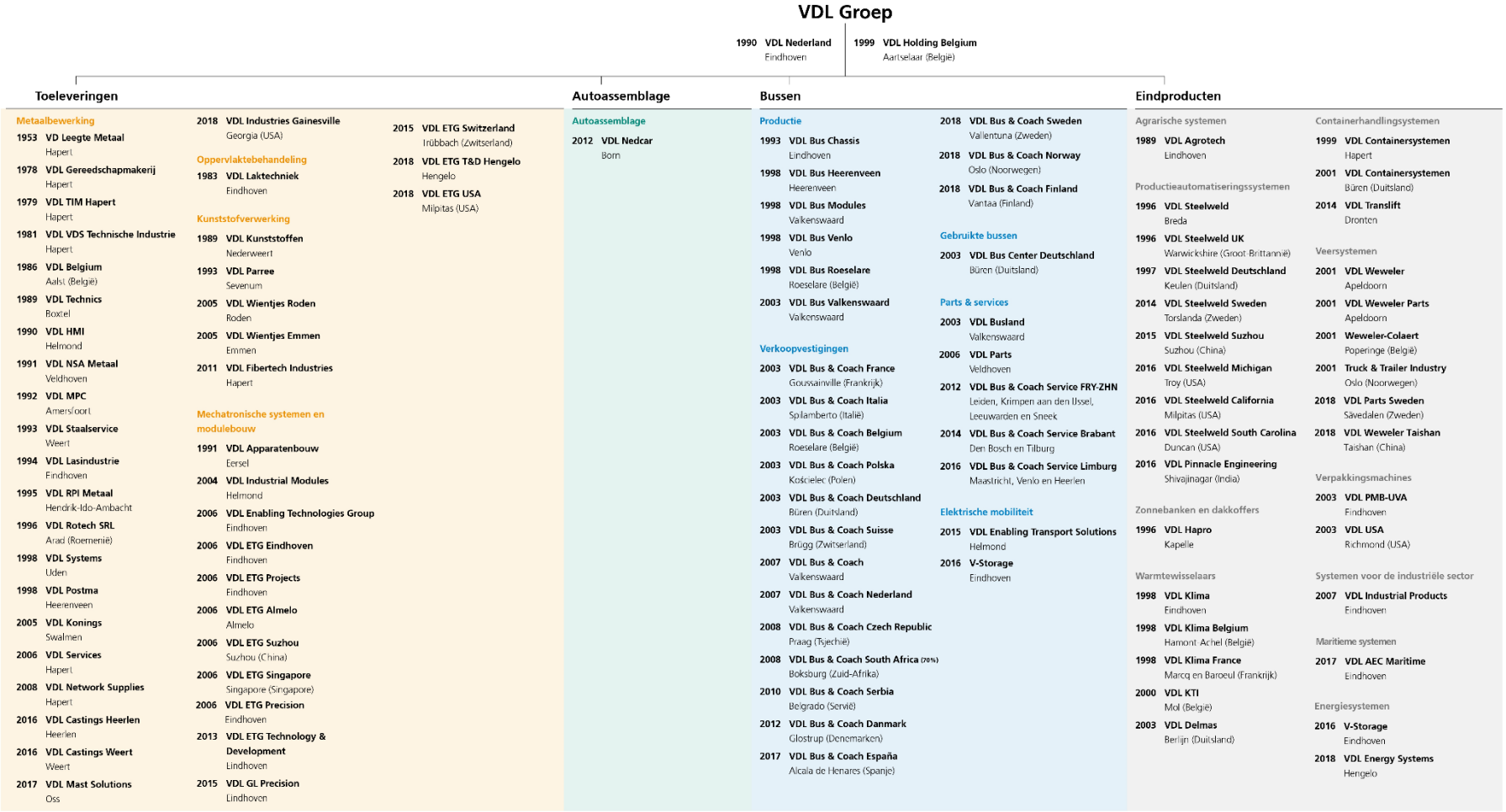


Figure 27: Organisational structure
(Source: (VDL Groep, n.d.))

Appendix B

Risk Management

In order to cope with sudden and unexpected events, VDL ETG Almelo has prepared several scenarios. When something happens, a plan B needs to be ready as a back-up, and if necessary, a plan C, D, etc (*Purchasing Director*, 2023). This pillar is a motivation for this research, to be ready for possible global supply chain events. A tool to categorise risk is the impact/probability risk matrix (Iqbal, 2023). This is used to determine what the risk of certain events is based on its impact combined with the probability of it actually happening. The impact/probability risk matrix indicates which risks need to be tackled for VDL ETG Almelo. Based on this, the Purchasing Director chooses a project in the supply chain which needs to be solved. In this way, risk management is constantly being monitored.

Highest quality

To be able to deliver products with the highest quality, supply base management is key. It is crucial to involve the supplier that can deliver components of the highest quality already in the early stages of the cooperation, to be able to set up an early supplier inclusion process in new product development projects (Schiele, 2019). The complete production process, from the production phase to the assembly phase, is required to happen in a consistent manner. Stagnation at the customer is avoided in this way, which potentially can cost a lot of money. Contract alignment is a way to make agreements with both customers and suppliers. Here it is determined what the customer expects with regards to quality, and this is then transferred to requirements in the contract with the supplier. 70% of the turnover value at VDL ETG Almelo is procurement, which emphasises that clear agreements have to be made on this aspect (*Purchasing Director*, 2023).

Material availability

Reliability of raw materials is important for this aspect. With the use of process control, it is made sure that the quality is verified when the product is sent to the customer. For this reason, the materials are also checked when they are received. Safety, ethics and environment are pillars in the process which have to be complied with. Compliances are in place to conform to the standards set in the specifications. Demand and supply control is an internal system in place to constantly stay flexible in the supply chain. This flexibility is required, while still remaining reliable. Where applicable, focus is laid on cycle time reduction to streamline the process and save costs.

Leading edge technology

Product family strategy management plays a role at VDL ETG Almelo. It is important to know what is happening in the market in a certain product commodity. In this way, continuous improvement of the product and processes can be realised, together with the suppliers. VDL ETG Almelo aims for the most advanced and innovative aspects of their products (*Purchasing Director*, 2023). This is an example of a production generation process where there is close cooperation with the supplier.

Optimal costs

Integral cost improvement programs are in place to keep reducing costs where possible, while maintaining all the values VDL ETG Almelo stands for. With the use of digitalisation of process, it becomes insightful where gains can be achieved. To accomplish lower costs, low-cost country initiatives exist. Further focus is laid on the supply chain utilisation and supply chain inventory. Having a high supply chain utilisation and low supply chain inventory reduces costs (while still meeting all requirements).

The overarching themes to accomplish these pillars are the use of multi-disciplinary teams, standard processes and creative ideas.

Appendix C

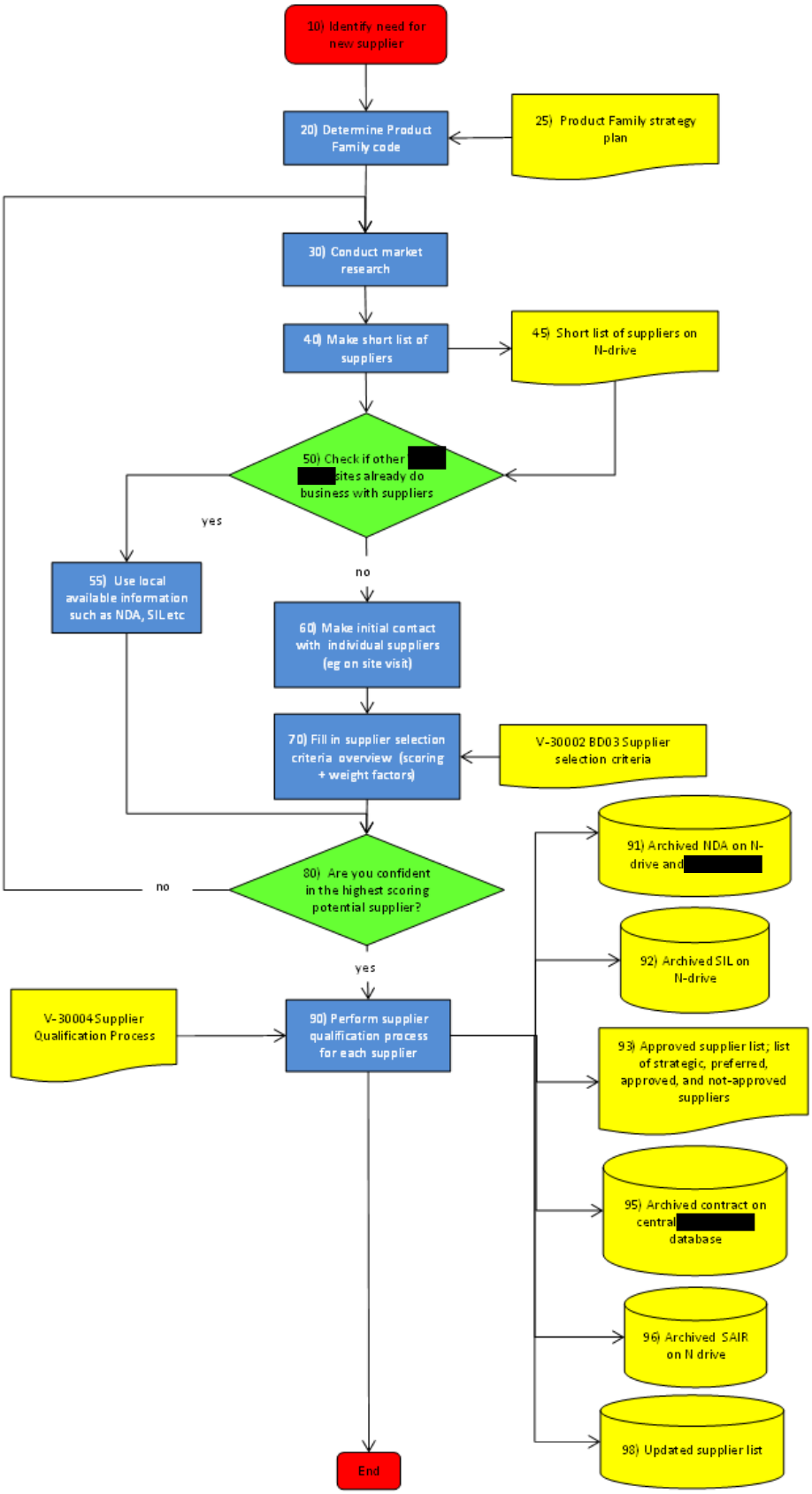


Figure 28: Supplier selection process (internal code V-30002)

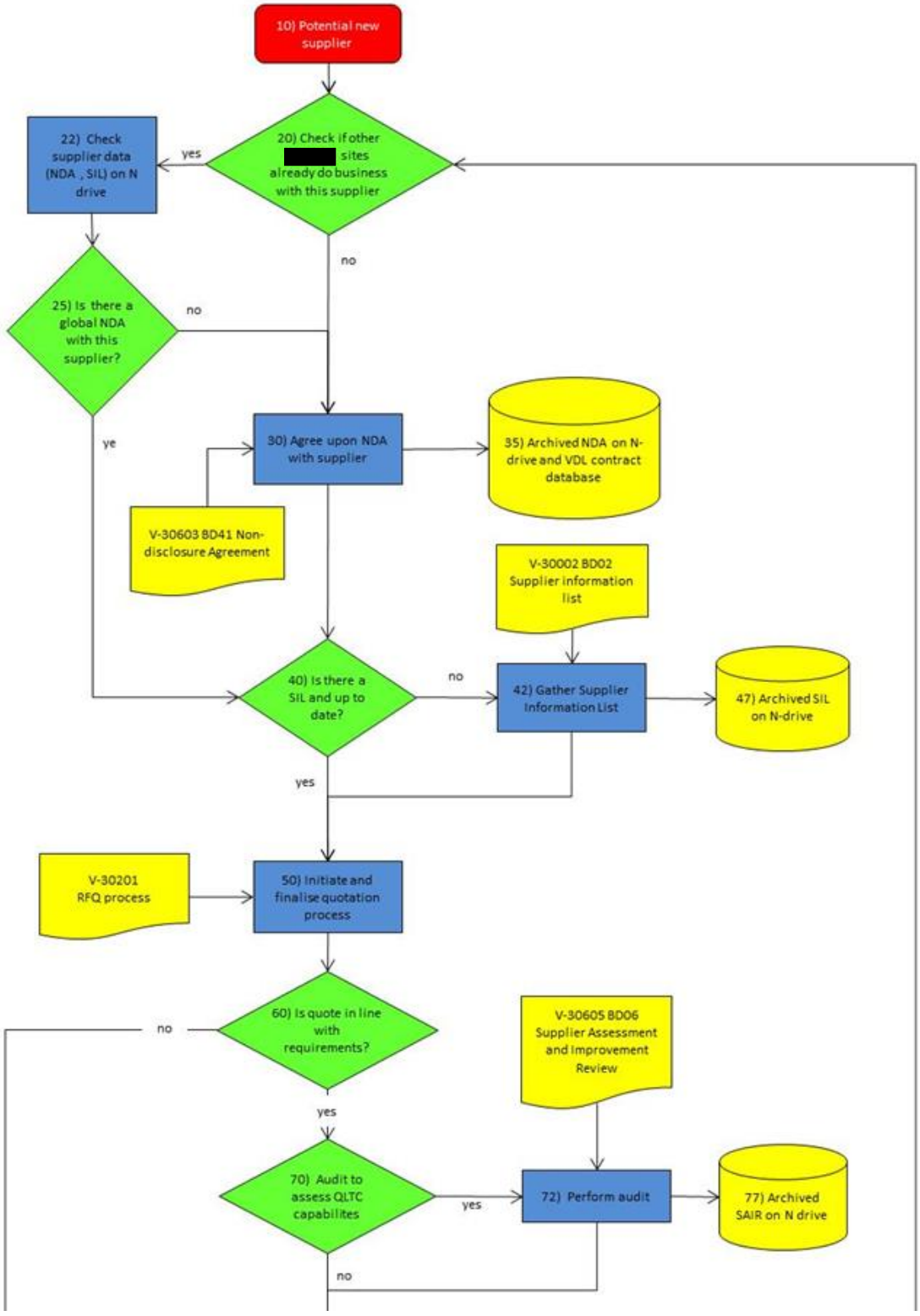


Figure 29: Supplier qualification process (internal code V-30004) (part 1)

