BACHELOR THESIS:
a purchasing performance measurement system

Purchasing performance measurement through selecting and implementing key performance indicators

A Bachelor Thesis in the field of Industrial Engineering & Management

What is the correct performance measurement system for VMI Holland to monitor and steer purchasing operations?

Author

W. van den Brink
BSc Industrial Engineering & Management

University of Twente

Drienerlolaan 5
7522 NB, Enschede
The Netherlands

Examination Board

dr. P.C. Schuur
Faculty of Behavioural, Management and Social sciences
Department of Industrial Engineering and Business Information Systems

dr. I. Seyran-Topan
Faculty of Behavioural, Management and Social sciences
Department of Industrial Engineering and Business Information Systems

VMI Group

Gelriaweg 16
8161 RK, Epe
The Netherlands

VMI Group Supervisor

dhr. T.C. Vonk, MSc
Supply Chain Innovation
Department of Purchasing and Logistics

Preface

Dear reader,

In front of you lies my thesis that concludes a bachelor study in the field of industrial engineering and management. During the last semester, I worked on this thesis on behalf of VMI, which gave me useful experience in the field of purchasing.

First of all, I thank Thiemo Vonk for all his help. Without Thiemo's thinking along, patience, and general help, this thesis could never be concluded like this. Secondly, I thank Tim Preeker for his valuable input. Tim's help and participation increased the practical relevance of this thesis greatly. And of course, I thank all VMI employees for their help with understanding VMI as an organization, answering any questions I had, and their voluntary feedback on my work.

Lastly, I thank supervisors Peter Schuur and Ipek Seyran-Topan for their feedback during the preparation and execution of this research. Peter and Ipek's feedback acted as essential stepping stones, continuously improving the quality of this thesis.

Wessel van den Brink

Kampen, June 2020

Management Summary

This management summary addresses a short introduction to the problem, how we solved the problem, and our solution. Lastly, a summarized recommendation to the company is given.

An introduction to the Problem

Within the purchasing department of VMI (Veluwse Machine Industrie), key performance indicators (KPIs) are used to monitor the performance of the department. However, these KPIs cannot be used to adequately steer purchasing operations to increase the performance of the purchasing process. The efficiency in which a certain degree of performance is achieved is not measured by any KPI, and therefore it is hard for the supply manager to make decisions on how to steer purchasing operations. Therefore, this research is conducted with the following goal:

To propose to the supply manager a performance measurement system containing the most suitable KPIs that can be of aid in monitoring and steering purchasing operations.

An adequate set of KPIs, that contains efficiency KPIs, is expected to help management monitor and steer purchasing operations better.

Solving the Problem

A plan is created to reach the goal of this research and thereby solve the problem at VMI. This research plan consists of five phases, ultimately aimed at adequate KPIs for the supply manager. We now summarize the five phases below.

Phase 1: Purchasing at the Veluwse Machine Industrie

The research starts by researching what purchasing at VMI entails. This is expected to increase our understanding of the operation of purchasing, which is the foundation of this research. Before KPIs are selected, it is necessary to understand what exactly to measure the performance of.

Phase 2: Theoretical Key Performance Indicators

Secondly, we search for KPIs in the literature. A systematic literature review is conducted to find potential purchasing KPIs. An important finding: both purchasing – and process KPIs are potentially suitable to solve the problem. Furthermore, a framework for KPI-classification that considers objectives and managerial perspectives is proposed.

Phase 3: Selection Criteria for Key Performance Indicators

Not every KPI is of the same quality. Therefore, thirdly, we seek selection criteria for KPIs in the literature. To tailor the KPIs specifically to VMI, the selection criteria are reformulated and verified by VMI experts. These criteria are then used in the next phase, together with the other findings.

Phase 4: Selecting Key Performance Indicators

In the fourth phase, KPIs are selected via a decision-making method that is based on several theories on purchasing, performance measurement, and decision-making. Moreover, the field-expertise of VMI-experts is used as input for such a model; which is expected to result in high-quality tailored KPIs. These KPIs are subsequently assessed in the next phase, where a plan for implementing these KPIs is proposed.

Phase 5: Implementing Key Performance Indicators

Selecting KPIs is only half the work of a performance measurement project. Implementing the KPIs cannot be underestimated if an organization wishes to complete the endeavour of setting up a functional performance measurement system. Key considerations involve: motivating the workforce

to initiate and complete the project; not underestimating the task of implementing the performance measurement system; and, finally, using the system once it is ready for use.

A Solution

The KPIs together with a general plan of implementation describe our solution. The most important findings on requirements for a purchasing performance measurement system (i.e. a set of purchasing KPIs) involve the following eight principles:

Key Performance Indicators

- KPIs must stem from organizational goals, and these goals should stem from a purchasing strategy.
- KPIs must measure both the effectiveness of achieving goals, as well as the efficiency in which these goals are achieved. Efficiency is the degree to which resources are consumed.
- The set of KPIs should indicate the maturity of supplier relationships somehow.
- The set of KPIs should indicate how well the purchasing department is saving costs.
- The set of KPIs should have leading- and following metrics. That means, leading metrics can be used to steer the purchasing process; following metrics are the result of this.
- The set of KPIs should be balanced such that both financial- and non-financial metrics are present.
- All KPIs in the set of KPIs at VMI should adhere to the VMI KPI criteria: clear, measurable, and useful.
- The set of KPIs should be few in numbers: seven plus or minus two.

Implementing Key Performance Indicators

Key considerations for implementing KPIs involve mitigating the risk of a failing purchasing performance measurement system. We find, based on Neely & Bourne (2000), three main potential failures. When implementing KPIs, these should be taken into consideration.

- The selected KPIs are nonsensical
- Implementing the new system of KPIs fails
- The new set of KPIs is not used after implementation

By correctly utilizing the *unfreeze, change, freeze* methodology by Lewin (1947) we expect to successfully implement the new set of KPIs. First, the organization has to unfreeze by sparking motivation throughout the department. This may be done by adequately explaining why the new set of KPIs will enhance e.g. the ease of work, or the performance of the department.

Secondly, the new set of KPIs is implemented. This is expected a difficult task, and should not be underestimated. Loss of motivation and lack of IT infrastructure are the main reasons for failure during this phase. To be hedged, try to not underestimate the endeavour of implementing new KPIs before the start. Furthermore, management should keep the employees who are responsible for change continuously motivated by reminding them of the benefits of the new set of KPIs.

Lastly, the new set of KPIs should be ‘frozen in place’ by utilizing them. To motivate the actual use of the set of KPIs, the organization may opt to visualize good performance; as this may be considered a reward for performing well.

Recommendations to VMI

From this solution follow recommendations to the VMI purchasing department. Ultimately, implementing the new set of KPIs for the supply manager is the first goal. These supply KPIs are later

given in the table below. Ideally, in the future, this goal is extended purchasing-wide. For VMI to reach this goal, we recommend to take the following actions:

What	Why	Who
Assessing the new set of supply KPIs once more (chapter 5 & 6), including their corresponding goals.	To establish the KPIs to implement with great certainty, before starting the implementation phase.	The supply manager and at least one experienced supply buyer. LMT* should be responsible for determining the final goals for the purchasing department. These goals, ideally, should be verified by the Vice President of the department.
Unfreezing the supply sub-departments.	After formally establishing goals and supply KPIs, all supply sub-departments should be motivated to implement the KPIs.	The supply manager.
Implementing the KPIs from chapter six.	If we want to use the new set of KPIs, we need to implement these.	Implementing KPIs involves fixing the IT requirements, this should be done by the SCI department. Throughout this phase, both supply- and SCI management should try to keep the workforce motivated for change.
Using the KPIs.	The supply KPIs are there for the supply manager to monitor and steer purchasing operations. This is expected to increase purchasing performance.	The supply manager may use the new set of KPIs to dictate the operations in the office. Operational workforce should have input in how to perform the tasks; and at least should be aware of why these tasks are expected to increase performance.
Complete the PPMS across the whole purchasing department, using the presented framework for KPIs or a better one.	Purchasing is not solely supply, it involves multiple sub-departments such as sourcing, quality, and innovation. For a harmonized department: implement KPIs for each department; which are ideally based on the same purchasing-goals.	The vice president may coordinate on a more general level. The LMT managers could be responsible for KPIs for their own department. KPIs may be established with corresponding experienced knowledge workers, and 'external' SCI supply chain engineers.

*LMT: Logistics Management Team

All taken together, this may be completed over the course of at least a full year. Unfreezing is expected to take approximately a month and concerns step one and two of the table above. Changing the current system by implementing the new set of KPIs is expected to take six months, and involves step three in the table above. Getting used to using the KPIs, if correctly implemented, is expected to take a month. This is the fourth step in the table above. Lastly, to complete the PPMS, if IT infrastructure is available and the purchasing department has learned from the supply department, may be done in, at the very least, four months. Which is the final step in the table above.

As for the specific supply KPIs, these are given below:

Objective	Effectiveness KPI (Following)	Efficiency KPI (Leading)
Financial* | "How do we look to shareholders?"		
- Survive	*Profit*	*Because all KPIs listed below affect total costs in any way, these affect the 'big' financial KPIs. Therefore, all are 'efficiency' KPIs in the context of the financial perspective.*
- Succeed	*ROA*	
- Prosper	*Annual Growth for Profit and ROA*	
*Survive, succeed & prosper is taken from the ECI case-study by Kaplan & Norton (1992)		
Customer | "How do (internal) customers see us?"		
- Delivery Reliability	*Material Completeness*	*Hours of Supply Buyers planned and realized in a week*
- Product Quality	*NCP_T + NCP_L*	*Yearly number of supplier quality projects towards sourcing initiated*
- Continuous Production	*NCP & Showstopper Solving Time towards Production*	*Yearly number of supplier relation projects initiated due to external NCP failures*
NCP: Non-Conforming-Parts. These are parts that are either damaged by logistics (L) or parts that are technically (T) unfit for the machine.		
Processes | "What must we excel at?"		
- Efficient Processes	*STP*	*Yearly number of process-efficiency projects realized*
- Cost Savings (Schiele, 2007)	*Total Costs Saved*	*Yearly number of cost related task-force projects initiated.*
Learning & Growth | "How can we continuously improve and create value?"		
- Supplier Flexibility/Relations (Van Weele, 2009)	*RLIP if < Leadtime*	*Time planned & realized time for contacting suppliers to improve supplier reliability.*

The KPIs above are the new set of KPIs for the supply manager. Most of these are readily available, but there is one new KPI: STP. This new KPI expresses how efficiently the supply process is operating by measuring the degree to which the supply process is adhering to the most efficient workflow. Assuming this management summary is for management at VMI, and management at VMI knows about these KPIs, we will not further discuss the KPIs in this management summary. For a more detailed explanation of these KPIs, please see section 6.2.3 in this document.