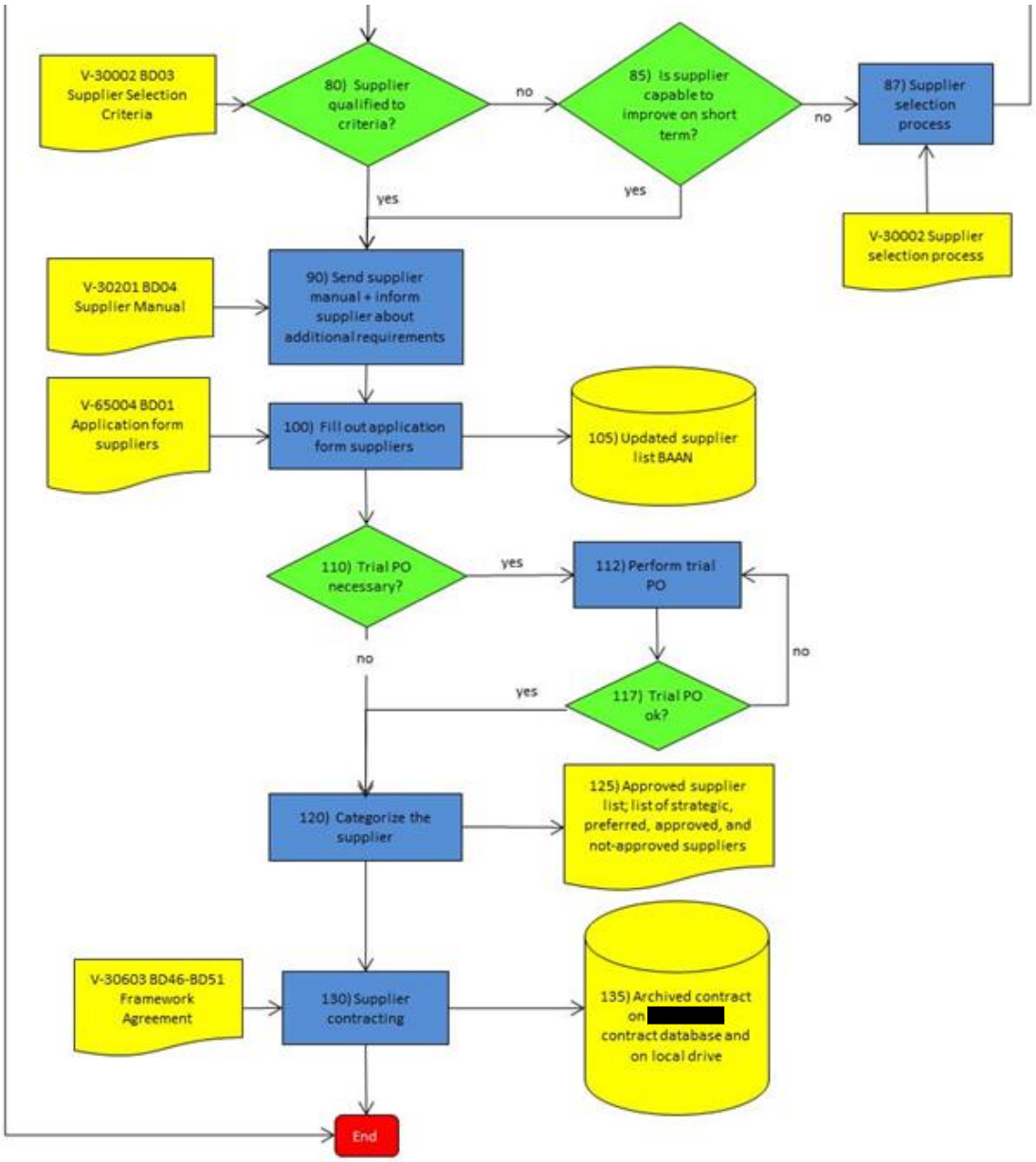


Figure 30: Supplier qualification process (internal code V-30004) (part 2)

Appendix D

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a multi-criteria decision-making method used to rank alternatives based on their proximity to an ideal solution. It is a straightforward method that helps decision-makers evaluate and rank alternatives in a structured way, considering multiple criteria and their relative importance. It is particularly useful when decisions need to be made based on a combination of quantitative data and expert judgment (Çelikbilek & Tüysüz, 2020).

Multi attribute utility theory (MAUT)

According to Bhole and Deshmukh (2018), the use of MAUT can help purchasing professionals to formulate viable sourcing strategies, as it is capable of handling multiple conflicting attributes inherent in international supplier selection. MAUT is a type of Multi-Criteria Decision Analysis (MCDA). They are both decision-making methodologies used to evaluate and compare alternatives based on multiple criteria or attributes. MAUT is considered more mathematical, whereas MCDA is more descriptive.

Multi-objective programming

The multi-objective programming approach is generally used in the JIT scenarios (Weber & Ellram, 1993). An additional flexibility of this approach is that it allows a varying number of suppliers into the solution and provides suggested volume allocation by supplier. However, the process is complex and, in many cases, impractical to implement (Weber & Ellram, 1993).

Data envelopment analysis (DEA)

According to Liu et al. (2000), DEA has been widely applied to address various decision analysis problems due to its usefulness in evaluating multi-criterion systems and providing improvement targets for such systems. In the work of Liu et al. (2000), DEA is applied as a supplier performance evaluation tool, however, it can also be applied as a supplier selection tool.

Appendix E

Table 15: Longlist suppliers

Supplier	Country	Region	Capable of processing materials: (stainless) steel/aluminium/titanium	Fully automated machining stations (turning and milling)	Measurement equipment and tooling (quality control department)	Capable of cylindrical or surface grinding	Small machine possible <1000&1000&1000mm
1	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
2	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
3	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
4	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
5	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
6	Spain	Aragon	Yes	Yes	Yes	Yes	Yes
7	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
8	Spain	Basque country	Yes	Yes	No	Yes	Yes
9	Spain	Cantabria	Yes	Yes	Yes	Yes	Yes
10	Spain	Basque country	Yes	Yes	Yes	Yes	No
11	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
12	Spain	Cantabria	Yes	Yes	Yes	No	Yes
13	Spain	Catalonia	Yes	Yes	Yes	Yes	No
14	Spain	Basque country	Yes	Yes	Yes	Yes	No
15	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
16	Spain	Navarra	No	Yes	No	No	Yes
17	Portugal	Marinha Grande	Yes	Yes	Yes	Yes	Yes
18	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
19	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
20	Spain	Catalonia	No	Yes	No	No	Yes
21	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
22	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
23	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
24	Portugal	Central Portugal	Yes	Yes	No	Yes	Yes
25	Portugal	Northern Portugal	No	Yes	Yes	Yes	Yes
26	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
27	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
28	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
29	Spain	Basque country	Yes	Yes	Yes	Yes	No
30	Spain	Basque country	Yes	Yes	No	Yes	No
31	Spain	Basque country	Yes	Yes	No	Yes	No
32	Spain	Galacia	Yes	Yes	Yes	Yes	No
33	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
34	Spain	Navarra	Yes	Yes	Yes	Yes	Yes
35	Spain	Andalusia	Yes	Yes	Yes	Yes	Yes
36	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
37	Spain	Galacia	Yes	Yes	Yes	Yes	Yes
38	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
39	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
40	France	Lyon	No	Yes	Yes	Yes	No
41	Spain	Basque country	Yes	Yes	No	Yes	Yes
42	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
43	Spain	Basque country	No	Yes	Yes	Yes	No
44	Spain	Galacia	Yes	Yes	No	No	Yes
45	Spain	Basque country	No	Yes	No	No	No
46	Spain	Basque country	No	Yes	Yes	Yes	Yes
47	Spain	Basque country	Yes	Yes	Yes	Yes	No
48	Spain	Madrid	No	No	No	No	Yes
49	Spain	Aragon	Yes	Yes	Yes	No	Yes
50	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
51	Spain	Catalonia	Yes	Yes	Yes	Yes	No
52	Portugal	Northern Portugal	No	Yes	Yes	Yes	Yes
53	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
54	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
55	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
56	Spain	Valencia	Yes	Yes	Yes	Yes	Yes

Table 16: List suppliers after first five criteria

Supplier	Country	Region	Capable of processing materials: (stainless) steel/aluminium/titanium	Fully automated machining stations (turning and milling)	Measurement equipment and tooling (quality control department)	Capable of cylindrical or surface grinding	Small machine possible <1000&1000&1000mm
1	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
2	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
3	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
4	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
5	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
6	Spain	Aragon	Yes	Yes	Yes	Yes	Yes
7	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
9	Spain	Cantabria	Yes	Yes	Yes	Yes	Yes
11	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
15	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
17	Portugal	Marinha Grande	Yes	Yes	Yes	Yes	Yes
18	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
19	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
21	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
22	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
23	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
26	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
27	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
28	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
33	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
34	Spain	Navarra	Yes	Yes	Yes	Yes	Yes
35	Spain	Andalusia	Yes	Yes	Yes	Yes	Yes
36	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
37	Spain	Galacia	Yes	Yes	Yes	Yes	Yes
38	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
39	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
42	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
50	Spain	Catalonia	Yes	Yes	Yes	Yes	Yes
53	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
54	Spain	Madrid	Yes	Yes	Yes	Yes	Yes
55	Spain	Basque country	Yes	Yes	Yes	Yes	Yes
56	Spain	Valencia	Yes	Yes	Yes	Yes	Yes

Table 17: List suppliers after capacity + remarks (part 1)

Supplier	Country	Region	High mix low volume willingness & capabilities	Certification ISO 9001 or equivalent or achievable within one year	At least clean room ISO 7 facilitated	Surface treatment i.e., NIP, anodizing	Temperature and humidity controlled production environment	Enough capacity/turnover	Remarks	Customer segments
1	Spain	Basque country	No	Yes	No	No	No	3,000 m2, distributed into two workshops.		
2	Spain	Basque country	Yes	Yes	No	No	Yes	20+ employees	Site only in Spanish, specialised in single parts and small series. Regular sized company, can be relevant. Air-conditioned workshop	
3	Spain	Basque country	No	Yes	No	Yes	No	Current plant with a surface area of 1,700 m²	CNC Lathes: Fagor en Fanuc vertical milling centers: Heidenhain	Oil 7 Gas, Foundry, Aluminium and glass packaging tech, energy industry, engineering services, automotive, other fields
4	Spain	Madrid	Yes	Yes	No	No	No	Looks large on Google Maps	Site only in Spanish, and is vague about machines	
5	Spain	Basque country	No	Yes	No	Yes	Yes	Activity in an industrial warehouse with an area of 1300 m2	Site only in Spanish, Air-conditioned room	
6	Spain	Aragon	No	Yes	No	No	Yes	More than 10 parking spots on Google Maps	5000 m² of air-conditioned workshop and 2000 m² of outdoor area. More than 50+ employees	Aerospace, aeronautics
7	Spain	Basque country	Yes	Yes	No	No	Yes	Regular sized company based on Google Maps	Temperature controlled room	
9	Spain	Cantabria	Yes	Yes	No	Yes	No	350+ employees		
11	Spain	Basque country	No	Yes	No	No	No	2500 m2 facilities		
15	Spain	Basque country	No	Yes	No	No	No	Not clear information on Google Maps	Website is poor-looking, info on Google Maps is vague. Chosen as a backup	Machining chip removal sector in all types of industrial and metal parts
17	Portugal	Marinha Grande	No	Yes	No	No	No			Automotive, Aerospace, Space, Defence, Automation, Robotics, Energy, Industrial machinery equipment
18	Spain	Basque country	No	Yes	No	No	No	Seems large on Google Maps		
19	Spain	Catalonia	No	Yes	No	Yes	Yes	Fleet of over 50 last generation CNC machine including machining centers with simultaneous lathing of high speed and high torque for all types of materials.	We industrialize and manufacture prototypes, short and medium series dimensions from ø0,5mm up to Ø800mm and from 5mm lengths up to 2m.	Aerospace, medical and robotic sectors
21	Spain	Basque country	No	Yes	No	Yes	No	40+ employees		

Table 18: List suppliers after capacity + remarks (part 2)

Supplier	Country	Region	High mix low volume willingness & capabilities	Certification ISO 9001 or equivalent or achievable within one year	At least clean room ISO 7 facilitated	Surface treatment i.e., NIP, anodizing	Temperature and humidity controlled production environment	Enough capacity/turnover	Remarks	Customer segments
22	Spain	Basque country	Yes	Yes	No	Yes	No	More than 10 parking spots on Google Maps, excluded	Based on Google Maps and site only in Spanish, we do not approach	
23	Spain	Basque country	Yes	Yes	No	Yes	Yes, Air	9800 m2 facilities	Site only in Spanish	
26	Spain	Basque country	No	Yes	No	Yes	No	Has a lot of machines		
27	Spain	Catalonia	No	Yes	No	No	No	1250 m2 facilities		
28	Spain	Madrid	No	Yes	No	No	No	3500 m2 facilities	Site only in Spanish	
33	Spain	Madrid	Yes	Yes	No	Yes	No	Small company based on Google Maps	Site only in Spanish	
34	Spain	Navarra	No	Yes	Yes, ISO	Yes	Yes	Surface area of 2900 m2, 39 employees	Production capacity of 50,000 hours.	Aerospace, Aeronautics, Capital goods, Research and medical, Renewable energies
35	Spain	Andalusia	Yes	Yes	No	No	No	Regular sized company based on Google Maps, excluded	Company looks great, but is only in Spanish. Located in Seville. Not special enough to include them.	
36	Spain	Basque country	No	Yes	No	No	No	3,200m2 and a team of close to 50 people.	English translater doesn't work on website	Aeronautical and aerospace
37	Spain	Galacia	No	Yes	No	No	No	20.000m2 distributed over four plants, over 21 million in annual turnover		
38	Spain	Basque country	No	Yes	No	Yes	Yes	100> employees	No cleanroom but their cleaning levels of up to 0.005mg/cm2 0.02mm maximum particles are achieved. Investigate what this is	Automotive, Bus & Truck, Hydraulic, handling
39	Spain	Catalonia	Yes	Yes	No	No	No	25+ employees	Site only in Spanish	
42	Spain	Basque country	Yes	Yes	No	Yes	No	35 employees, 2000m2	Small batches or repetitive parts	Automotive, Aeronautics, Machine tools, Medicine, Aerospace
50	Spain	Catalonia	Yes	No	No	Yes	No	800 m2 facilities		
53	Spain	Basque country	Yes	Yes	No	Yes	No	Small company based on Google Maps	Based on Google Maps, it looks too small, so this company is excluded	
54	Spain	Madrid	No	Yes	No	No	No	More than 10 parking spots on Google Maps	Site only in Spanish	
55	Spain	Basque country	No	Yes	No	No	No	4000 m2 facilities		
56	Spain	Valencia	No	Yes	No	Yes	No	Small, <10 parking spots on Google Maps	Site only in Spanish	

Table 19: Shortlist suppliers

Supplier	Region	High mix low volume willingness & capabilities	Certification ISO 9001 or equivalent or achievable within one year	At least clean room ISO 7 facilitated	Surface treatment i.e., NIP, anodizing	Temperature and humidity controlled production environment	Enough capacity/turnover	Remarks	Customer segments
1	Basque country	No	Yes	No	No	No	3,000 m2, distributed into two workshops.		
2	Basque country	Yes	Yes	No	No	Yes	20+ employees	Site only in Spanish, specialised in single parts and small series. Regular sized company, can be relevant. Air-conditioned workshop	
3	Basque country	No	Yes	No	Yes	No	Current plant with a surface area of 1,700 m²	CNC Lathes: Fagor en Fanuc vertical milling centers: Heidenhain	Oil 7 Gas, Foundry, Aluminium and glass packaging tech, energy industry, engineering services, automotive, other fields
5	Basque country	No	Yes	No	Yes	Yes	Activity in an industrial warehouse with an area of 1300 m2	Site only in Spanish, Air-conditioned room	
6	Aragon	No	Yes	No	No	Yes	More than 10 parking spots on Google Maps	5000 m² of air-conditioned workshop and 2000 m² of outdoor area. More than 50+ employees	Aerospace, aeronautics
7	Basque country	Yes	Yes	No	No	Yes	Regular sized company based on Google Maps	Temperature controlled room	
9	Cantabria	Yes	Yes	No	Yes	No	350+ employees		
11	Basque country	No	Yes	No	No	No	2500 m2 facilities		
18	Basque country	No	Yes	No	No	No	Seems large on Google Maps		
19	Catalonia	No	Yes	No	Yes	Yes	Fleet of over 50 last generation CNC machine including machining centers with simultaneous lathing of high speed and high torque for all types of materials.	We industrialize and manufacture prototypes, short and medium series dimensions from ø0,5mm up to Ø800mm and from 5mm lengths up to 2m.	Aerospace, medical and robotic sectors
21	Basque country	No	Yes	No	Yes	No	40+ employees		
23	Basque country	Yes	Yes	No	Yes	Yes, Air	9800 m2 facilities	Site only in Spanish	
26	Basque country	No	Yes	No	Yes	No	Has a lot of machines		
34	Navarra	No	Yes	Yes, ISO	Yes	Yes	Surface area of 2900 m2, 39 employees	Production capacity of 50,000 hours.	Aerospace, Aeronautics, Capital goods, Research and medical, Renewable energies
36	Basque country	No	Yes	No	No	No	3,200m2 and a team of close to 50 people.	English translater doesn't work on website	Aeronautical and aerospace
37	Galacia	No	Yes	No	No	No	20.000m2 distributed over four plants, over 21 million in annual turnover		
38	Basque country	No	Yes	No	Yes	Yes	100> employees	No cleanroom but their cleaning levels of up to 0.005mg/cm2 0.02mm maximum particles are achieved. Investigate what this is	Automotive, Bus & Truck, Hydraulic, handling
42	Basque country	Yes	Yes	No	Yes	No	35 employees, 2000m2	Small batches or repetitive parts	Automotive, Aeronautics, Machine tools, Medicine, Aerospace
50	Catalonia	Yes	No	No	Yes	No	800 m2 facilities		
55	Basque country	No	Yes	No	No	No	4000 m2 facilities		

Table 20: Categories and KPIs supplier selection tool

GENERAL
Management commitment for doing business with VDL (ETG)
VDL (ETG) potential spend between 5% and 20% of suppliers turnover
Experience on a comparable market / customer segments
High mix low volume willingness & capabillities
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template
QUALITY
Certification ISO 9001 or equivalent or achievable within one year
RoHs, REACH compliant
Culture of continuous improvement
Quality Management System (KPI/Calibration/deployment)
Operational Quality Performance
Measurement equipment and tooling
LOGISTICS
Leadtime
Delivery performance for orders placed according to agreed leadtime
Delivery conditions
Barcoding on product and shipping documents possible
TECHNOLOGY
Cleanroom ISO7 surface cleaning and packaging facilitated
Capable of wire EDM / spark machining
Capable of cylindrical or surface grinding
Small machine possible (< 1000mm x 1000mm x 1000mm)
Shape and position tolerances (0.1 - 0.001)
Local surface treatment company
COST
Open book calculation
SERVICE
Timely responsiveness on request for questions
Multiple English speaking sales employees
Pro-active communication and information
SUSTAINABILITY
Policy on environment, health, safety and ethics
RESILIENCE
Financial stability
Flexible in volume changes / ramp-up or ramp-down
Back-up possibilities for supplier's partners
Recovery time objectives (RTOs)
Extra information, no weight
Size of organisation (office / work floor)
Capable of processing materials: (stainless) steel / aluminium /
Fully automated machining stations (turning and milling
MOQ and/or order costs applicable
Viewpoint supplier on customer

Table 21: KPIs with range in scores (part 1)

KPIs	Determination of range in scores
GENERAL	
Management commitment for doing business with VDL (ETG)	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.
Experience on a comparable market / customer segments	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.
High mix low volume willingness & capabillities	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	NDA and GPA are hard requirements
QUALITY	
Certification ISO 9001 or equivalent or achievable within one year	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1
RoHs, REACH compliant	Ask for evidence that supplier does comply for our products. This is a European requirement.
Culture of continuous improvement	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean
Quality Management System (KPI/Calibration/deployment)	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5
Operational Quality Performance	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1
Measurement equipment and tooling	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is
LOGISTICS	
Leadtime	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1
Delivery performance for orders placed according to agreed leadtime	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5
Delivery conditions	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5
Barcoding on product and shipping documents possible	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5
TECHNOLOGY	
Cleanroom ISO7 surface cleaning and packaging facilitated	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5
Capable of wire EDM / spark machining	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5
Capable of cylindrical or surface grinding	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5
Small machine possible (< 1000mm x 1000mm x 1000mm)	Dimensions of machining
Shape and position tolerances (0.1 - 0.001)	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0.1 = score 1, 0.1 = score 2, 0.01 = score 3, 0.001 = score 4, <0.001 = score 5
Local surface treatment company	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5

Table 22: KPIs with range in scores (part 2)

KPIs	Determination of range in scores
COST	
Open book calculation	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5
SERVICE	
Timely responsiveness on request for questions	Responsiveness based on our experience. In general response time <5 working days.
Multiple English speaking sales employees	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5
Pro-active communication and information	Up-front and pro-active information regarding order book. Based on our experience with the supplier.
SUSTAINABILITY	
Policy on environment, health, safety and ethics	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5
RESILIENCE	
Financial stability	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant
Flexible in volume changes / ramp-up or ramp-down	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).
Back-up possibilities for supplier's partners	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5
Recovery time objectives (RTOs)	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5
Extra information, no weight	
Size of organisation (office / work floor)	Size of the company
Capable of processing materials: (stainless) steel / aluminium / titanium	Can supplier machine / process multiple types of material?
Fully automated machining stations (turning and milling	Supplier has automated machining stations to reduce costs
Viewpoint supplier on customer	Focussed on communication aspects, what is required from your side for a beneficial cooperation?

Table 23: Weight determination 'General' category

GENERAL	Management commitment for doing business with VDL (ETG)	VDL (ETG) potential spend between 5% and 20% of suppliers turnover	Experience on a comparable market / customer segments	High mix low volume willingness & capabillities	Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	Criteria weights	Conclusion	
Management commitment for doing business with VDL (ETG)	1.000	3.083	2.917	3.633	1.403	0.394	λ_{max}	5.137
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	0.324	1.000	1.021	1.458	1.181	0.161	n	5
Experience on a comparable market / customer segments	0.343	0.980	1.000	1.000	1.181	0.150	Consistency index (CI)	0.034
High mix low volume willingness & capabillities	0.275	0.686	1.000	1.000	1.181	0.136	Consistency ratio CR = CI/RI	0.031
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	0.713	0.847	0.847	0.847	1.000	0.159	Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	

Table 24: Weight determination 'Quality' category

QUALITY	Certification ISO 9001 or equivalent or achievable within one year	RoHs, REACH compliant	Culture of continuous improvement	Quality Management System (KPI/Calibration/deployment)	Operational Quality Performance	Measurement equipment and tooling	Criteria weights	Conclusion	
Certification ISO 9001 or equivalent or achievable within one year	1.000	2.250	2.250	2.500	2.500	1.869	0.303	λ_{max}	6.075
RoHs, REACH compliant	0.444	1.000	1.833	1.833	1.813	1.656	0.199	n	6
Culture of continuous improvement	0.444	0.545	1.000	1.250	1.250	0.542	0.118	Consistency index (CI)	0.015
Quality Management System (KPI/Calibration/deployment)	0.400	0.545	0.800	1.000	1.000	0.550	0.103	Consistency ratio CR = CI/RI	0.012
Operational Quality Performance	0.400	0.552	0.800	1.000	1.000	0.583	0.104	Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	
Measurement equipment and tooling	0.535	0.604	1.846	1.818	1.714	1.000	0.172		

Table 25: Weight determination 'Logistics' category

LOGISTICS	Leadtime	Delivery performance for orders placed according to agreed leadtime	Delivery conditions	Barcoding on product and shipping documents possible	Criteria weights	Conclusion	
Leadtime	1.000	0.729	2.000	2.000	0.280	λ_{max}	4.029
Delivery performance for orders placed according to agreed leadtime	1.371	1.000	4.250	3.750	0.463	n	4
Delivery conditions	0.500	0.235	1.000	1.250	0.134	Consistency index (CI)	0.010
Barcoding on product and shipping documents possible	0.500	0.267	0.800	1.000	0.123	Consistency ratio CR = CI/RI Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	0.011

Table 26: Weight determination 'Technology' category

TECHNOLOGY	Cleanroom ISO7 surface cleaning and packaging facilitated	Capable of wire EDM / spark machining	Capable of cylindrical or surface grinding	Small machine possible (< 1000mm x 1000mm x 1000mm)	Shape and position tolerances (0.1 - 0.001)	Local surface treatment company	Criteria weights	Conclusion	
Cleanroom ISO7 surface cleaning and packaging facilitated	1.000	2.250	2.250	1.750	1.750	1.000	0.251	λ_{max}	6.034
Capable of wire EDM / spark machining	0.444	1.000	0.875	0.708	0.750	0.653	0.114	n	6
Capable of cylindrical or surface grinding	0.444	1.143	1.000	0.688	0.667	0.653	0.117	Consistency index (CI)	0.007
Small machine possible (< 1000mm x 1000mm x 1000mm)	0.571	1.412	1.455	1.000	1.250	0.653	0.158	Consistency ratio CR = CI/RI	0.005
Shape and position tolerances (0.1 - 0.001)	0.571	1.333	1.500	0.800	1.000	0.653	0.146	Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	
Local surface treatment company	1.000	1.532	1.532	1.532	1.532	1.000	0.213		