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Abbreviations

Table 1 | List of Abbreviations

Abbr.	Definition	Introduced
LMT	Logistics Management Team	vi
VMI	*Veluwse Machine Industrie*	1
SCI	*Supply Chain Innovation*	1
P&L	*Purchasing & Logistics*	1
KPI	*Key Performance Indicator*	1
PMS	*Performance Measurement System*	1
PPMS	*Purchasing PMS*	5
BPM	*Business Process Model*	6
IT	*Information Technology*	6
STP	*Straight Through Process*	8
ERP	*Enterprise Resource Planning*	10
BOM	*Bill of Materials*	12
SLR	*Systematic Literature Review*	15
BSC	*Balanced Scorecard*	19
SMART	*Specific, measurable, attainable, relevant, time-bound*	20
AHP	*Analytic Hierarchy Process*	21
ANP	*Analytic Network Process*	21
ISO	*International Organization for Standardization*	21
NIST	*National Institute of Standards and Technology*	22
PMM	*Performance Measurement Matrix*	24
NCP_T	Non-Conforming-Parts, Technical	38
NCP_L	Non-Conforming-Parts, Logistical	38

Chapter 1 | Methodology

The first chapter of this research discusses the research methodology in three sections. First, the company and the assignment are introduced (1.1). Secondly, the assignment is researched such that a core problem is formulated (1.2). Lastly, a method for solving this core problem is proposed (1.3).

1.1 | Introduction and Assignment Description

Firstly, this section gives an introduction to the assignment given by the Veluwse Machine Industrie (VMI) and the department where the research is conducted (1.1.1). Secondly, the motivation for the research (1.1.2) and a short description of the assignment (1.1.3) are given.

1.1.1 | Introduction to Veluwse Machine Industrie

The daily business of VMI is to engineer and produce the world's most prominent production machinery. Their expertise shows across several industries, ranging from the tire- and rubber industry to the pharmaceutical industry. All these machines require components. These are purchased by the Department of Purchasing & Logistics (P&L). Their main goal: the on-time delivery of high-quality parts to the correct VMI warehouse. A team of supply-chain engineers is continuously working on optimizing the global VMI supply chain, this is the Supply Chain Innovation (SCI) team. The motivation for this research, performed with the SCI team, is discussed in the next sub-section.

1.1.2 | Motivation: Steering the process based on relevant insight

The SCI team serves the P&L department by continuously improving on the drivers of quality, logistics, technology and cost, through innovative ways. As a part of innovation in the long term, SCI wants the P&L department to migrate towards a management by exception strategy based on a higher level of automation.

To reach this goal, the purchasing department needs a correct and complete performance measurement system (PMS). This measurement system is expected to give the P&L managers the ability to monitor and steer operations within the purchasing department. From this, the measurement system may be of use in identifying opportunities for further improving- and automating the operations and processes of purchasing. Which allows for formulating the goal of this assignment, in the next sub-section.

1.1.3 | Research Goal and Assignment Description

The assignment involves designing an adequate measurement system to measure purchasing performance. The system should be able to give insight into the performance of the supply process through the most suitable Key Performance Indicators (KPIs). The research goal is defined:

> *"To propose to the supply manager a performance measurement system containing the most suitable KPIs that can be of aid in monitoring and steering purchasing operations."*

1.2 | Problem Statement

To reach the goal of this research, the problem is further analysed. In this section, the management problem (1.2.1) and the problem cluster (1.2.2) are discussed. From this problem cluster, the core problem (Heerkens & Van Winden, 2017) is identified. With the core problem identified, the problem is quantified by assigning variables and discussing the discrepancy between the Norm & Reality (1.2.3) (Heerkens & Van Winden, 2017) of the company.

1.2.1 | Management Problem

Recall that management formulated a goal to reach a higher level of purchasing process automation. To do this, a performance measurement system is required because such a system may be used to measure the effect of managerial decisions on purchasing performance. Currently, there is no insight in how efficiently the purchasing department is operating, therefore it is difficult for the managers to make decisions on how to steer operations to increase the performance of the purchasing department in terms of efficiency. From this management-problem, a problem cluster is designed that leads to the core-problem.

1.2.2 | Problem Cluster & Core Problem

From the management problem we start asking 'Why?' and follow the downward stream until the end. When an end is reached, this problem is assessed by the criteria from Heerkens & Van Winden (2017). The problem cluster (Figure 1) shows the result of preliminary research on the management problem.

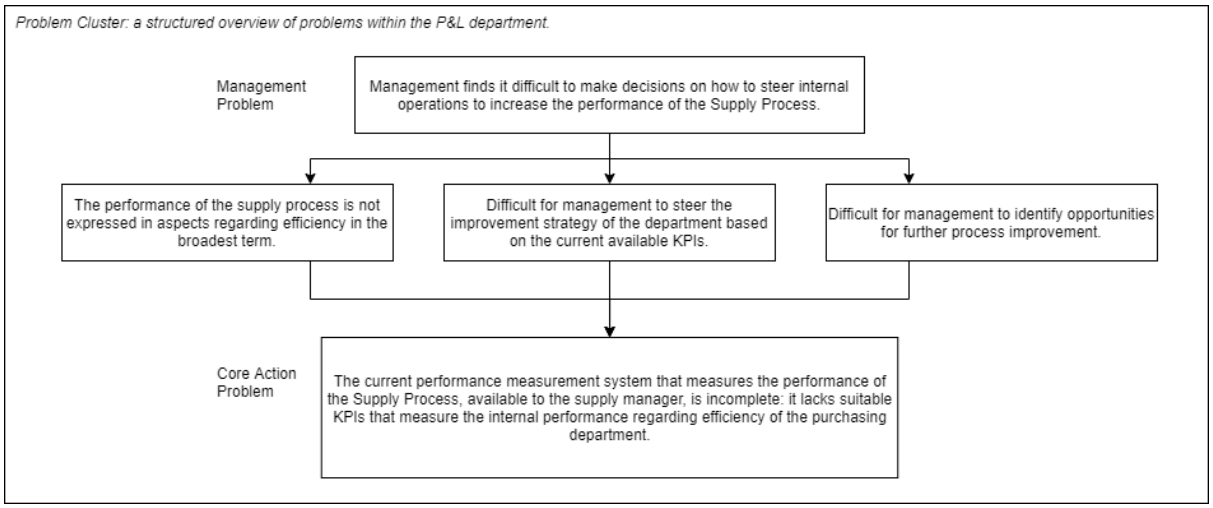

Figure 1 | Problem cluster

The management problem has grown from the core problem, which shows a discrepancy between the desired norm of VMI and the current situation. This discrepancy is discussed in the next section. Before moving on, the core problem is formulated:

> *"The current performance measurement system that measures the performance of the Supply Process, available to the supply manager, is incomplete: it lacks suitable KPIs that measure the performance regarding efficiency of the purchasing department."*

1.2.3 | Norm and Reality: The Core Problem Quantified

After the implementation of a solution, it is necessary to check if the core problem is solved. Hence, variables are defined to quantify the core problem. These variables allow for comparing the situation before and after implementing a solution. The following table discusses the discrepancy.

Table 2 | Norm & Reality

Reality: The current system to measure performance	Norm: The desired measurement system to measure performance
VMI runs different performance macros through excel in order to calculate the values of different Supplier Performance KPIs. These supplier-performance-KPIs, assuming supplier performance can be influenced by VMI, show the result of the work of the purchasing department. This is achieved with a VMI-constructed VBA tool, computing the following KPIs: $\boldsymbol{CLIP}$: Confirmed Line Item Performance indicates the percentage of orders delivered within the supplier linking-date-interval. $\boldsymbol{Delta}$ $+/-$: The range, indicated in days, in which 1-CLIP does deliver. $\boldsymbol{RLIP}$: Requested Line Item Performance The percentage of suppliers who confirmed and delivered according to the initial requesting date. $\boldsymbol{NCP/\#Orders}$: Fraction of Non-Conforming Products of the total orders.	The problem owner requires insight into the efficiency of the purchasing process. Therefore, KPIs are required that can measure performance in terms of efficiency. **Intended Final Deliverable (norm):** A measurement system structured as an advisory report that proposes how to best measure the performance of the supply process, such that management has the desired insight in the performance of the purchasing process. From the wishes of VMI, this measurement system ideally contains carefully selected KPIs, where for each KPI the following is defined: - KPI manager (role) - KPI description - KPI formula - Method of measurement (formula explained in words) - Frequency of evaluation - Norm indication - Reaction strategy - Method of Implementation

1.3 | Problem Approach Overview

To reach the norm set by the company, a deliverable is proposed that could solve the core problem (1.3.1). Secondly, an approach to reach this deliverable is discussed (1.3.2).

1.3.1 | Intended Final Deliverable

To solve the core problem we intend to give VMI an adequate measurement system that can be used to measure at least the operational performance of the purchasing process regarding efficiency. This measurement system consists of specifically selected KPIs for VMI, structured as follows for each KPI.