Table 27: Weight determination 'Service' category

SERVICE	Timely responsiveness on request for questions	Multiple English speaking sales employees	Pro-active communication and information	Criteria weights	Conclusion	
Timely responsiveness on request for questions	1.000	1.550	1.688	0.427	λ_{max}	3.116
Multiple English speaking sales employees	0.645	1.000	3.000	0.388	n	3
Pro-active communication and information	0.593	0.333	1.000	0.185	Consistency index (CI)	0.058
					Consistency ratio CR = CI/RI	0.111
					Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	

Table 28: Weight determination 'Resilience' category

RESILIENCE	Financial stability	Flexible in volume changes / ramp-up or ramp-down	Back-up possibilities for supplier's partners	Recovery time objectives (RTOs)	Criteria weights	Conclusion	
Financial stability	1.000	2.625	2.750	3.125	0.468	λ_{max}	4.092
Flexible in volume changes / ramp-up or ramp-down	0.381	1.000	2.583	2.000	0.260	n	4
Back-up possibilities for supplier's partners	0.364	0.387	1.000	1.375	0.147	Consistency index (CI)	0.031
Recovery time objectives (RTOs)	0.320	0.500	0.727	1.000	0.126	Consistency ratio CR = CI/RI	0.035
						Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	

Table 29: Weight determination 'Service' category after correction

SERVICE	Timely responsiveness on request for questions	Multiple English speaking sales employees	Pro-active communication and information	Criteria weights	Conclusion	
Timely responsiveness on request for questions	1.000	1.550	1.708	0.431	λ_{max}	3.094
Multiple English speaking sales employees	0.645	1.000	2.750	0.379	n	3
Pro-active communication and information	0.585	0.364	1.000	0.190	Consistency index (CI)	0.047
					Consistency ratio CR = CI/RI	0.090
					Green (consistent) if CR ≤ 0.10, red (inconsistent) if CR > 0.10	

Table 30: Final weights KPIs

KPIs	Weight
GENERAL	**15.81%**
Management commitment for doing business with VDL (ETG)	6.22%
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%
Experience on a comparable market / customer segments	2.37%
High mix low volume willingness & capabillities	2.15%
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%
QUALITY	**24.48%**
Certification ISO 9001 or equivalent or achievable within one year	7.43%
RoHs, REACH compliant	4.86%
Culture of continuous improvement	2.89%
Quality Management System (KPI/Calibration/deployment)	2.53%
Operational Quality Performance	2.56%
Measurement equipment and tooling	4.21%
LOGISTICS	**17.46%**
Leadtime	4.90%
Delivery performance for orders placed according to agreed leadtime	8.08%
Delivery conditions	2.33%
Barcoding on product and shipping documents possible	2.15%
TECHNOLOGY	**17.00%**
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%
Capable of wire EDM / spark machining	1.94%
Capable of cylindrical or surface grinding	1.99%
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%
Shape and position tolerances (0.1 - 0.001)	2.49%
Local surface treatment company	3.62%
COST	**7.65%**
Open book calculation	7.65%
SERVICE	**9.74%**
Timely responsiveness on request for questions	4.20%
Multiple English speaking sales employees	3.69%
Pro-active communication and information	1.85%
SUSTAINABILITY	**3.28%**
Policy on environment, health, safety and ethics	3.28%
RESILIENCE	**4.58%**
Financial stability	2.14%
Flexible in volume changes / ramp-up or ramp-down	1.19%
Back-up possibilities for supplier's partners	0.67%
Recovery time objectives (RTOs)	0.58%

Appendix F

Table 31: Results supplier selection tool - Supplier A

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier A	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	4	0.25	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	We had a meeting with the CEO. 2 years ago, a colleague from VDL ETG Eindhoven visited them. It is the same conclusion now. They can produce the products and the surface treatment, but they cannot facilitate the cleanroom and they do not know someone who can. We have been given a contact that does cleaning, we will call him about the possibilities.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	2	0.05	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Their turnover is 4,2 million. He said that the partnership is to be started slowly, so we do not immediately do 20%. This year, capacity is full. In the future, we will see how much % we can place there, but he is open to do more for us in the future.
Experience on a comparable market / customer segments	2.37%	5	0.12	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Aerospace, Science and Medical
High mix low volume willingness & capabillities	2.15%	5	0.11	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	This is their focus area. He said that they do batch sizes of 1, with the maximum now 100. This can increase in the future because of automation and robots.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.65**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	They have ISO 9001 and ISO 9100.
RoHs, REACH compliant	4.86%	1	0.05	Ask for evidence that supplier does comply for our products. This is a European requirement.	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Culture of continuous improvement	2.89%	4	0.12	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean	The workplace is clean, tools are placed on their locations. The paths are empty.
Quality Management System (KPI/Calibration/deployment)	2.53%	1	0.03	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	Tools are being measured at the machine. If a deviation exists in the tool, it is noticed there before producing. 22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Operational Quality Performance	2.56%	1	0.03	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Measurement equipment and tooling	4.21%	4	0.17	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	They have 2 CMMs, one for bigger parts and one for smaller parts. The quality control room is air conditioned.
		Total	**0.75**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier A	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	5	0.24	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	The cycle time roughly is 4-8 weeks, it also depends on the product. 4 weeks is the minimum because of their planning horizon.
Delivery performance for orders placed according to agreed leadtime	8.08%	2	0.16	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	He said around 80%.
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Both
Barcoding on product and shipping documents possible	2.15%	1	0.02	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.54**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	He is willing to facilitate this somewhere else (if he knows the requirements), but it is all unclear what the specific requirements are and what the costs/benefit would be.
Capable of wire EDM / spark machining	1.94%	4	0.08	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	They have at least one in-house.
Capable of cylindrical or surface grinding	1.99%	5	0.10	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	They can do this in-house with multiple machines.
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	5	0.13	Dimensions of machining	This is their focus area.
Shape and position tolerances (0.1 - 0.001)	2.49%	4	0.10	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0.1 = score 1, 0.1 = score 2, 0.01 = score 3, 0.001 = score 4, <0.001 = score 5	Their sweet spot is 5 microns, the CMM can measure up to 2 microns.
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They have multiple partners for surface treatment nearby.
		Total	**0.56**		
COST	**7.65%**				
Open book calculation	7.65%	1	0.08	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.08**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier A	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	1	0.04	Responsiveness based on our experience. In general response time <5 working days.	First response was 9 days later, we also had to adapt the planning because later he said that he was not available on the day that we scheduled him (which we sent him a long time before that)
Multiple English speaking sales employees	3.69%	3	0.11	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	4 English speaking employees, the English of the CEO was okay but sometimes it was difficult in the meeting and we misunderstood each other.
Pro-active communication and information	1.85%	2	0.04	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	As soon as we were in the planning phase of the visit, we got quick responses. In the beginning this was not the case and communication was more difficult. Till 22-12-2013 there was still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.19**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	2	0.07	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	Waste is collected by another company, it is assumed that they recycle it. It all sounded a bit vague.
		Total	**0.07**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Turnover last year was 4,2 million, this year 4,3. So financially stable. They have space left for new machines so they can grow more. He said that the aim is to buy a new machine each year.
Flexible in volume changes / ramp-up or ramp-down	1.19%	4	0.05	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	75% of capacity is used
Back-up possibilities for supplier's partners	0.67%	4	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	They have a lot of suppliers nearby. He did not give numbers but it can be assumed that there exist more suppliers.
Recovery time objectives (RTOs)	0.58%	5	0.03	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	They focus on a fast reaction in case of a problem. He said something about 1 week as an aim.
		Total	**0.21**		
Totals	**100.00%**				
		Total	**3.06**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	35 employees
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	They use all kinds of materials
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	Yes, some with storage of 25 pallets.
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	Focus on partnership. Start slow. With their current customers they have been doing business for 40+ years.

Table 32: Results supplier selection tool - Supplier B

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier B	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	3	0.19	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	We had a meeting with the CEO of the company. She is the second generation of the company, her father has retired. She had already send us the company presentation. She was prepared for our visit. At the end she gave us umbrellas because it was raining. She was nice but did not really know a lot about VDL.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	2	0.05	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Their turnover is 3 million yearly. More than 20% share of a customer is something they usually do not want. At the beginning of a relationship, a customer can do a couple of % of their turnover.
Experience on a comparable market / customer segments	2.37%	1	0.02	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Glass container industry, automotive, aluminum extrusion, science, energy. Not really our segments.
High mix low volume willingness & capabillities	2.15%	5	0.11	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	They focus on smaller batch sizes, think of 1 to 5 products. Sometimes also batches up to 100 products. On a pallet in the facilities was a pallet with a large batch of products (40), she said that this was already a quite big batch.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.49**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	ISO9001, ISO14001, ISO45001
RoHs, REACH compliant	4.86%	5	0.24	Ask for evidence that supplier does comply for our products. This is a European requirement.	Answer from CEO: No restricted substances listed in the RoHS and REACH regulations are used in the manufacture of our parts. In addition, we control the compliance of our suppliers/collaborators. However, this is a requirement from some for our customers, so therefore we issue certificates where this is reflected yearly.
Culture of continuous improvement	2.89%	4	0.12	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	She is not really focussed on growth and expanding, more about making the process more efficient and effective. Next year there will be a new machine and the floorplan will be changed. Overall the work space seemed mostly clean, at some parts there was scrap material on the group (fallen out of the wheelbarrow).
Quality Management System (KPI/Calibration/deployment)	2.53%	4	0.10	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	She measures quite a lot of KPIs (she is an industrial engineer so that was a nice match, I understood why she measured all of them). She talked about non conformaties, turnover, quationation in terms of numbers or money wise, training of staff, absence, average delay of work) When I asked about the lead time, she did not know that and said that they don't measure this. This is an improvement possibility because it is important to also measure this.
Operational Quality Performance	2.56%	2	0.05	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	No more than 3000 euros worth of non conformities per 6 months. Percentage wise the % the goal of the non conformities is set at 5%. This is always achieved, now it is 3%.
Measurement equipment and tooling	4.21%	4	0.17	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	There is one CMM in a climate controlled room. Tools and the CMM are checked periodically and calibrated by an external partner (tools at the external location, CMM stays there)
		Total	**1.05**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier B	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	5	0.24	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	She mentioned a guess of an average of 2-3 weeks. This includes making the technical model in the software, based on the technical drawings, production time by the machine, checking and transportation. Of course it depends on the product and the batch size. It was a bit vague and I guess this lead time is quite ambitious, but still it is below 8 weeks.
Delivery performance for orders placed according to agreed leadtime	8.08%	3	0.24	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	Their aim is 85%. Currently it is 90% delivered on time. In case of a delay, the goal is set to solve this asap, but within 2 days (if this is realistic of course)
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Both
Barcoding on product and shipping documents possible	2.15%	2	0.04	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	Answer CEO: We do not work with barcode system for shipments, but we do provide a packing list for every freight. We identify the packages with the content, order reference, weight, etc. or the information that you require with the means at our disposal.
		Total	**0.65**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	Her customers do not require this, so she does not have this nor a partner for it. She mentioned the company DTK technologies for a possible cleanroom.
Capable of wire EDM / spark machining	1.94%	3	0.06	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	This is done at an external partner.
Capable of cylindrical or surface grinding	1.99%	5	0.10	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	This is done both internally as externally, so still a 5.
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	5	0.13	Dimensions of machining	The focus area is on small dimensions. There are also machines that are capable of larger dimensions.
Shape and position tolerances (0.1 - 0.001)	2.49%	3	0.07	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	The most accurate that the machines can do is 0,01, so 10 microns. Customers find this accurate enough, so she also does not feel the urge to improve the accuracy (now).
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	Multiple surface treatment partners exist nearby.
		Total	**0.52**		
COST	**7.65%**				
Open book calculation	7.65%	1	0.08	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	Answer CEO: We are known for being a transparent and trustworthy company but we do not provide our internal cost segmentation.
		Total	**0.08**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier B	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	5	0.21	Responsiveness based on our experience. In general response time <5 working days.	She always responds quickly. Often on the same day or a day later.
Multiple English speaking sales employees	3.69%	3	0.11	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	There are four English speaking people in the departments that we will be in contact with.
Pro-active communication and information	1.85%	5	0.09	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	She sent us her brochure beforehand and is thinking with us.
		Total	**0.41**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	5	0.16	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	ISO14001 and ISO45001 are in place. She said that this helps them a lot.
		Total	**0.16**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	4	0.09	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	They have a yearly steady turnover of slightly more than 3 million and this is increasing slightly.
Flexible in volume changes / ramp-up or ramp-down	1.19%	4	0.05	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	80% of capacity is used. There is the possibility to quickly put production orders in between the schedule if required, because products often can be produced on multiple machines. Sometimes a supplier is the bottleneck in the process. For example, subcontractors of heat treatment and wire EDM. 5 axes machines at Amets could be the bottleneck when there are a lot of products to be produced. Sometimes the vertical lathes are also the bottleneck.
Back-up possibilities for supplier's partners	0.67%	5	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	There are a lot of backups for this nearby.
Recovery time objectives (RTOs)	0.58%	3	0.02	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	Asap, real average in delay is 2 days.
		Total	**0.18**		
Totals	**100.00%**				
		Total	**3.55**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	27 employees
Capable of processing materials:	0			Can supplier machine / process multiple types of material?	Yes, all the materials
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	No
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	A good partnership, flexibility and transparency.