Table 3 | Proposed deliverable

Name of the KPI selected specifically for VMI's supply process.	
Aspect	Explanation
Manager	Stakeholder responsible for KPI value management
Description	A description of the KPI
Measurement method	How the KPI is measured (formula explained in words)
Formula	The formula of how the KPI is measured
Method of implementation	Description of a method of implementation.
Frequency of evaluation	Frequency of evaluating the value of the KPI
Norm indication	An indication of the norm should be the value to strife for
Proposed reaction strategy	What can management do if the KPI deviates from the norm?

1.3.2 | Problem Approach Overview

To reach this deliverable, five research phases are defined. For each phase, a research question is formulated and supported by sub-questions. The next paragraphs discuss each phase. Subsequently, a conceptual research model is given to visualize the approach (1.4). For a detailed plan of approach, research design, sub-questions, etc. please consult Appendix A. First and foremost, a main research question is formulated from the earlier stated research goal:

What is the correct performance measurement system for VMI Holland to monitor and steer purchasing operations?

Phase 1: The current situation

To successfully finish a performance measurement project, it is important to understand what we want to measure the performance of. Therefore, the following research question is formulated.

What does the business process model of the supply process look like and what data is available to analyse this process?

After defining the process for which performance needs to be measured, theoretical KPIs are retrieved from literature. This is phase 2 of this research and is explained in the next section.

Phase 2: Theoretical purchasing Key Performance Indicators

With the purchasing process defined, this research seeks performance indicators. Research on purchasing KPIs is selected through a systematic literature review protocol, discussed in Appendix B. The following research question is formulated.

What are potential suitable KPIs to measure the performance of a purchasing process according to the literature?

With a list of potential KPIs for VMI to use, a method to select these KPIs is necessary, the next phases discuss the parts of such a method.

Phase 3: Selection Criteria for KPI selection

Not all KPIs are the same. Phase 3 of this research involves researching what describes a good KPI, for VMI. Literature is assessed on KPI selection criteria, after which the criteria are validated by VMI. Furthermore, a method for scoring KPIs on criteria is researched. The following research question is defined.

What selection criteria should be taken into consideration when selecting suitable KPIs for the supply process at VMI and how to give these selection criteria a value?

The KPI-criteria that are the result of this phase is input for the next phase, where a KPI-selection methodology is formulated.

Phase 4: Selecting KPIs for VMI

With the KPI selection criteria set, a method for selecting KPIs is designed and subsequently used by VMI in this phase. The outcome should yield the most suitable KPIs for VMI. The following research question is defined.

What are the most suitable KPIs, specifically for VMI, based on the selection criteria, the value of these criteria, and the decision-making method?

Phase 4 yields KPIs that should be part of the performance measurement system (PMS) for VMI. The next phase involves creating this PMS from the selected KPIs for VMI.

Phase 5: Implementing the Performance Measurement System

The proposed deliverable is constructed by assessment of all the selected KPIs. The following research question is defined, supported by sub-questions regarding validity and reliability, as well as KPI-implementation methodology. Recall, these sub-questions and more can be found in the detailed plan of approach (Appendix A).

What performance measurement system(s) can be advised to VMI?

The following section visualizes the 5 phases of this research.

1.4 | Visualizing Methodology: A Conceptual Model

This section visualizes the research using a theoretical model (Figure 2) that shows a general overview of this 5-phase-research. Potential KPIs *(phase 2)* and their selection criteria *(phase 3)* are found from literature and VMI stakeholders. Subsequently, KPIs are selected using decision-making theory found in the literature *(phase 4)*. This yields KPIs suitable specifically for VMI, which is expected to increase the correctness and completeness of the purchasing performance measurement system (PPMS) after implementation *(phase 5)*. Clearly, the increased quality of the PPMS allows the managers to better monitor and steer the purchasing process. Figure 2 concludes and summarizes the methodology chapter of this report. In the next chapters, the five-phase plan of approach is executed, starting with *phase 1* (chapter 2) where purchasing at VMI is researched.

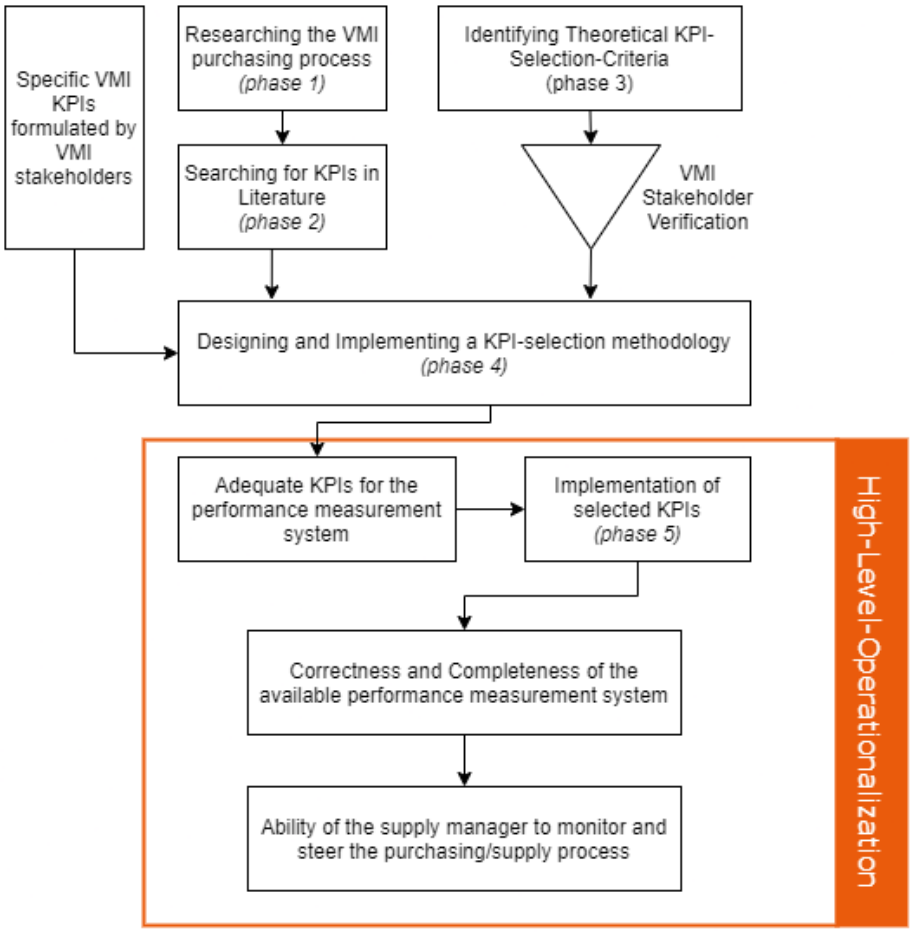

Figure 2 | Model and overview of the research

Chapter 2 | Purchasing at VMI

The goal of this chapter is to visualize the purchasing process for VMI by means of business process modelling. This business process model (BPM) lays the foundation of what ensures adequate purchasing-process KPIs, specifically for VMI.

First, the importance of BPM in performance measurement is addressed (2.1). Secondly, the purchasing process at VMI is visualized by means of a BPM (2.2). Lastly, chapter 2 is concluded (2.3).

The chapter is concluded by answering the phase 1 research question, supported by 4 sub-questions which are listed in section 2.3.

What does the business process model of the supply process look like and what data is available to analyse this process?

2.1 | The role of BPM & IT in Performance Measurement

Firstly, this section emphasizes the importance of BPM in performance measurement (2.1.1). Secondly, the role of IT in BPM is addressed (2.1.2) as well as BPM modelling language and -scope (2.1.3). Lastly, classic process KPIs are introduced (2.1.4). All of this lays the foundation for visualizing purchasing at VMI in the next section (2.2).

2.1.1 | BPM & Performance Measurement

The BPM deliverable is selected as the goal of this phase because developing KPIs to measure process performance is a complex task that requires a thorough understanding of the business or operation (Collins, Hester, Ezell & Horst, 2016). The importance of defining business processes is further stressed by Weske (2012): the definition (visualization) of a business process, should be done in order to analyse the performance of the process. Furthermore, according to Weske, the visualization should be done carefully as unclear models are a source of inefficiency. Van Sinderen (2018) stresses BPM as a company-tool that is used to understand what the company does, indicating that a BPM brings clarity to processes and thus to operations.

Therefore, before KPIs are formulated and selected to measure performance, it aids the validity of the outcome of this research to lay the foundation by means of business process modelling.

2.1.2 | BPM & IT

Business process management is the result of understanding that products delivered by organizations to their customers are the result of activities (Weske, 2012). The activities are performed by entities in the company that work towards achieving a business goal, e.g. the on-time delivery of high-quality parts for complex manufacturing machines to the correct warehouse. Such processes are evermore supported by IT (e.g. for communication and data-storage). Sometimes this IT support fully automates the business process, electronic transactions are an example of this.

An interesting application of automated business processes was the once strategic focus of banks to allow their customers easy transactions through designing the *straight-through-processing* of processes (Schabell & Hoppenbrouwers, 2009), which is a form of back-office automation. That means the customer gets what he or she wants without human-to-human interaction.

Therefore, it can be concluded that IT has a supportive role in process management and can be of aid in measuring performance by converting process-data to KPIs.

2.1.3 | BPM Scope

When dealing with complex organizations such as VMI, it is wise to determine the scope of the business process before visualizing this. Weske (2012) distinguishes between four different BPM classes, the first one resembling the strategy of the organization. The strategy determines the organization of the operations. That means: strategy determines management, management determines operations (Figure 3).

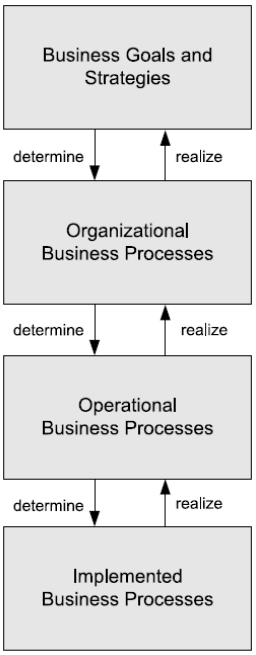

Figure 3 | BPM Hierarchy
Source: Weske (2012)

This phase aims at describing the (operational) business process of the purchasing process, from an operations management (organizational) point of view. However, if one logic-entity in the model describes *checking invoice* and no further detail is given while a *workflow, work-instruction, or protocol* exists to check the invoice, is it organizational or operational? As Weske (2012) defines it, organizational business processes describe and ensure a high-level business functionality and operational business processes describe the activities and interrelationships. Organizational business processes are management, organization, controlling, and optimization of business processes (Schmelzer & Sesselman, 2010) and process-based activities are not at all addressed.

One method of distinguishing between organizational and operational is by making use of the modelling language BPMN (Business Process Modelling Notation). BPMN represents the organizational level of a business process by adequately making use of *pools and lanes*. That means, different departments (lanes) operate towards a common goal (pool). This is later visualized in section 2.2.4, where the purchasing BPM is explained.

The pools & lanes technique clearly indicates the participation of different organizational stakeholders and their role in achieving a business goal. As procurement is considered a support activity (Porter, 1985) that is present throughout the value-chain of a business, it can be concluded that procurement is interacting with different departments; this may be visualized using the *pools and lanes* technique from BPMN.

2.1.4 | BPM & KPIs

The performance of processes may be expressed through KPIs. Van Sinderen (2018) lists seven examples of measures that can be used in business process performance analysis. The measures are given in Table 4 and show classical measures which are commonly used in manufacturing - and healthcare processes. These indicators are referred to as *technical indicators* by Weske (2012) and are distinguished from *business indicators,* which are e.g. cost-reduction. Important is that KPIs are determined from business goals, it is better not to blindly measure all that is possible.

Table 4 | Process KPIs by Van Sinderen (2018)

Measure	**Definition**
Capacity	Maximum output rate, measured in units produced per unit of time.
Capacity utilization	Fraction of the maximum capacity that is being used at any time, or on average during a time-interval.
Throughput rate	The rate at which units flow past a point in the process.
Throughput time	Average time for a unit to be processed by the full process.
Cycle time	Time between successive outputs: $cycle\ time = 1/throughput\ rate$
Idle time	Time during which no work is done.
Inventory	From Little's Law: $inventory = througput\ rate\ *$ throughput time

2.2 | Researching Purchasing at VMI

This section discusses the purchasing BPM (Figure 4) in section (2.2.1). Secondly, the cooperation of the strategic- and tactical purchasing functions at VMI is discussed (2.2.2). Lastly, stakeholders are identified (2.2.3) and the BPM is concluded (2.2.4).

2.2.1 | Purchasing BPM

The supply process at VMI is part of the purchasing process which entails sourcing and supply, but they are a sequence. Therefore, the performance of supply *(operational purchasing)* is, generally speaking, influenced by the performance of sourcing *(strategic purchasing)*. Interviews with VMI stakeholders indicated the impact of strategic- on operational-purchasing performance as well; this empirical, yet specific evidence is highly taken into consideration to make the final deliverable VMI specific. Therefore, both sourcing and supply are assessed in the model.

The way this is done is by assessing the VMI purchasing process from a general perspective. That is, we observe the purchasing department on their compliance with the general well-known purchasing process by Van Weele (1988), which is later discussed in the next chapter, and use this general process as a conceptual framework. This framework is visible in the BPM (Figure 4), by setting global purchasing activities as the main process where sub-processes are modelled inside.

At VMI, a best-practice purchasing process exists such that the order-flow is highly efficient. In such a case, there are no deviations because all data is correctly available. The order is received on-time without the need for expediting, therefore there is compliance to the initial request and the order is delivered on-time to the correct warehouse. Qualitatively and quantitatively there were no issues as the part moved to production and took its place in the machine. This order-flow is given in the BPM by the green line and will be further regarded to as the straight-through-process (STP).

The role of IT in the VMI purchasing process is visualized by using database icons where-from and -to information-flows are modelled using dashed lines. For each order, this information concerns 37 attributes. The time-bound attributes consider the order dates, planned- and confirmed receipt date as well as their mutations. Lastly, the start of the project is linked to an order as a JIT deadline.

2.2.2 | The impact of Sourcing on Supply

The sourcing and supply dependencies are in terms of data-quality (communication) and quality of the available suppliers. When orders are monitored through the ERP system, anything may occur resulting in deviations from the STP. Quality of the selected supplier to fulfil the need is highly affected by the quality of the available suppliers. Furthermore, data availability from sourcing to supply through the IT systems is crucial for adhering to the most efficient flow (STP).

2.2.3 | Stakeholders

Stakeholders are identified through Appendix C which is taken from the definitions of process stakeholders by Weske (2012).

Stakeholders within the complete purchasing process involve the vice president (VP) of global purchasing and logistics. Moving downward in the organization, each lane in the pool has a manager. These managers are responsible for the performance and development of the process. In terms of Weske, they are the Chief Process Officer (VP) and the Process Owners. Under the management of the process owners is the VMI operational workforce (process participants). These are titled either supply- or sourcing-buyers. As IT is completely integrated in the process, this operational workforce may be regarded to as knowledge-workers.

2.2.4 | Introducing the BPM

The BPM (Figure 4) gives an adequate overview of purchasing at VMI because the BPM is validated by the knowledge workers of the supply department by conducting an unstructured interview where the process was discussed step-by-step. Furthermore, the supply chain engineer is taken through the BPM and we were not able to find significant deviations from the perceived real-world process that could be of hindrance in further continuation of this performance-measurement research. Lastly, the model was presented to the supply manager who concluded that, for this research, the model adequately resembles the real purchasing process.

> "Supply cannot be visualized by one model. The knowledge and expertise of the supply buyer influence the real-world-process."
>
> VMI SUPPLY MANAGER

On a critical note, we state that no model can fully accurately resemble the real-world process of purchasing. Supplier relationships are subject to many factors, orders can deviate from the process in many ways and there are even more ways at VMI to solve the deviation.

Before concluding this chapter, the BPM is introduced and explained along the six-step purchasing process (Figure 6), discussed in the next chapter. The BPM is given on the next page, and distinguishes five main processes. These processes are conducted between four different departments (visualized by lanes), all working towards the goal of ensuring the on-time delivery of high-quality parts to the correct VMI warehouse (the pool). Now, the BPM is described.

First, the needs for Production are specified by the Engineering Department. These needs are then given a planned production date by the WVB Department. Therefore, the first task (*1. Specification*) generates a bill of materials and a production date on which the part is ultimately required.

Secondly, if the order concerns a new part then the order moves through *2.Selection* and *3.Contracting*. That means, a supplier is selected and the necessary agreements are made. Both these operations are part of the sourcing department. Our model visualizes this by placing the 'big-blocks' in the correct lanes. These 5 *big-blocks* resemble the Van Weele purchasing process.

After the necessities of selecting a supplier and signing the contracts, an order is placed. Here, the supply department takes over (new lane) by ensuring *4.Ordering*, *5.Monitoring* and *6.After-Care.* As visualized, the order is placed (*4.*) and monitored (*5.)* using an IT system. If nothing happens, the order is delivered to the warehouse, approved and used in production; as visualized by the green line, which resembles the most efficient process (STP).

However, monitoring and after-care are significantly part of the process for a reason. Anything may go wrong, as a result: *expediting*. From here, the *supply buyer* contacts the supplier and starts doing his job. Summarized for modelling convenience, there are three hierarchies of importance: *general-, bottleneck-, and showstopper* expediting. Important is that any type of expediting may be considered a deviation from the most efficient process, and that all expediting may be successful or not. Any adjustments to the order are noted such that up-to-date monitoring is ensured, and the order goes back on the monitor-list until delivered or further management is required.

On a last critical note: if the order reaches the warehouse incompletely then a new order is placed if planning allows. Otherwise, it is a showstopper. This is visualized by the last '**+**' gateway. Which is a BPML inconsistency, but the order-flow is clear, so this is accepted for practical purposes.