Table 33: Results supplier selection tool - Supplier C

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier C	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	5	0.31	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	We had a meeting with the managing director. He is the third generation of the company, together with his brother (technical director) and sister (financial director). He mentioned that he looked on the website and talked about the cleanroom facilities that we have. He was kind and gave us coffee, the talk with him was nice. At the end he gave us a bottle of wine. He was well prepared for our visit.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	3	0.08	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Their yearly turnover is 4,6 million and have 20 clients. They have no limit regarding the maximum percentage of turnover per client, but they do not prefer a too large percentage. Still, 1 client has 30% of the total turnover now. This is caused by the two sectors that are their priorities, which are railway and energy.
Experience on a comparable market / customer segments	2.37%	4	0.09	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Their market segments are: energy, **aeronautics, aerospace**, railway and mechanical transmissions. The ones in bold are not their main segments, for this reason a 4.
High mix low volume willingness & capabillities	2.15%	5	0.11	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	They do series sizes between 1 and 200.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.72**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	
RoHs, REACH compliant	4.86%	5	0.24	Ask for evidence that supplier does comply for our products. This is a European requirement.	Answer Luis: According to our suppliers and data sheets of the main chemicals we use, they are REACH compliant.
Culture of continuous improvement	2.89%	3	0.09	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	It looked quite clean, although the floor was old and sometimes a bit broken. Also, there was oil/liquid on some parts of the walking path. Luis mentioned replacing multiple machines, which is also a form of continuous improvement. Measuring department was also very clean.
Quality Management System (KPI/Calibration/deployment)	2.53%	4	0.10	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	They measure some KPIs in the ERP system. The performance of every department is measured. Every month they have a discussion about this. Every three months they have a deeper discussion. Claims are also measured.
Operational Quality Performance	2.56%	5	0.13	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	They have a goal in their quality system to achieve no more than 1% in rejects/complaints.
Measurement equipment and tooling	4.21%	5	0.21	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	They have a very modern and big MMC (Altera) in a climate controlled room. This room looked really organized and the MMC is also one of the better MMCs that we have seen. Also, they have an even bigger MMC (also in a climate controlled room), for the even bigger parts.
		Total	**1.14**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier C	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	4	0.20	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	It depends. If the customer supplies the raw material, then the lead time (also depends on complexity of course) is 3-4 weeks. If they buy the raw material, the lead time is longer. Depending on how the supplier gets the raw material, the total lead time changes. For forging/casting, the total lead time is 12 weeks. For cutting of a block it is 7-8 weeks. When intermediate treatments are required, this adds 1-2 weeks to the lead time.
Delivery performance for orders placed according to agreed leadtime	8.08%	4	0.32	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	They achieve a delivery performance of 98% for their large sectors, which are railway and wind. Achieving a good delivery performance has a high priority for them. They have a production planning of up to 6 months for this, which helps them to achieve this.
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	They can do both.
Barcoding on product and shipping documents possible	2.15%	5	0.11	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	Answer Luis: Yes we can use barcoding, Code 128.
		Total	**0.74**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	They do not have a cleanroom and no partner for this. Customers also do not require this from them.
Capable of wire EDM / spark machining	1.94%	3	0.06	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	They do not have it in-house, but they have a partner for it.
Capable of cylindrical or surface grinding	1.99%	3	0.06	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	They do not have it in-house, but they have a partner for it.
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	5	0.13	Dimensions of machining	They have machines of high quality, see the pictures. They have machines for larger dimensions, but they also have machines for smaller dimensions. Most turning and milling machines are equiped with a pallet loader, capacity varies from 2-6 pallets.
Shape and position tolerances (0.1 - 0.001)	2.49%	4	0.10	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	The Nigata machine that they have should have an accuracy of up to 4 microns. For the turning machines, this is 8 microns.
Local surface treatment company	3.62%	4	0.14	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They do some processes in-house: liquid painting, shot blasting and sand blasting. In Zaragoza: heat treatment, zinc plating and metalising. Rest of Spain: rest of treatments.
		Total	**0.54**		
COST	**7.65%**				
Open book calculation	7.65%	3	0.23	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	Normally they don't. He mentioned that they have higher prices sometimes. This is caused by high costs for preparation work (divided over a few units when batch size is low). Sometimes the costs of preparation work are higher than the actual machining costs. Sometimes, he describes the cost drivers to illustrate this, if required by the customer. For this reason a 3.
		Total	**0.23**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier C	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	5	0.21	Responsiveness based on our experience. In general response time <5 working days.	Quick responses
Multiple English speaking sales employees	3.69%	3	0.11	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	4 English speaking employees. His English was really good.
Pro-active communication and information	1.85%	5	0.09	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	Good communication with him.
		Total	**0.41**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	3	0.10	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	They do not have the official certificate, but they do all the things mentioned in the certificate. They have a solar plant on the roof, generating 20% of their electricity usage. Their electricity supplier has a certificate that the energy is renewable. Waste has to be controlled and recycled according to Spanish regulations. For oils, used filters etc, this is picked up by an external partner. They have seperate containers for all the metals and these are reused by an external supplier. Before visiting the workfloor, we had to read the safety instructions. During the visit we wore the safety vest. All these measures are enough for a grade 3.
		Total	**0.10**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Yearly turnover of 4,6 million, which is quite stable over the years.
Flexible in volume changes / ramp-up or ramp-down	1.19%	4	0.05	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	They can do 3 shifts if required. The employees always work 2 shifts at minimum, this is not always the case for the machines (they can also do 1 shift). Products can be made on multiple machines. He mentioned a capacity of 70-80%.
Back-up possibilities for supplier's partners	0.67%	5	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	For their critical treatments (heat treatment, anodizing, chromium) and materials (stainless steel and aluminium) they have at least 2 backups. The rest is more.
Recovery time objectives (RTOs)	0.58%	3	0.02	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	They try to solve it asap. Contact the customer first.
		Total	**0.21**		
Totals	**100.00%**				
		Total	**4.09**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	43 employees of which 32 in production
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	Yes
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	Some machines have pallet capacity of 2-6 pallets.
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	Important that it lasts. Some of their customers are around for more than 50 years. Win-win relationship. Regarding communication, they prefer email because it lasts

Table 34: Results supplier selection tool - Supplier D

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier D	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	2	0.12	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	We had a meeting with the market manager who focused on (among others) the Dutch market. In general he was nice and we had a good chat beforehand. He did not know about VDL and it turned out that there was a complete mismatch in what we were doing. Their focus area is investment casting and metal injection moulding. They also have a machining department, but this is used for the finishing of the parts made by these processes. In the mail we told him about what we were doing and what we are looking for, so it was weird that he did not say this earlier. We did not even fill in the question paper as it would have been a waste of time. Questions are answered where it is possible, if it is not possible, the lowest grade is given and the comment is given 'Not applicable'. We will not be in business with them.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	1	0.03	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Yearly turnover of 48 million for the group (which has the different departments in it).
Experience on a comparable market / customer segments	2.37%	1	0.02	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Automotive is a large one for them. Large batches and no high precision.
High mix low volume willingness & capabillities	2.15%	1	0.02	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	Not applicable
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.32**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	
RoHs, REACH compliant	4.86%	1	0.05	Ask for evidence that supplier does comply for our products. This is a European requirement.	Not applicable
Culture of continuous improvement	2.89%	3	0.09	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	They are growing in their sector and have a lot of different buildings close to each other. Investments in new machines and facilities.
Quality Management System (KPI/Calibration/deployment)	2.53%	1	0.03	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	Not applicable
Operational Quality Performance	2.56%	1	0.03	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	Not applicable
Measurement equipment and tooling	4.21%	5	0.21	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	They have a quality control department with CMMs in a climate controlled room.
		Total	**0.77**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier D	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	1	0.05	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	Not applicable
Delivery performance for orders placed according to agreed leadtime	8.08%	1	0.08	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	Not applicable
Delivery conditions	2.33%	1	0.02	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Not applicable
Barcoding on product and shipping documents possible	2.15%	1	0.02	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	Not applicable
		Total	**0.17**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	No cleanroom
Capable of wire EDM / spark machining	1.94%	1	0.02	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	Not applicable
Capable of cylindrical or surface grinding	1.99%	1	0.02	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	Not applicable
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	5	0.13	Dimensions of machining	
Shape and position tolerances (0.1 - 0.001)	2.49%	1	0.02	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	The products did not have a high accuracy. When we entered we only saw these products with very low accuracy.
Local surface treatment company	3.62%	4	0.14	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They have external partners for this, some processes are done in-house.
		Total	**0.39**		
COST	**7.65%**				
Open book calculation	7.65%	1	0.08	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	Not applicable
		Total	**0.08**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier D	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	2	0.08	Responsiveness based on our experience. In general response time <5 working days.	Quick response only after calling, mails take ages to be answered.
Multiple English speaking sales employees	3.69%	5	0.18	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	He and the receptionist spoke in English, a lot of office people. It is assumed that at least 8 speak English
Pro-active communication and information	1.85%	1	0.02	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	He could have known in advance that we were not going to be a match. It is stated very clearly in our emails. On their website it seems that they have a large machining department, but it has a completely different purpose.
		Total	**0.29**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	3	0.10	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	They have ISO14001, but it did not seem/smell/look very sustainable and/or healthy. We did have to wear a safety vest.
		Total	**0.10**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Yearly turnover of 48 million.
Flexible in volume changes / ramp-up or ramp-down	1.19%	1	0.01	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	Not applicable
Back-up possibilities for supplier's partners	0.67%	1	0.01	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	Not applicable
Recovery time objectives (RTOs)	0.58%	1	0.01	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	Not applicable
		Total	**0.13**		
Totals	**100.00%**				
		Total	**2.24**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	350+ employees
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	Yes
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	No
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	Not applicable

Table 35: Results supplier selection tool - Supplier E

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier E	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	5	0.31	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	There were four people at the meeting. They had the following functions: quality director, commercial department and manager. Before the plant visit, the CEO also came to meet us. They were impressed by the size of VDL. Beforehand, they looked at the example products and told us which products they could not produce and why. In this sense they were prepared.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	3	0.08	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	They have multiple customers and thus we can assume that a customer won't have a too large share of the turnover. Their current turnover is 6,5 million. They have capacity left over in their third shift.
Experience on a comparable market / customer segments	2.37%	1	0.02	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Automotive 34%, energy 33%, machine tools 6%
High mix low volume willingness & capabillities	2.15%	2	0.04	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	This varies. Batches of 5 exist, till mass production in automotive (size in 10000s). In the plant, mostly big sizes can be seen.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.58**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	
RoHs, REACH compliant	4.86%	5	0.24	Ask for evidence that supplier does comply for our products. This is a European requirement.	Answer: Yes
Culture of continuous improvement	2.89%	3	0.09	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	The plant was clean. They had a system for scrap material that operators at the machine could throw the scrap material in a ditch below the machines. A thread is moving through this ditch and pushes the waste material to the central collection place. The culture of continuous improvement does not really seem to exist.
Quality Management System (KPI/Calibration/deployment)	2.53%	4	0.10	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	Answer: We had 33 KPI and they are measured monthly.
Operational Quality Performance	2.56%	5	0.13	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	Answer: For the last 3 months our rejections are 1 complaint/month and the cost is 0,001% from billing.
Measurement equipment and tooling	4.21%	2	0.08	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	They had a CMM in a climate controlled room. It is not a very large CMM but it does the job. Still, the CMM looked quite outdated in comparison to the other quality departments that we have seen.
		Total	**1.01**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier E	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	5	0.24	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	6-8 weeks on average. Depends on the material and treatment.
Delivery performance for orders placed according to agreed leadtime	8.08%	3	0.24	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	This was a bit vague. At first he said almost 100%. I asked for a number, he could not really tell this. Then he said at least more than 90%. Then I said, so 95%? That was a bit too optimistic. Thus a 3.
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Both
Barcoding on product and shipping documents possible	2.15%	5	0.11	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	Answer: Yes, we use barcodes. By default, the label we stick in the boxes is VDA 4902 (the automotive standard one). We had some customers with modified labels and documentation, so if it is necessary, there will be no problem to adjust any document
		Total	**0.71**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	They don't have a cleanroom in-house. They do have a room in mind where they could build the cleanroom. He mentioned that they have a cleanroom partner, but he did not want to give us the name because he was scared that we would skip supplier E and only go to the cleanroom. For this reason, it is still a 1.
Capable of wire EDM / spark machining	1.94%	3	0.06	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	They have a partner for this.
Capable of cylindrical or surface grinding	1.99%	4	0.08	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	They have machines for this at their finishing department, which is at another location but nearby. For this reason it is a 4, a mix between outsourced and having it internally.
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	3	0.08	Dimensions of machining	3 and 4 axes machines exist. They make shoesized products, but they cannot produce parts that are very thin.
Shape and position tolerances (0.1 - 0.001)	2.49%	3	0.07	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	The most accurate that they can do is up to 5 microns. They said that they could not produce multiple products because the required accuracy was too high and the products would be too thin.
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They have partners for this, so they outsource it. Also a lot is done nearby.
		Total	**0.44**		
COST	**7.65%**				
Open book calculation	7.65%	5	0.38	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	Answer: If there is any special cost for example tools, they will be detailed on the quotation.
		Total	**0.38**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier E	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	5	0.21	Responsiveness based on our experience. In general response time <5 working days.	First response was within a couple of days. In general she responded quite quickly.
Multiple English speaking sales employees	3.69%	4	0.15	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	People in the office can speak English (but not too good, also the people at the meeting could not speak English very well). They said that they have 10-12 employees in the office. It is given a 4 because of the English level of the four people at the meeting.
Pro-active communication and information	1.85%	4	0.07	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	Signing the NDA went fast. They gave comments on feasibility of the product examples but this was sometimes vague. During the meeting it became clear what they meant.
		Total	**0.43**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	3	0.10	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	They have solar panels on the roof. They are working on getting the sustainability certificate. It is expected that they acquire this next year. The waste is separated and recycled. We had to wear a safety jacket.
		Total	**0.10**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Yearly turnover of 6,5 million.
Flexible in volume changes / ramp-up or ramp-down	1.19%	5	0.06	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	60-70% of capacity is used.
Back-up possibilities for supplier's partners	0.67%	5	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	They have 4 or 5 important suppliers for raw materials. For treatments they have 6-8 suppliers.
Recovery time objectives (RTOs)	0.58%	3	0.02	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	Asap. He said that if necessary, he drives to the supplier to fix something.
		Total	**0.22**		
Totals	**100.00%**				
		Total	**3.88**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	62 employees, they work in 3 shifts.
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	Not titanium now, perhaps later. The rest of the materials yes.
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	No
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	Establish a partner relationship, win-win situation