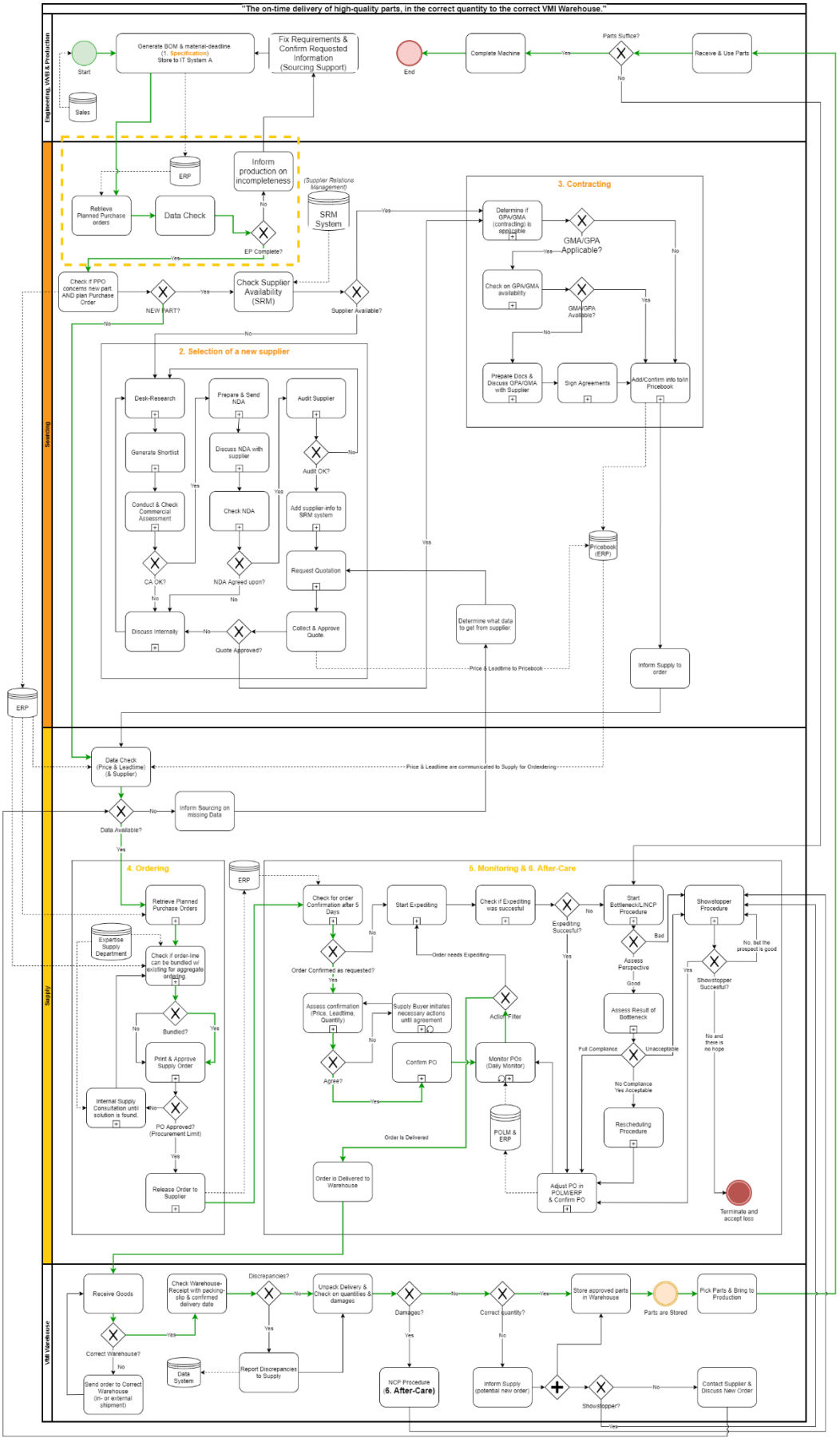

Figure 4 | The Purchasing BPM for VMI

2.3 | Concluding Chapter 2

This section concludes chapter 2 by answering the main question and its sub-questions. Chapter 2 discussed the importance of BPM and IT in the field of performance measurement, and subsequently addresses potential KPIs to measure process performance. From this basis, the BPM of the purchasing process is visualized.

This BPM is the foundation for further research because it defines what this research aims to measure the performance of, how the different departments work together, and is the foundation for the implementation of technical indicators. This section concludes chapter 2 by formulating answers to the following research questions.

What does the business process model of the supply process look like and what data is available to analyse this process?

Figure 4 shows the BPM of the purchasing process, lane *supply* shows the model of the supply process, answering the first half of the main research question of this chapter.

- *Within the scope, what are the flowcharts of the procedures within the supply process?*

The supply process is part of the purchasing process and is shown in its own *sub-lane*. This is a high-level overview, based on the interviews and observation of process participants and work-instructions. The level of operational detail allows for an adequate overview of the supply process, based on validation interviews with the supply chain engineer and a knowledge worker.

- *Who are the stakeholders involved in the supply process?*

The lanes represent the high-level stakeholders in terms of departments, but process-participants and knowledge-workers differ in each lane. The process owner differs as well, VMI structured the purchasing process such that every lane has a process-owner, who is a manager. The stakeholders are potentially taken into consideration when selecting KPIs through a stakeholder-involved multi-criteria decision-making methodology (chapter 5).

- *Within the defined scope, what are the IT systems used in the process?*
- *What data is available on the IT systems to analyse the process?*

IT systems and the relevant data these store are visualized by database icons in the BPM (Figure 4), the role of IT is visualized using dashed lines as information flows. The data that is stored to analyse the performance of the process are the time-bound criteria and their mutations.

Chapter 3 | Theoretical Framework on Purchasing and KPIs

The goal of this chapter is twofold. First, a conceptual framework for purchasing and performance measurement is created (3.1). Secondly, this framework is used to find theoretical KPIs by conducting a systematic literature review (3.2). After this, more literature KPIs are discussed (3.3), and the chapter is concluded (3.4).

3.1 | Theoretical Framework

This section creates a theoretical framework for purchasing and performance measurement. First, a theoretical perspective is defined (3.1.1). Secondly, purchasing and performance measurement are defined (3.1.2). Lastly, these are combined (3.1.3).

3.1.1 | Theoretical Perspective

The research is conducted through the perspective of operations- and performance management combined with management science. This perspective is selected because the assignment involves proposing a measurement system that measures the (operational) performance of the supply process. The correct KPIs need to be selected to propose a measurement system; the selection of KPIs is done by application of decision-making models and techniques (management science) on potential KPIs (operations- and performance management).

The theoretical perspective throughout this research is a combination of Operations- and Performance Management, in the context of purchasing.

3.1.2 | Purchasing and Performance

Purchasing Process

Telgen (1994) defines purchasing simplistically: "Purchasing is anything resulting in an invoice!" This is a broad definition, and it should be stated that this definition does not distinguish, according to de Boer & Telgen (n.d.), between different kinds of items purchased. For example, an auditor is hired and sends an invoice: purchasing. The office requires new chairs, the chairs are purchased: purchasing.

Table 5 | Item Example (de Boer & Telgen, n.d.)

	Direct	**Indirect**
Goods	Materials	Office supplies
Services	Temporary Labor	Cleaning
Works	Factory	Head Office

With purchasing defined, a new question is asked. Why does a company get an invoice? Most likely because the company needed something. Table 5 distinguishes between 'Goods, Services and Works' classified in Bill Of Material (direct, BOM) and Maintenance, Repair and Operations (indirect, MRO). Clearly, an invoice is received because the company made use of any of these classes.

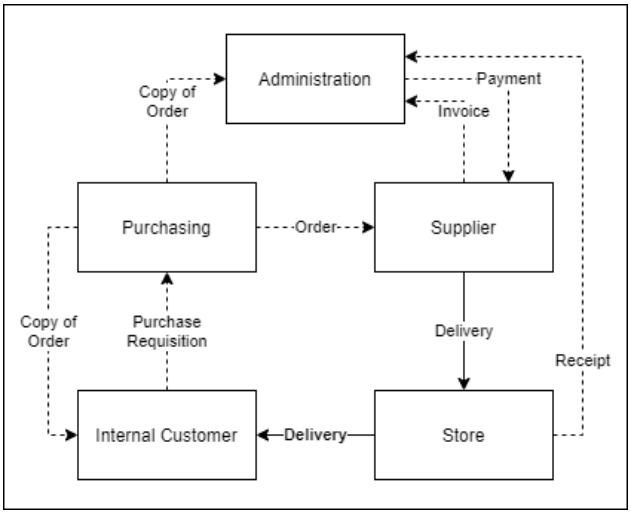

Figure 5 | Typical flowchart of the ordering process
After: Telgen & Lenselink, 1998

The function of a purchasing process in an industrial context is no different. At VMI an internal demand is generated by the production department. This demand is then fulfilled by letting the purchasing department do its job. As VMI states, "VMI's purchasing department is tasked with converting planned purchase orders into on-time delivery of high-quality parts to the different

global production locations." This empirical definition is in line with the well-known definition of Telgen (1994).

Figure 5 shows a typical ordering process, after Telgen and Lenseling (1998). From this flowchart, it can be concluded that the process ends at *Delivery* to the internal customer. It can be concluded that the goal of a purchasing process is 'delivery of a purchase requisition that has been transformed into a purchase order'.

Activities that shape a general purchasing process

With purchasing and its goal defined, this review aims at finding how purchasing achieves its goal. The literature is reviewed to gain insight into the working of general purchasing processes.

The model designed by Van Weele (1988) defines the purchasing process as six activities (Figure 6). These activities can be classified as tactical or operational. Throughout the literature, the tactical function may be referred to as strategic procurement.

As becomes clear from the model, the strategic function contains the product, supplier and contract specifications. This part has the greatest cost impact, according to de Boer & Telgen (n.d.). The operational side of the purchasing process is mostly about monitoring of the procured orders. After ordering, which can be done through a multiple of communication methods, the order is 'kept an eye-on'. Different activities may be part of the monitoring phase, but the most important activity may arguably be expediting.

Expediting is one alternative that is used to complete projects on schedule (Hu, Cui, & Demeulemeester, 2014) and the decision to do so is made by the result of a time-cost trade-off problem. Clearly, an arsenal of planning & scheduling techniques may be used to determine if/how expediting is cost-efficient. Mostly, this depends on the organization and the ease of rescheduling work, e.g. production. The most common technique is likely the common sense and expertise of the operational purchaser, even though highly advanced stochastic critical path methods have been modified to improve the expediting of projects by Johnson & Schou (1990).

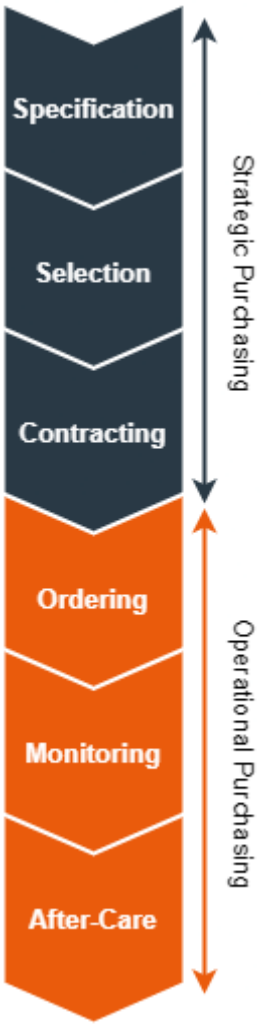

Figure 6 | Purchasing process

Operations Management

The operational purchasing function within companies is there to make sure projects can be followed according to a predefined schedule. Workers are performing the tasks listed in Figure 6 until the delivery of the order, as seen in Figure 5Figure 6. This is an operation, that should be managed. Operations Management: "Operations management is the activity of managing the resources that create and deliver services and products." (Slack, Jones & Johnston, 2013, p.6).