Table 36: Results supplier selection tool - Supplier F

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier F	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	5	0.31	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	We already had a Teams meeting with him beforehand, so we already knew each other and he knew about VDL ETG Almelo. He was definitely invested in us. The visit was good, we got coffee and some wireless earplugs. He also went with us to the other facility 30 minutes away to show the high precision machines there. The bigger facility has the big machines and the big parts (in size of a lot of meters), the smaller facility has 3 Hermle machines that produce the high precision parts. 3 shifts of 8 hours are done here, for 5 days. If needed, the weekend is also used.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	3	0.08	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	The turnover of Goimek is 10-11 million, for the high precision parts this is 3 million. Focus is laid on the whole company.
Experience on a comparable market / customer segments	2.37%	2	0.05	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Aerospace, defence
High mix low volume willingness & capabillities	2.15%	4	0.09	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	Batch size of 1 or only a couple of products happen a lot. The largest batch they do is 500, but this is an exception.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.65**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	ISO9001, ISO9100, ISO14001, ISO45001
RoHs, REACH compliant	4.86%	5	0.24	Ask for evidence that supplier does comply for our products. This is a European requirement.	Answer: Yes
Culture of continuous improvement	2.89%	4	0.12	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	The focus is on the smaller facility where the high precision parts are. That facility is going to move to the larger facility so they have everything at one location (they are expanding there). The smaller facility is in an old building and it is clear that it is old. in September 2024, everything is at its proposed location. The bigger facility was clean in the areas where it was needed, around the very large machines (talk about several meters), this was not always the case. They were also moving machines there, so it was sometimes a bit messy. A lean internal project was started last year. This is all part of continuous improvement.
Quality Management System (KPI/Calibration/deployment)	2.53%	5	0.13	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	A lot of operational performance is being measured, examples where shown to us about delivery performance, capacity of machines, progress system which shows where there exist errors. Answer: 68 (CMO). Each KPI has different measuring method. It is not the same measuring financial KPI or sales KPI. Most of them are measured taking the data from our ERP system.
Operational Quality Performance	2.56%	3	0.08	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	Answer: ICF 2,67% in the last 3 months
Measurement equipment and tooling	4.21%	3	0.13	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	There is a CMM in the smaller facility, which is in a climate controlled room. In fact, the whole of the smaller facility is climate controlled.
		Total	**1.06**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier F	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	5	0.24	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	4 weeks for simple parts, 10 weeks for the most complex parts. On average 6-8 weeks.
Delivery performance for orders placed according to agreed leadtime	8.08%	3	0.24	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	Average of the total in the last three months is 91%, average of high precision in the last three months is 87%.
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Both are possible
Barcoding on product and shipping documents possible	2.15%	3	0.06	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	Answer: To be analyzed. Normally QR is used for internal traceability. I do not expect a limitation here.
		Total	**0.67**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	AVS (added value solutions) is a possible partner. Goimek has done very little business with them, but perhaps they could do the cleanroom activity. WIP
Capable of wire EDM / spark machining	1.94%	3	0.06	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	Not in house, this is outsourced
Capable of cylindrical or surface grinding	1.99%	5	0.10	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	3	0.08	Dimensions of machining	They have 3 Hermle machines. However, they have a lot more large machines.
Shape and position tolerances (0.1 - 0.001)	2.49%	4	0.10	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	Accuracy of up to 5 microns
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They have external partners for this nearby.
		Total	**0.49**		
COST	**7.65%**				
Open book calculation	7.65%	5	0.38	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	Answer: Yes, following cost break down: % raw material, % machining cost and % logistic cost.
		Total	**0.38**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier F	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	5	0.21	Responsiveness based on our experience. In general response time <5 working days.	He always responds quickly and open
Multiple English speaking sales employees	3.69%	4	0.15	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	Sufficient English speaking employees in the quality, production and sales departments. His English has a good level. Total number is unknown, for this reason a 4.
Pro-active communication and information	1.85%	5	0.09	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	Communication with him is really quick and transparent.
		Total	**0.45**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	5	0.16	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	ISO14001 and IOS45001 are in place for sustainability and health & safety
		Total	**0.16**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Goimek is doing 11 million each year, the high precision parts of 3 million. They have multiple focus areas so they are not too dependent on one focus area. They are growing and investing a lot. They build new facilities at the bigger location where the smaller location moves to. Goimek is part of the Danobat group, this group has a turnover of 254 million yearly.
Flexible in volume changes / ramp-up or ramp-down	1.19%	4	0.05	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	85% of capacity is planned
Back-up possibilities for supplier's partners	0.67%	4	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	There are multiple suppliers for the simpler raw materials. Only for special stainless steel (which they used to get out of Russia) they have one supplier now, but they used to have more for this product.
Recovery time objectives (RTOs)	0.58%	3	0.02	Do you already have RTOs in place with current customers? No = score 1, yes = score 5	15% of capacity is used for this. In terms of capacity, there is backup planned for the machines, they try to be flexible. They have a system in which they can see what the current status is per product.
		Total	**0.20**		
Totals	**100.00%**				
		Total	**4.06**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	85 employees, 7000 m2 larger facility, 2500 m2 smaller facility
Capable of processing materials:	0			Can supplier machine / process multiple types of material?	Yes, a lot of materials
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	No, not yet. This is an issue with the culture in Spain. The operators are too proud and want to do the work manually in their way. They first have to see the benefit. This is a process which takes time. In the same way, the system has been developed for the errors etc
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	A match has to be found in what we do, they are flexible to customer demand. Forecast is important as an indication. Stability in relationship, also on price. Not only a spot order, but focus on long term relationship. A lof of developments in engineering, they do it with the customer.

Table 37: Results supplier selection tool - Supplier G

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier G	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	3	0.19	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	We had a meeting with the executive president and a representative of f4e (fusion for energy project). It seemed that they had not seen the example products yet. The meeting was good and the executive president talked enthousiastically about his company. We got coffee. The other person did not know from which company we were, so he was not too prepared. I guess that the second person was there for English help if it was needed, because the English level of the executive president was not always very high.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	5	0.13	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Their turnover is 14 million. Over the last years, the demand has increased with 30% per year. All of their sectors increase. One of their biggest customers has 20% of the share. They do not want that the share of a single customer is too high.
Experience on a comparable market / customer segments	2.37%	5	0.12	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	High tech market segments like aerospace, analytical, aeronautics, defence, nuclear and medical
High mix low volume willingness & capabillities	2.15%	5	0.11	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	A minimal batch size of 1 is possible, they do a lot of smaller batches between 1 and 10. If required, they can do batches of up to 200 or 300.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.67**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	
RoHs, REACH compliant	4.86%	5	0.24	Ask for evidence that supplier does comply for our products. This is a European requirement.	
Culture of continuous improvement	2.89%	5	0.14	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	They document all their processes and measure the KPIs. The workfloor was clean and organised. They have a tool storage in which you can ask for a specific tool and then the location of that specific tool opens.
Quality Management System (KPI/Calibration/deployment)	2.53%	5	0.13	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	We have seen a special area where they place all these papers with the KPIs and their scores daily. He named a lot of KPIs and they were important for them. They have meetings based on these KPIs.
Operational Quality Performance	2.56%	5	0.13	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	There are almost no rejects because of the strict quality measures and the system to control all the quality procedures. He said that it is almost 0, like 0,02%.
Measurement equipment and tooling	4.21%	5	0.21	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	They have three Zeiss CMMs in a climate controlled environment. It all looked very clean and organised.
		Total	**1.22**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier G	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	5	0.24	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	Only machining can be done in 1-2 weeks. The bottleneck for them is surface treatment. They used to have a supplier for this, but the plant burned down. They partically recovered but priority is given to Airbus. For this reason, it can take up to 4 weeks for surface treatment.
Delivery performance for orders placed according to agreed leadtime	8.08%	4	0.32	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	Average delivery performance of 95%.
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Both, they do what the customer requires.
Barcoding on product and shipping documents possible	2.15%	5	0.11	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	They do so according to the requirements of the customer.
		Total	**0.79**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	4	0.17	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	They call it white rooms. They have 3 white rooms ISO class 8. Improving to ISO class 7 is possible, but it is expensive. Now the demand for class 7 is minimal, in case it increases a lot, they are open for improving the cleanroom to ISO class 7. We also asked if we could then use their cleanroom to clean parts from other suppliers, they would be open to this.
Capable of wire EDM / spark machining	1.94%	4	0.08	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	Yes, 1 machine in-house.
Capable of cylindrical or surface grinding	1.99%	5	0.10	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	5	0.13	Dimensions of machining	We have seen a lot of relevant shoebox size parts, see the pictures.
Shape and position tolerances (0.1 - 0.001)	2.49%	4	0.10	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	Calibration is up to 2 microns, machining up to 5 microns.
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They have external partners for this.
		Total	**0.69**		
COST	**7.65%**				
Open book calculation	7.65%	5	0.38	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	They are open in this. They show preparation costs, machining costs and non-recurring costs (only for the first time doing business). In this way, customers can decide what their optimal batch size is.
		Total	**0.38**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier G	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	5	0.21	Responsiveness based on our experience. In general response time <5 working days.	Responses are often within a day, so that is good.
Multiple English speaking sales employees	3.69%	5	0.18	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	There are at least 10. Although the English level of the executive president was not the best, we could communicate with him. Sometimes we needed the help of the other person.
Pro-active communication and information	1.85%	5	0.09	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	Open and quick communication. They already sent the machine list and company presentation.
		Total	**0.49**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	2	0.07	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	They do not have the ISO certificate for this, but they have all the procedures in place. They used to have it, before it was acquired (when it was focussed on automotive).
		Total	**0.07**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Yearly turnover is 14 million, with an increase in demand of 30% per year.
Flexible in volume changes / ramp-up or ramp-down	1.19%	4	0.05	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	Approximately 80% of capacity is used.
Back-up possibilities for supplier's partners	0.67%	4	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	They have at least 2 or more back-up for raw materials and surface treatment.
Recovery time objectives (RTOs)	0.58%	3	0.02	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	They take into account a buffer of 2 weeks to be able to cope with unforeseen things happening. This is their policy to cope with disruptions.
		Total	**0.20**		
Totals	**100.00%**				
		Total	**4.51**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	100 employees and the facilies together are 20000 m2.
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	Yes, only titanium is difficult now with the titanium sanctions for Russia.
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	Yes, the 5 axis CNC machines are palletizes with 2 pallets.
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	Good communication, to define the parts well precisely. Establish a partnership for a long time. Planning in advance! Achieve a win-win situation.