Performance Management

Any department in a company has a defined goal. When the goal is defined, the department goes to work. The performance of the department lies in achieving these goals. Performance Management: "is the 'process of assessing progress toward achieving predetermined goals. It involves building on that process, adding the relevant communication and action on the progress achieved against these predetermined goals. It helps organizations achieve their strategic goals'" (Slack, Jones & Johnston, 2013, p.651).

Performance Measurement

"Performance measurement is the process of quantifying action, where measurement means the *process of quantification* and the performance of the operation is assumed to derive from actions taken by its management." (Slack, Jones & Johnston, 2013, p.645).
In other words: (1) Management takes an action, this (2) determines the performance of the operation, this performance is measured by (3) the process of quantifying the action in terms of process performance.

Key Performance Indicators

"Key performance indicators are a summarized set of the most important measures that inform managers how well an operation is achieving organizational goals." (Boddy, 2014, p.619)

Management Science

Management Science (MS) is the science of decision making. As becomes clear from the theoretical model of this research plan (Figure 2), a decision method is to determine adequate KPIs for VMI. A problem is solved based on criteria. Hence, a good MS definition may be: *"the application of quantitative techniques and scientific concepts to help executives solve the planning, decision making and control problems of large, complex organizations."* (Cohen, n.d.).

3.1.3 | Purchasing and Performance Measurement

As described in the problem statement, the research involves selecting the most suitable KPIs for the purchasing (supply) department of VMI. The race-car model (Figure 7) depicts the (K)PIs as the road on which the car drives. I.e. the purchasing department steers on the performance indicators. Concluding, the purchasing department needs KPIs to steer operations.

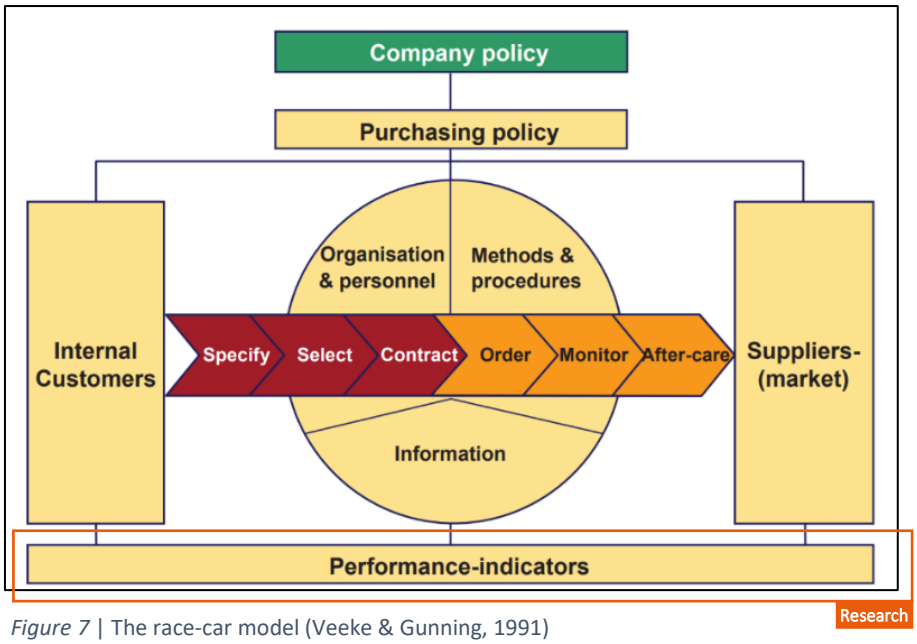

Figure 7 | The race-car model (Veeke & Gunning, 1991)
Source on illustration: Schotanus (2018)

Theoretical KPIs are searched for in the next section, which uses this theoretical framework as direct input for a systematic literature review.

3.2 | Purchasing Key Performance Indicators

The goal of this section is to find potential suitable KPIs to measure the purchasing performance of VMI. In other words: the goal is to answer the research question of phase 2 as described in section 1.3.2. The research question is answered by using the theoretical perspective (3.1) as direct input for a systematic literature review (SLR). The following knowledge problem is defined:

According to the literature, what are potential suitable KPIs to measure the performance of a purchasing process?

The first sub-section discusses the SLR (3.2.1), after which a concept matrix is created based on the integration of different theories (3.2.2). This integration of theories is subsequently analysed, discussing how an organization such as VMI may make use of such a framework (3.2.3). Lastly, the framework is discussed on ambiguities (3.2.4).

3.2.1 | Systematic Literature Review

A systematic literature review is conducted to find useful papers to answer the research question above. The protocol of this review is given in Appendix B. Furthermore, bibliographical notes that summarize the selected papers are given in Appendix G. The SLR yields 12 objectives that KPIs can measure, this may be managed through the management perspectives of operational, tactical and strategic. Lastly, the SLR yields 29 potential KPIs, although some are not metrics. These are placed in the conceptual framework (Table 7).

3.2.2 | Concept Matrix

Papers are assessed on the dimensions or objectives of the measurement. An overview of this assessment, which summarizes the thought process behind Table 6 and Table 7 is given in Appendix G. Table 6 answers the sub-question of phase 2, as given in Appendix A.

Table 6 | Concept matrix of KPI objectives

	Papers Discussing the Listed Dimensions				
Dimension or objective	Caniato, Luzzini & Ronchi (2012).	Habibi, Kermanshachi & Rouhanizadeh (2019).	Nabelsi (2011).	Van den Heuvel & Papazoglou (2010)	Gunasekaran, Patel & Tirtiroglu (2001)
Cost	X	X	X		X
Time	X	X	X	X	X
Quality	X	X	X		X
Flexibility	X				X
Reliability	X		X	X	
Innovation	X				
Sustainability					
Quantity		X	X		
Effectiveness					X
Capacity					X
Efficiency					X

Table 7 answers the main research question of phase 2. Selected KPIs and metrics are classified along the hierarchical decomposition of Anthony (1965) and Hans & van Houdenhoven (2011), and are classified along the main objectives identified in table 6.

Table 7 | The selected KPIs classified

KPI or Metric	**Decomposition according to Hans & van Houdenhoven (2011); merged operational**		
Dimension or **Objective**	Strategic (Long term decision making)	Tactical (operational, but longer horizon)	Operational (Short term decision making)
Cost		*Cost of purchasing function*	*Cost per operation hour*
Time	*Total cash flow time* *Order lead time* *#Times supplier started manufacturing too late.*	*Purchase order cycle time* *#Orders shipped too late* *Transportation Delays*	*Total throughput time* *Purchasing throughput time* *%Orders meeting on-time delivery goals*
Quality	*Supplier performance*	*Supplier ability to respond to quality problems* *Material Quality*	*Quality of delivery documentation* *Quality of delivered goods*
Flexibility	*Flexibility of service systems to meet particular customer needs*		
Reliability	*%Unacknowledged orders by supplier after X days* *%Orders late commitment ship date* *%Suppliers meeting the service conditions*	*Delivery reliability*	*% of procurement requests, purchase orders, bids, mandates and call for tenders emitted without intervention and error*
Effectiveness	*Delivery performance*	*Effectiveness of delivery invoice methods*	*Number of tenders to be renewed or renegotiated*
Capacity		*Capacity utilisation*	
Efficiency		*Supplier assistance in solving technical problems*	*Efficiency of purchase order cycle time* *use of e-procurement*

3.2.3 | A Framework for Classification of KPIs

The KPI-classification framework (Table 7) may be used for generating KPIs in phase 4 of this research. That means, management may set objectives for performance management and thus these objectives need measuring. Different managerial hierarchies may require different KPIs that monitor the performance of purchasing. The use of this model is best explained with an example.

Say, an organizational objective is to improve *efficiency* by reducing the *time* in which an invoice is processed. On the y-axis of the framework, *time* is set. Secondly, a managerial perspective is selected. That means, to reduce time through *operational, tactical* or *strategic* management of e.g. processing the invoice. The framework is consulted to select KPIs from literature. Each managerial perspective may require different KPIs. There is however some ambiguity, as discussed in the next section.

3.2.4 | Discussion on SLR Literature

Comments on Hierarchical Decomposition

First, it should be noticed that the hierarchy proposed by Anthony (1965) and Hans & van Houdenhoven (2011) is multi-interpretable when no process has been set as a constant. For example, the metric '*#Times supplier started manufacturing too late'* may have several root-causes.

A poor sourcing strategy or poor sourcing *(strategic/tactical)* may have resulted in poor supplier selection; which has resulted in late manufacturing by the supplier. Secondly, if the planning and scheduling of jobs *(tactical)* is not done according to the lead-times in the contract, the result may be that according to *your* planning the supplier has started the manufacturing too late even if it is still within the boundaries of the agreed-upon contract. In this case, the fault lies with the production planning. Or, if the planning is set and subsequently needs are procured, the fault may be in the contracting part of the purchasing process, which is considered *strategic* purchasing.

If all contracts are the same it may be part of the ordering (*operational)* procedure, e.g. standard 'terms and conditions' are sent when placing an order before the supplier has accepted. Another reason for manufacturing starting too late could be failed expediting; which is purely *operational* and unplanned, most of the time.

Concluding, depending on the nature of the purchasing process and its place within the company, the KPIs may be classified differently. Therefore, an adequate understanding of the company-specific KPIs is necessary before selecting and classifying KPIs. However, thinking based on objectives and managerial perspectives may be of aid in formulating KPIs; therefore the empty model, that is an empty Table 7, is not discarded for practical use.

3.3 | More Key Performance Indicators

Recall, chapter 2 has arguably more to do with process technology than it has to do with purchasing. However, process KPIs are useful technical KPIs to measure the operational performance of especially the supply department, because their tasks could be summarized as transaction-process-management. Hence, the process KPIs from chapter 2 are added to the literature-KPI list. This list may be found in Appendix H.

3.4 | Concluding Chapter 3

This section concludes phase 2 of the research by answering one sub-question and the main research question.

What are potential suitable KPIs to measure the performance of a purchasing process according to the literature?