Table 38: Results supplier selection tool - Supplier H

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier H	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	2	0.12	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	We had email contact with the CEO, but when we arrived, the CEO was in a video call and thus we had the meeting with the COO. The COO did not know about us and the CEO did not come by in the meantime. No reception, we had to wait in a weird room that looked unfinished. We were not allowed to take pictures.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	2	0.05	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Supplier H has a turnover of 8 million €, divided over (what used to be) different companies in house. One of these companies is the smaller sub-company, with whom we have been in contact with, for a possible visit as well. The smaller sub-company cancelled our visit last minute because he did not respond to our mail on time and had a business trip. Supplier H is focused on high precision machinery. When supplier H bought the smaller sub-company a couple of years ago, the smaller sub-company was almost bankrupt. Also because of covid, they have little orders for the smaller sub-company and only have 3 capable machines. Since
Experience on a comparable market / customer segments	2.37%	3	0.07	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Supplier H's segments are aerospace, aeronautic, machinery and defence. Machinery is about the very big products and is irrelevant in this research. Also almost turnover is machinery.
High mix low volume willingness & capabillities	2.15%	5	0.11	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	Currently they are doing a lot of prototyping to get new customers, they are willing to do smaller batches.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	1	0.03	NDA and GPA are hard requirements	Our NDA has been sent, but they have not signed it and sent it back yet. 22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.38**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	Supplier H has ISO 9001, on top of that the smaller sub-company has ISO 9100.
RoHs, REACH compliant	4.86%	1	0.05	Ask for evidence that supplier does comply for our products. This is a European requirement.	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Culture of continuous improvement	2.89%	3	0.09	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	Not super clean and sometimes products were just laying on the floor. Tools were clearly located.
Quality Management System (KPI/Calibration/deployment)	2.53%	3	0.08	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	The machines itself measure if the tools are still of good quality. There is no system which indicates which tool needs to be checked periodically for example.
Operational Quality Performance	2.56%	1	0.03	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Measurement equipment and tooling	4.21%	4	0.17	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	They have a CMM. It is not completely clear how and when they calibrate their tools, they do so when the machine that uses the tool, tells them to. The temperature is controlled in this room.
		Total	**0.78**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier H	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	5	0.24	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	He told us that it depends on the type of product and the batch size etc. but his estimation is 3-4 weeks for 1 part
Delivery performance for orders placed according to agreed leadtime	8.08%	1	0.08	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	They can do both.
Barcoding on product and shipping documents possible	2.15%	1	0.02	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.46**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	He told that some customers also require this. He was talking about a room where products can be cleaned, but it sounded more just like a temperature controlled room like ISO 8 or (, not ISO 7.
Capable of wire EDM / spark machining	1.94%	4	0.08	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	They can facilitate it. Sometimes internally, sometimes externally.
Capable of cylindrical or surface grinding	1.99%	5	0.10	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	3	0.08	Dimensions of machining	Small machine is possible, but they only work on prototyping now.
Shape and position tolerances (0.1 - 0.001)	2.49%	1	0.02	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	Depends on type of product? Still no response, concluded to give a score of 1 if answer is missing.
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	In Basque Country and Navarra are already 6 partners for surface treatment.
		Total	**0.43**		
COST	**7.65%**				
Open book calculation	7.65%	1	0.08	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.08**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier H	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	1	0.04	Responsiveness based on our experience. In general response time <5 working days.	In the beginning pro-active, after that it became very difficult and slow from their side. I had to email them that I wanted a response on a day and that I would go somewhere else if they did not respond (then they were able to respond very quickly).
Multiple English speaking sales employees	3.69%	5	0.18	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	9 in total for the company, of which 1 or 2 for a smaller sub-company. They move employees around where there is work, so the number of employees for the smaller company is not fixed. The English level of the COO was sufficient.
Pro-active communication and information	1.85%	1	0.02	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	They have not signed the NDA yet after asking them multiple times. Still no response till 22-12-2023, concluded to give a score of 1 if answer is missing.
		Total	**0.25**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	2	0.07	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	The COO worked at a larger company (which is one of the companies that is bought by supplier H), there they had ISO 14001 (sustainability). At Supplier H they do not have this certificate, but the COO says that they work according to this ISO certificate, but it is not official.
		Total	**0.07**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Supplier H is financially stable, but the smaller sub-company is not. Since we are analysing Supplier H, it is given a 5 but specified on the smaller sub-company it should be a 1.
Flexible in volume changes / ramp-up or ramp-down	1.19%	4	0.05	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	In November/December capacity at the smaller sub-company is 50%, supplier H is 75-80%
Back-up possibilities for supplier's partners	0.67%	5	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	A lot of steel suppliers are near, in general quite a lof of suppliers are near. There exist multiple backup suppliers.
Recovery time objectives (RTOs)	0.58%	1	0.01	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.19**		
Totals	**100.00%**				
		Total	**2.63**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	9800 m2, 45 employees of which 5 for the smaller sub-company
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	Different materials are named.
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	Yes, 3 of them at the smaller sub-company which are relevant. +gf+ 800 is their best machine. They produce in 2 shifts of 8 hours.
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	View on partnership is important, not just a customer-supplier relationship

Table 39: Results supplier selection tool - Supplier I

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier I	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	4	0.25	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	This was a random visit, which means that they did not have the chance to prepare something beforehand. Still, within a couple of minutes we were able to have a meeting with the CEO, General Manager and sales manager. This was the first time that they have experienced a random visit, but they really appreciated it (can also be seen in the mail he sent after that).
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	3	0.08	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Their turnover is 4 million. If you also incorporate the raw materials that they buy for the customer, the turnover yearly is 10 million. Answer: We work with different partners to complete our range of parts manufacturing. This allows us to have flexibility with different types of work.
Experience on a comparable market / customer segments	2.37%	2	0.05	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Oil/gas, **aerospace**, energy, marine
High mix low volume willingness & capabillities	2.15%	5	0.11	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	They are doing batches of 1,5, 10-20. In the long term perhaps a batch can go to 100.
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	They signed the NDA quickly after sending it (within a week with all the other information as well).
		Total	**0.61**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	They have ISO9001.
RoHs, REACH compliant	4.86%	1	0.05	Ask for evidence that supplier does comply for our products. This is a European requirement.	Answer: No, we are not. We do not manufacture electrical or electronic components. We machine precision parts and carry out small mechanical assemblies.
Culture of continuous improvement	2.89%	3	0.09	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	The workplace looked clean. Not too special. Based on gut feeling a 3.
Quality Management System (KPI/Calibration/deployment)	2.53%	3	0.08	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	Answer: Yes, we do. We have different indicators to take care of our quality control and management. We will be able to check if the measures implemented are improving the process and the quality of the machined parts.
Operational Quality Performance	2.56%	4	0.10	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	Answer: The objective set by supplier I is that the operational quality performance is less than 10%. This includes internal rejections, repeal requests that are resolved favorably or unfavorably, and customer complaints. Currently, customer complaints for defects found and not detected by supplier I are less than 1.5%
Measurement equipment and tooling	4.21%	4	0.17	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	They have a CMM in a climate controlled environment.
		Total	**0.85**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier I	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	1	0.05	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	Answer: As we machined different products for different costumers, we do not have a generic lead-time. We adjust our production pacification to our customer needs. 22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Delivery performance for orders placed according to agreed leadtime	8.08%	1	0.08	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	Answer: We check the delivery date when receiving the order and get it updated, also with repeated parts we have a delivery date agreed with the customer. 22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Answer: We are willing to work using both conditions. We adapt to our client. Sometimes the client decides to send their own transportation and on other occasions we agree with partners.
Barcoding on product and shipping documents possible	2.15%	2	0.04	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	Answer: We use barcodes to track WOs that are in progress within the shop. In this way we know each operator and each machine where they are working and what process they are doing. Based on vague answer and the lack of external documentation, only a 2 is given.
		Total	**0.29**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	1	0.04	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	They do not have a cleanroom, their customers also do not require this.
Capable of wire EDM / spark machining	1.94%	3	0.06	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	Answer: No, we are not. We have partners that are near us and we are used to work with them.
Capable of cylindrical or surface grinding	1.99%	3	0.06	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	Answer: No, we are not. We have partners that are near us and we are used to work with them.
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	2	0.05	Dimensions of machining	They have one machine in this range.
Shape and position tolerances (0.1 - 0.001)	2.49%	3	0.07	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	They can work with an accuracy of up to 10 microns.
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They have partners nearby for this.
		Total	**0.40**		
COST	**7.65%**				
Open book calculation	7.65%	1	0.08	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.08**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier I	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	2	0.08	Responsiveness based on our experience. In general response time <5 working days.	Three people were in the meeting within a couple of meetings. This can be considered as highly responsive in the beginning. Later response is very slow.
Multiple English speaking sales employees	3.69%	5	0.18	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	At least the three people who were at the meeting could communicate in English. Answer: Yes, there are. Almost all technical office can speak and understand English. 9 peolple.
Pro-active communication and information	1.85%	2	0.04	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	The first mail back from them came 5 working days later. Answers to questions took long and was incomplete. Till 22-12-2013 there was no response, concluded to give a score of 1 where a score was missing.
		Total	**0.31**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	1	0.03	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
		Total	**0.03**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Yearly turnover of 4 million which is stable.
Flexible in volume changes / ramp-up or ramp-down	1.19%	1	0.01	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	Answer: The machines capacity are planned for a month. We plan the loading of the machines a month in advance to know at all times the situation in which the pieces are progressing and to be able to act in time if something unusual happens. 22-12-2013: Still no response, concluded to give a score of 1 if answer is missing.
Back-up possibilities for supplier's partners	0.67%	2	0.01	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	Customers buy almost all raw materials. This means that Launa does not have this large network of raw materials themselves.
Recovery time objectives (RTOs)	0.58%	3	0.02	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	Answer: We carry out a daily review of the production planning so that out of the process, we can act quickly and effectively.
		Total	**0.15**		
Totals	**100.00%**				
		Total	**2.71**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	48 employees
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	Yes, see their slides.
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	No
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	According to a slow process together with the customer. Launa wants a win-win partnership and not the traditional customer-supplier relationship.

Table 40: Results supplier selection tool - Supplier J

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier J	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
GENERAL	**15.81%**				
Management commitment for doing business with VDL (ETG)	6.22%	4	0.25	Do they know what VDL ETG is doing? How prepared are they for our visit? Based on our gut feeling.	They were very open and enthousiastic. We had meetings with the General Manager and the sales manager. The CEO (who is the father of the General Manager), greeted us in the beginning and at the end. He does not speak English, so that is why he was not present during the meeting. Straight to business talk, no starting coffee or something. Everyone at the company was in company clothes.
VDL (ETG) potential spend between 5% and 20% of suppliers turnover	2.55%	3	0.08	Preferrably between >5% and <20%. Ask about their turnover, willingness to do business with new customers, (upscalable) capacity. Combined turnover with percentage determines score. Relative to other suppliers. <5% or >20% = score 1. Rest of scores is determined by combination and finalized by gut feeling.	Their turnover is 4,5 million € this year.
Experience on a comparable market / customer segments	2.37%	5	0.12	Possible market segments are: semicon, analytical, solar, LED, aviation, healthcare. Minimal one of these.	Analytical, aviation (big one). Airbus is a very large customer.
High mix low volume willingness & capabillities	2.15%	3	0.06	Series size between 1 and 100 is optimal. Series size 1 = score 5, series size>100 = 1.	Optimal batch size = 20-1000, but smaller is possible. Batch size of 1 is possible, but not preferred
Willingness to sign non disclousure agreement and general purchase agreement according to the VDL ETG template	2.52%	5	0.13	NDA and GPA are hard requirements	
		Total	**0.63**		
QUALITY	**24.48%**				
Certification ISO 9001 or equivalent or achievable within one year	7.43%	5	0.37	Ask copy of certifications or action plan to come to accreditation. This is a requirement. ISO9001 = score 5, no ISO9001 but with action plan = score 3, no ISO9001 and no willingness = score 1	ISO 9001, ISO 9100
RoHs, REACH compliant	4.86%	5	0.24	Ask for evidence that supplier does comply for our products. This is a European requirement.	Answer: We comply. Both requirements are monitored for our suppliers. Registration and regular updating in DOC 8.4.3 List of approved suppliers
Culture of continuous improvement	2.89%	5	0.14	Implementation of Lean, 5S, 6 sigma, SPC. Workfloor experience. Clean environment for example.	Lean manufacturing and 5S are implemented, which can be seen. It is very clean. Clear walking paths and everything has its own location.
Quality Management System (KPI/Calibration/deployment)	2.53%	5	0.13	Tools available to determine KPI scoring. What is being measured? No KPI = score 1, some inextensive KPIs = score 3, sufficient elaborated KPIs = score 5	They have a large tooling measurement system in house. One employee is fulltime busy with checking the tools and calibrating them. The system tells him which tools to analyse (apart from the obvious cases that a tool needs to be checked).
Operational Quality Performance	2.56%	5	0.13	Quality performance, based on: rejects, complaint %, attitude, based on average of last three months. Ask about the 8D form. When are you satisfied? Projects department aim is maximum 1.5% rejects. 0-1% rejects = score 5, 1-2% rejects = score 4, 2-3% rejects = score 3, 3-5% rejects = score 2, 5%> score 1	The value shown by our ERP for 2023: 3.97% internal non-conformity costs and 0.45% customer complaint costs.
Measurement equipment and tooling	4.21%	5	0.21	Modern and well maintained measurement tooling, also for calibration. This is a requirement. Based on gut feeling what the quality of their equipment is	
		Total	**1.22**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier J	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
LOGISTICS	**17.46%**				
Leadtime	4.90%	5	0.24	What is the cycle time? 6-8 weeks is required and has score 5. 9-10 weeks = score 4, 11 weeks = score 3, 12 weeks = score 2, >12 weeks = score 1	Cycle time is 4-8 weeks (depends on product of course). Answer: +- 6 weeks
Delivery performance for orders placed according to agreed leadtime	8.08%	2	0.16	Ask what their average delivery performance is based on the last three months. (May be biased by supplier). <80% = score 1, 80-85% = score 2, 86-94% = score 3, 95-99% = score 4, 100% = score 5	Answer: -Last month (Octobre) → 94.3 %. - 1st. Quarter 2023 → 83.4% -2nd. Quarter 2023 → 86.73% -3rd. Quarter 2023 → 84.43% (we take this one) Average 2023 → 84.85% Average 2022 → 82.60%
Delivery conditions	2.33%	5	0.12	Can supplier accept DDP or DAP? If not, score = 1, if yes, score = 5	Both are possible, depends on the wishes of the customer
Barcoding on product and shipping documents possible	2.15%	3	0.06	Can supplier provide bar coding on products and shipping documents in line with our coding requirements? Do not want = score 1, not able to but willing to = score 3, able to = score 5	They usually do not do this, but they are open for it. They need more information for this.
		Total	**0.59**		
TECHNOLOGY	**17.00%**				
Cleanroom ISO7 surface cleaning and packaging facilitated	4.27%	2	0.09	No cleanroom facilitated, but willing to facilitate this on the short term (1 year) = score 1, cleanroom facilitated at external partner = score 3, cleanroom in-house = score 5	They do not have a cleanroom in house yet, but they want to build this (expected to be operational in 2025, 40 m2). They have cleanroom partners in their cluster, but these are mostly universities and technological centres, so they do not have the full industrial capacity. Answer: The ISO class of our partners is ISO class 5. They have more customers that ask this.
Capable of wire EDM / spark machining	1.94%	3	0.06	No wire EDM facilitated = score 1, wire EDM facilitated at external partner = score 3, wire EDM in-house = score 5	Answer: Now we subcontract EDM. We will be able to do EDM from March 2024 with our own means. The purchase of a wire machine (most likely a Makino U5) is foreseen.
Capable of cylindrical or surface grinding	1.99%	5	0.10	No grinding activity facilitated = score 1, grinding activity facilitated at external partner = score 3, grinding activity in-house = score 5	
Small machine possible (< 1000mm x 1000mm x 1000mm)	2.69%	5	0.13	Dimensions of machining	Core business is small products with high precision, in 5 axis machines. Range is from 4 mm to 650 mm.
Shape and position tolerances (0.1 - 0.001)	2.49%	4	0.10	Accuracy of turning and milling machines. What is the supplier's sweet spot? >0,1 = score 1, 0,1 = score 2, 0,01 = score 3, 0,001 = score 4, <0,001 = score 5	For turning tolerance is 3 microns, for milling 5 microns. Smallest possible hole is 0,25 mm in diameter.
Local surface treatment company	3.62%	3	0.11	Is supplier using a local surface treatment company in Spain? Not necessarily done in a cleanroom. Note which treatments they facilitate. No surface treatment facilitated, but willing to facilitate this on the short term (1 year) = score 1, surface treatment facilitated at external partner = score 3, surface treatment in-house = score 5	They have a large cluster with companies for surface treatment. 1 hour by car. Also suppliers outside the cluster.
		Total	**0.59**		
COST	**7.65%**				
Open book calculation	7.65%	5	0.38	Is supplier willing to provide open cost information showing the most important cost drivers? No = score 1, yes = score 5	They wanted to talk about quotations to see if we are talking about the same prices. We told them that that is not the goal of our visit and that it will come later. They were though open to talk about costs.
		Total	**0.38**		

VDL Enabling Technologies Group: Supplier selection criteria mechanical products ISO Class 7					
New supplier: Supplier J	**Weight**	**Score (scale 1-5)**	**Weighted score**	**Determination of range in scores**	**Comments**
SERVICE	**9.74%**				
Timely responsiveness on request for questions	4.20%	5	0.21	Responsiveness based on our experience. In general response time <5 working days.	Communication went smooth. First response was within a day. I always got a quick response.
Multiple English speaking sales employees	3.69%	5	0.18	Are there multiple English speaking employees available within the company? At least 2 are required due to practical reasons (holidays).1 English speaking employees = 1, 2-3 English speaking employees = 2, 4-5 English speaking employees = 3, 6-7 English speaking employees = 4, 8> English speaking employees = 5	The General Manager and the Sales Manager both speak English. CEO does not speak English. In total, more than 15 people at Supplier J speak English.
Pro-active communication and information	1.85%	5	0.09	Up-front and pro-active information regarding order book. Based on our experience with the supplier.	Communication went smooth. I always got a quick response. We both received an USB with the company presentation and video.
		Total	**0.49**		
SUSTAINABILITY	**3.28%**				
Policy on environment, health, safety and ethics	3.28%	3	0.10	What is the policy of the company (ISO45001)? What are they doing to reach carbon footprint goals (ISO14001)? No ISO certificates and no effort made = score 1, one of ISO certificates = scores 3, both ISO certificates = score 5	They have solar panels on the roof. They recover coulant in the production process, recycle it and reuse 25-30% of coulant per year. The blazer coulant is used, which is an environmental friendly coulant. ISO 14001 is work in progress.
		Total	**0.10**		
RESILIENCE	**4.58%**				
Financial stability	2.14%	5	0.11	Contact privately owned companies for their turnover of last year, growth/investment plans. A requirement is at least a yearly turnover of 1 million €. < 1 million = score 1, 1-2 million = score 2, 2-3 million = score 3, 3-4 million = score 4, > 4 million = score 5. Growth plans can influence the score positively if it is found relevant	Yearly turnover of 4,5 million €.
Flexible in volume changes / ramp-up or ramp-down	1.19%	5	0.06	Management of its organisation and 2-tier to meet volume fluctuations. How much capacity is planned on machines? At VDL ETG, capacity of 80-85% of machines is planned. 100% = score 1, 95-99% = score 2, 86-94% = score 3, 75-85% = score 4, <75% = score 5. (Remark is that this only focusses on the benefits of having extra capacity, the cause is not taken into account).	70% of capacity is used during the week. In weekends it is approximately 50%. There is enough space to place more machines.
Back-up possibilities for supplier's partners	0.67%	5	0.03	Focus on partners of raw materials, cleaning and surface treatment. No back-up = score 1, 1 back-up per service = score 3, 2 or more back-ups per service = score 5	They have a lot of different suppliers. Regarding surface treatment, they already have 3 suppliers in Madrid, 6 in the area, 4 technological centres (nearby?) and 2 in France (1 hour away).
Recovery time objectives (RTOs)	0.58%	3	0.02	Do you already have RTOs in place with current customers? No = score 1, no official policy but has priority = score 3, yes = score 5	Quality and service is always the most important, they live up to the responsibility that they have. It is their top priority.
		Total	**0.22**		
Totals	**100.00%**				
		Total	**4.22**		
Extra information, no weight	**0**				
Size of organisation (office / work floor)	0			Size of the company	45 employees, they have grown a lot. Only 5 employees in 2004. 3000 m2 facility
Capable of processing materials: (stainless) steel / aluminium / titanium	0			Can supplier machine / process multiple types of material?	They do all materials. In the warehouse there are a lot of raw materials, they also stated the variety in raw materials that they have.
Fully automated machining stations (turning and milling	0			Supplier has automated machining stations to reduce costs	Yes, some machines can produce a lot of pallets. Work just continues
Viewpoint supplier on customer	0			Focussed on communication aspects, what is required from your side for a beneficial cooperation?	They want to establish a partnership, not the traditional customer-supplier relationship.

Appendix G

Supplier G

Supplier G is located in Barcelona. The meeting was held with the executive president and a representative of f4e (which is the fusion for energy project). Supplier G has a yearly turnover of €14 million, has 100 employees and the facilities together are 20000 m^2. To illustrate the size, a picture of the plant is given below in Figure 31.

Figure 31: Plant Supplier G

Over the last years, their demand has been increasing significantly. They are present in high tech market segments like aerospace, analytical, aeronautics, defence, nuclear and medical. A minimal batch size of 1 is possible, they do a lot of batch sizes from 1 to 10. The production facilities are clean and organized. Shoebox size products are their focus area, with some example products given below in Figure 32. Approximately 80% of their capacity is used now, so there is space available for products of VDL ETG Almelo. The accuracy of their machining is up to five microns, calibration is up to two microns.

Figure 32: Example products Supplier G

Three ISO class 8 white rooms are present at Supplier G. Improving to ISO class 7 is possible, but it is expensive. Now the demand for class 7 is minimal. In case it increases a lot, they are open to improving the cleanroom to ISO class 7. They are also open to using their cleanroom capacity for other suppliers of VDL ETG Almelo. An overview of the machinery is given in Table 41 below.

Table 41: Machinery Supplier G

Type machine production equipment	Amount	Dimensions (mm)	Extra comments
CNC milling	8	800x1200	5 axes
CNC milling	1	600x800x2000	4 axes horizontal
CNC milling	6	600x600x2000	3 axes vertical
CNC turning	2	Ø500x1500	
CNC turning	16	Ø695x1501	
CNC turning	1	Ø300x600	4 axes
CNC turning	1	Ø695x1500	6 axes
CNC turning	1	Ø600x1500	7 axes
CNC turning	1	Ø600x1500	9 axes
Milling & turning	1	600x1500	9 axes, (turning Ø695x1500mm)
Milling & turning	3	1000x800	5 axes, turning vertical
Grinding	1	400x1200	DANOBAT RCP V1 1200
Grinding	2	Ø350x1200	
Electroerosion	1	400x800	

Type machine measurement equipment	Amount
CMM Zeiss	3
CMM Mitutoyo	2
Roughness tester	1
Durometer	1
Profilometer	1
Nikon Profile Projector	1
3D Olympus Microscope	1
KOBA Calipers	1

Supplier J

Supplier J is located in Pamplona. The meeting was held with the General Manager and the Sales Manager. Their turnover is €4.5 million this year. They have grown a lot, from five employees in 2004 to 45 employees nowadays. Their facility has a surface of 3,000 m^2 and can be seen in Figure 33 below.

Figure 33: Plant Supplier J

They do not have a cleanroom in house yet, but they want to build this (expected to be operational in 2025, 40 m2). Space has been reserved for this in their plant and they are open to research the requirements together with VDL ETG Almelo. They have cleanroom partners in their cluster, but these are mostly universities and technological centres, so they do not have the full industrial capacity. They are present in the analytical, medical, aerospace and aeronautics sectors, with Airbus being a large customer.

The accuracy for turning is up to three microns, for milling five microns. The smallest possible hole to be bored has a diameter of 0.25 mm. 70% of capacity is used during the week. During the weekends it is approximately 50%. There is enough space to place more machines. This means that there are enough means to grow (significantly). Sometimes they do batch sizes of 1, but it is not preferred as the costs for the customer increase quite a lot in this way. Their optimal batch size starts from 20 pieces, but smaller batches are possible. Shoebox size products are their focus area, with a range from 4 to 650 mm. Some example products can be seen below in Figure 34. An overview of the machinery is given in Table 42 below.

Figure 34: Example products Supplier J

Table 42: Machinery Supplier J

Type machine production equipment	Amount	Dimensions (mm)	Extra comments
CNC milling	2	700x630x510	Vertical machining centres with double pallet
CNC milling	1	600x300x350	Vertical machining equipped with 4 and 5 axes, with Fanuc automation
CNC milling	1	400x600x400	Equipped with Erowa 55 pallet manufacturing cell
CNC milling	1	500x350	5 axes equipped with Erowa Easy 10 pallet robot
CNC milling	2	700x700x800	Manufacturing cell equipped with 24 pallets and 400-tool store, 3 axes
CNC milling	2	1760x560x660	4 axes
CNC turning	4	Ø350	Double spindle, Y axis, motorized tools and advance bars
CNC turning	1	Up to 450	Double spindle, bottom turret, 86 tools equipped with Halter automation

Type machine measurement equipment	Amount
CMM Zeiss	3

Supplier C

A meeting was held with the managing director of Supplier C. He is the third generation of the company, together with his brother (technical director) and sister (financial director). Supplier C is located in Zaragoza. Their turnover is €4.6 million, which has been quite stable over the years. They have 43 employees, of which 32 in production. They have 5,000 m² of air-conditioned workshop and 2,000 m² of outdoor area. An overview of their plant is given in Figure 35 below.

Figure 35: Plant Supplier C

Supplier C is active in the energy, aeronautics, aerospace, railway and mechanical transmission sectors. Their main sectors are railway and energy. The batch sizes are between 1 and 200. They do not have a cleanroom, nor a partner for this. This is caused by their customers not requiring cleanroom activities. They have machines for both small and large products. The accuracy of milling is up to four microns, for the turning machines this is eight microns. Currently, a capacity of 70-80% is used. They can do three shifts if required. There are a minimum of two employee shifts per day, and a minimum of one machine shift. Both are easily up scalable. Some example products can be seen in Figure 36 below.

Figure 36: Example products Supplier C

An overview of the machinery is given in Table 43 below.

Table 43: Machinery Supplier C

Type machine production equipment	Amount	Dimensions (mm)	Extra comments
Boring machine	1	3000X2500X2200	4 axes
CNC milling	9	2000x1500x1200	4 axes
CNC turning	3	Ø2700x1750	Vertical lathes
CNC turning	4	Ø1050x4000	Horizontal lathes
Milling & turning	5	Ø640x1300	5 axes

Type machine measurement equipment	Amount
CMM	2
High precision calibration	1
Level 2 non-destructive testing: M.P. & P.L.	1