Suitable KPIs involve purchasing-, transactional-, process-, and general supply-chain-KPIs. An overview of which is presented in Appendix H. In the process of KPI-selection, the framework presented in Table 7 may be consulted to define objectives and how to measure/manage these through the managerial dimensions of operational, tactical and strategic. Different managerial perspectives may require different KPIs to measure and manage an objective. Thereby answering the sub-question of this phase: 'According to the literature, along which dimensions should KPIs be classified?'.

In the next phases of this research, the theoretically suitable KPIs may be assessed by VMI stakeholders. Chapter 5 proposes a model for KPI selection, therefore the theoretically suitable KPIs from this chapter are not yet explicitly discussed.

The next chapter (phase 3) combines literature and VMI stakeholders to formulate criteria that KPIs should meet. These KPI criteria may be used in describing the goodness of a KPI, if given a score. Together with the KPIs we have just identified, these are input for the chapter 5 KPI-selection methodology.

Chapter 4 | KPI Selection Criteria

The goal of this chapter is to find KPI-selection criteria that may be used to select KPIs for VMI in the next chapter. The following research question is answered:

What selection criteria should be taken into consideration when selecting suitable KPIs for the purchasing process at VMI and how to give these selection criteria a value?

To answer this question, three sub-questions (SQ) are formulated. These sub-questions consider theory on performance measurement to identify aspects of good KPIs. Secondly, VMI stakeholders identified in chapter 2 are asked to verify and/or reformulate the theoretical criteria. Lastly, methods for scoring KPIs on the selection-criteria are researched. The following SQ's are considered:

- What aspects does a good KPI have and how can these be used as selection criteria?
- Which of the identified stakeholders to take into consideration when determining criteria?
- How to determine the value of the identified criteria?

The first section explains why and how selection criteria are retrieved (4.1). The following three sections discuss KPI theory (4.2), KPI selection methods (4.3) and performance measurement systems (4.4). These sections are then summarized and assessed on selection criteria (4.5).

After selection criteria are found these are verified by VMI stakeholders (4.6). After which a method for valuing criteria is discussed (4.7) before concluding the chapter (4.8).

4.1 | Introduction to Theoretical KPI Selection Criteria

This sub-section discusses the reason for making use of selection criteria (4.1.1) and hypothesizes where these criteria may be retrieved from literature (4.1.2).

4.1.1 | Why focus on Selection Criteria?

Before we start enumerating, what may seem like, random selection criteria it is important to think about in what way criteria are used in the context of KPI selection. The use of the criteria in this research is, after all, to be able to select adequate KPIs for VMI.

After preliminary research on KPI criteria and aspects, it can be concluded that the body of knowledge on KPIs can be extended by taking into consideration both *KPI-selection-methods* and *performance measurement systems* (PMS). Which means, by taking one-step-ahead (to where the criteria and the KPIs are used), we greatly enlarge the body of knowledge that may be used to derive KPI selection criteria from.

Selection criteria may be used to describe the goodness of KPIs. This is important because KPIs build the PMS. Hence, good selection criteria are the start of an adequate PMS, reducing the probability of failing this measurement initiative.

Neely and Bourne (2000) claim here that 70% of balanced scorecard (BSC) implementations fail. According to Neely and Bourne, there are two main reasons for failure. The first, the selected metrics make no sense (Bagett & Hester, 2013) and are numerous; strict selection based on selection criteria may reduce the number of KPIs and ensure a certain KPI-standard such that the KPIs do make sense.

Secondly, Neely and Bourne discuss the behavioural aspect of KPI implementation. An interesting example is the *time to answer* metric in a call-centre: agents picked up the phone quickly after it rang and hung-up immediately just so the numeric value of a KPI was sufficient. Clearly, this decreases the performance of the call-centre. A criterion to take into consideration here:

manipulability; also stressed by Carter (1991). To avoid behavioural failure, the manipulability criterion may be taken into consideration if VMI stakeholders deem this necessary.

Concluding, carefully selected and verified selection criteria are expected to reduce the probability of a failing PMS. The following sub-section discusses a model for retrieving further selection criteria.

4.1.2 | A Model for Retrieving Criteria

Figure 8 distinguishes three tracks that may lead to potential KPI selection criteria. First, KPI theory is assessed to find selection criteria (4.2). Secondly, KPI-selection-methods are assessed (4.3), to analyse what researchers use as selection criteria. Lastly, PMSs are assessed (4.4) on aspects of good performance measurement, because KPIs measure performance.

The results are then analysed on KPI-selection criteria after which a method for stakeholder-verification is proposed and conducted.

Finally, selection criteria for further use are determined; thereby concluding this chapter.

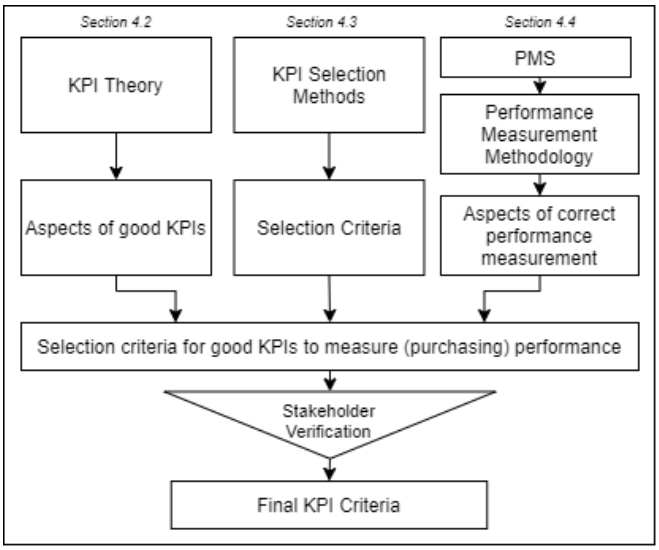

Figure 8 | Retrieving Criteria

4.2 | Retrieving Criteria from KPI Theory

This section aims to answer the question: 'According to the literature, what is a good KPI?' Clearly, this is a broadly formulated research question, and many criteria may be formulated.

However, think of criteria and one may think of the S.M.A.R.T. criteria by Doran (1981) which are widely known across academia, mainly used to define and assess goals. But these criteria also have strong ties to performance measurement, as these criteria can set objectives for KPIs (Brummelhuis, 2016). KPIs can contribute to the measurement of how well the organization is achieving its goals, if using a target-range (goal) for the KPI (Weske, 2012). Ideally, that target needs to be *Measurable*.

Further practical use of the SMART criteria is proven by Bexelius, Carlberg & Löwing (2018), goals that are formulated based on the SMART criteria are relevant to both clients and experts in paediatric rehabilitation-treatment.

Hence, a set of five potential selection criteria are identified: *Specific, Measurable, Achievable, Realistic and Timely.* These are added to the criterion found in the introduction: *manipulability*.

4.3 | Retrieving Criteria from KPI-Selection-Methods

Recall the criteria-retrieval model (Figure 8). This section retrieves criteria from selection methods. First, methods for selecting/formulating KPIs are identified from literature (4.3.1). Secondly, these methods are assessed on selection criteria (4.3.2). Lastly, a summary is given that gives an overview of the identified selection criteria (4.3.3)

4.3.1 | Identifying Selection Methods

An extensive literature review on KPI-selection methods is done by Zwanenburg (2018) where five selection methods are discussed. Interestingly, no combination of methods is proposed or discussed. However, the relevancy of process experts in KPI-selection is addressed, based on the work of

Coppola, et al. (2014) and Lai, Molinari, Fiasché, & Luglietti (2016); and is even regarded to as a method of KPI selection in itself. Furthermore, incorporating process experts in KPI selection has shown success for VMI in earlier research by Brummelhuis (2016).

The five methods by Zwanenburg involve *consulting managers, consulting literature, using a management-standard, using selection criteria,* and*, using a decision model*. These may be combined by using the AHP (Saaty, 1980) methodology where selection criteria are gathered from literature and process experts. Process experts formulate KPIs, by possibly taking ISO standards and literature into consideration. Subsequently, the KPIs are scored and these matrices may then be used in a decision model such as the AHP. The following section discusses the use of AHP in KPI-selection methods. The use of AHP requires using criteria. But what criteria?

AHP… but what criteria?

The AHP is a well-known process that is used to develop a structure of hierarchy to a set of potential decisions. For a comprehensible description of AHP see e.g. Winston (2003). In KPI-selection the KPIs can be compared to each other on pre-determined criteria. This method has proven useful across literature and is still applied in modern-day KPI-selection.

Podgórski (2015), Shahin et al. (2007), and Chorfi et al. (2015) use the AHP to select KPIs that measure the performance of systems by setting SMART requirements for KPIs. The SMART criteria are given weights through pairwise comparison of the criteria and KPIs by a team of experts. The use of SMART criteria is justified by Podgórski from a comparison of the work of by Kjellén (2009) and Carlucci (2010). However, Kjellén uses the criteria by Rockwell (1959) where the *time-bound* criterion is not addressed. Carlucci neglects the time-bound criterion as well. Furthermore, Carlucci does not consider the *achievable* criterion. We consider both these criteria potential crucial aspects of KPIs, because it should be possible to track when the performance *(time-bound)* reaches an *achievable* goal. Furthermore, in a complex organization, the ability to measure KPIs may require significant investments. Therefore, achievability in the context of ability to measure the KPI is considered as well.

Carlucci advocates the Analytical Network Process (ANP) (Saaty, 1996) to prioritize KPIs, because KPIs can have relationships (Carlucci, 2010) (Kang et al., 2016). Selection criteria are partly SMART, as previously discussed. The use of the ANP methodology is further used by Van Horenbeek & Pintelon (2014) for selecting maintenance KPIs based on criteria derived from different managerial perspectives: operational, tactical and strategic. The criteria are selected through these perspectives based on literature-based objectives of maintenance, indicating that selection criteria for KPIs should be in-line with the goals of the organization. When field experts are assessed to formulate organizational goals, the literature on that goal may be consulted afterwards. Further successes of combining literature and field-experts in formulating criteria are by Kibira & Feng (2017) and Gonçalves, Dias, & Machado (2014).

On the topic of advances in AHP-SMART, Kaganski, Majak, Karjust, & Toompalu (2018) further advance the model of Shahnin & Mahbod by adding two additional criteria: *explainable* and *relative*. *Explainable* meaning that KPIs are not meaninglessly measured, but rather have a reason for them to be measured; overlapping with definitions of *Relevant*. *Relative* meaning that KPIs are still relevant when the organization grows in any way. Which is an unnecessary selection criterion when an organization chooses to frequently assess their KPIs, as recommended by Horst (2020), based on best-practices. Next to the additional two criteria, the AHP is complexed by using the fuzzy-AHP, indicating that the scores given to criteria by stakeholders or process-experts may be uncertain.

Concluding, the AHP and its successors ANP and fuzzy-AHP are widely used to select KPIs based on how well KPIs perform on selection criteria. Common selection criteria are often SMART criteria, and criteria that are the result of opinions of field-experts. Commonly, process experts score KPIs on the SMART criteria. However, this is not the only criteria-based selection method.

The NIST Method

Consulting managers, process- and field-experts is a popular concept in KPI-selection methods. Field experts are heavily relied on by the *Networked Control Systems Group,* which is part of the *National Institute of Standards and Technology* (NIST) and known for their contributions to the relevancy of the International Standardization Organization (ISO). The work of NIST on KPI-selection has shown great improvement in the performance of two major international manufacturing companies, both the chemical enterprises of Johnson-Matthey and BASF acknowledge the usefulness of the NIST methodology and would revise their KPIs in a one-month project once a year (Horst, 2020). The work of NIST on KPI-selection-methodology is recent literature, and their method focusses on field-application.

NIST: AHP but Different

The work of NIST and the Old Dominion University on KPI-selection methodology is extensive, and discusses several aspects and methodologies. Horst (2015) proposes an approach where a team of industry-professionals participate in a protocol where KPIs are formulated, and subsequently scored on numerous KPI-effectiveness criteria (Appendix I). Furthermore, Horst discusses the importance of a balanced set of KPIs. Therefore, after the scoring of individual KPIs, sets of KPIs are scored on *balanced-ness*. This indicates that it might not be best to propose a PMS consisting of some KPIs that are high on the criteria-based hierarchy list. Balanced-ness of a set of KPIs in the work of NIST is determined by field- or process-experts. The set with the highest score average score is selected.

The selected KPIs form the PMS and may be assessed in a different project. Hester et al. (2016) build on the Horst (2015) methodology by proposing a KPI-assessment-method. The proposal is based on Value-Focussed-Thinking, and involves the utilization of a value function for the criteria by Horst (2015). For each KPI, each criterion is given a score x. This score is then transformed using a value function $V(x)$. Clearly, stakeholder preferences are taken into consideration when determining the KPI score for each criterion because each stakeholder has to make use of the value-function when scoring KPIs on the criteria. After this KPI assessment, the output are scores for KPI-Criterion pairs. This result can then be used for further KPI improvement, as is discussed in the next section.

Improving KPI-Criterion pairs

Building on the work of Hester et al. (2016) a new paper arises by Collins, Hester, Ezell & Horst (2016) that discusses where to invest resources in improving KPIs on the criteria by Horst (2015). KPI-Criterion pairs are assessed on their ability to improve the utility of a KPI. However, the assumed improvements are not linear. That is, a company may have a budget for k improvements but the increased utility of a KPI with the $k-1\ th$ improvement is greater than the $k\ th$ improvement.

Assuming PMS are made of KPIs, this may indicate that a KPI could be assessed on how this KPI may increase the utility of a given PMS based on how the KPI scores on selection criteria before adding the KPI to a PMS. Therefore, a selection criterion of a KPI may be *added utility* to a given PMS; indicating that KPIs need to be *few-in-numbers* and yet make an excellent PMS.

4.3.2 | Analysing identified Selection Methods to find Selection Criteria

The literature review on KPI-selection-methodology (4.3.1) yields criteria from unique methodologies. This section analyses the identified selection methods to find KPI-selection-criteria.

Consulting Professionals, Literature and ISO-Standards

Literature indicates that field-experts may be consulted in formulating selection criteria, as well as in scoring selection criteria retrieved from literature. Furthermore, ISO management standards may be used as 'industry-literature' because ISO9001 requires an organization to formulate KPIs, and ISO22400 provides a list of KPI-criteria (Kikolski, 2019). However, ISO22400 in itself is not useful for measuring purchasing performance because, amongst others, no planning indicators are taken into consideration (D'Orazio, Schiraldi & Varisco, 2018).

Multi-Criteria Decision Analysis

The SMART(ER) criteria and dynamic expert-specific criteria are frequently used input for the AHP.

Table 8 | SMART Criteria

Criterion	**Description** from Podgórski (2015), Horst (2015) and Kaganski, Majak & Karjust (2018).	**Authors**
Specific	The name of the indicator or metric should define the corresponding phenomenon in a precise way, and the indicator should be adequately appropriate for measuring the effectiveness of actions towards a goal.	[a] [b] [h] [d] [e]
Measurable	It should be possible to technically measure the KPI based on a proper unit of measurement. The indicator should provide adequate accurate and repeatable measurement. The (human) resources for measurement are sufficiently available for adequately measuring the KPI.	[a] [b] [h] [d] [e]
Attainable	The target-range (lower-bound, upper-bound) should be achievable under the given circumstances of a foreseeable time-period.	[a] [h] [d] [e]
Relevant (Explainable [e])	Measuring the KPI helps to steer the process to achieve better process-performance according to the defined goal of the process. The value of the KPI is relevant to both management- and operational workforce.	[a] [b] [h] [d] [e]
Time-bound	It should be possible to set a goal-value of the KPI on a timeline based on a benchmarking methodology (historical, base, standard (Caplice & Sheffi, 1994; Brummelhuis, 2016)) and it should be possible to track the progress of the value of the indicator.	[a] [d] [e]
Relative	The KPI should still be relevant when an organization grows.	[e]
Dynamic field-expert selection-criterion	Any criterion the process-expert (both operational and management) deems an important KPI criterion. The definition of which is to be determined by the criterion proposer.	[c] [f] [g] [i]
NIST Criteria	The SMART criteria are a subset of the 20 NIST criteria.	[x,y,z]
[a] Podgórski, D. (2015); [b] Carlucci, D. (2010); [c] Van Horenbeek, A., & Pintelon, L. (2014); [d] Shahin, A., & Mahbod, M. A. (2007); [e] Kaganski, S., Majak, J., & Karjust, K. (2018); [f] Kibira, D., & Feng, S. (2017); [g] Gonçalves, C. D. F., Dias, J. A. M., & Machado, V. A. C. (2014); [h] Kjellén, U. (2009); [i] Possible indirect/unconscious result of the normal ISO9001: 2015 procedure; [x,y,z] three NIST papers.		

4.3.3 | Summarizing KPI Selection Methods

Literature makes frequent use of the SMART criteria, this is not an outdated concept. However, other recent literature on KPI selection use the NIST criteria. These criteria are arguably more

abstract than the SMART criteria, and certainly they are more numerous. Which is unfavourable, because it may confuse or tire decision-makers.

Due to the volume of SMART criteria in the field of KPI selection methodology and general KPI-theory (4.2), all SMART criteria are added to the criteria-list for VMI stakeholders to potentially verify. Furthermore, these SMART criteria should be assessed on their definitions by VMI stakeholders and adjusted if deemed necessary.

Adjusting definitions of SMART criteria may be considered the same as formulating selection criteria for KPIs. Furthermore, the SMART concept may be of aid as a framework for defining selection criteria.

The NIST criteria should be discussed with VMI stakeholders. However, these are stationary and rather abstract (Appendix I). Hence, the SMART criteria should be given priority.

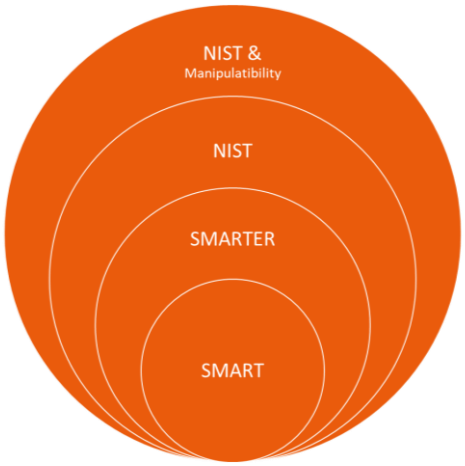

Figure 9 | NIST Extensiveness

4.4 | Retrieving Criteria from Performance Measurement Systems

Recall the model for retrieving selection criteria (Figure 8). This section analyses existing performance measurement systems (PMS) to find aspects of good KPIs (4.4.1). Secondly, purchasing specific PMS (PPMS) are analysed (4.4.2) to find how KPIs can measure the performance of a purchasing process. Lastly, the findings are summarized (4.4.3).

4.4.1 | Performance Measurement Systems

General PMS such as the balanced scorecard are systems that support measuring performance. A KPI in itself may be considered a PMS, as an algorithm should exist that measures the value of the KPI. Furthermore, if the KPI is correctly implemented in an organization the KPI is likely placed in a managerial-framework that allows for relevant management of an organization or process. KPIs are not often referred to as a PMS, therefore the most widely known and discussed PMS involve systems that support the development of performance measures such as KPIs.

The most commonly referred to PMS include: the *balanced scorecard* (Kaplan and Norton, 1996); the *performance measurement matrix* (Keegan et al., 1989); and the *performance prism* (Neely et al., 2002). In the context of procurement, the BSC seems most applicable because it directly links performance to organizational goals (Komatina, Nestić, & Aleksić, 2019). Nonetheless, three of the most common PMS are briefly discussed in the following sections for assessment on KPI-selection criteria.

Performance Measurement Matrix, the Balanced Scorecard and a Prism

The essence of the performance measurement matrix (PMM) is to measure how well an organization is achieving strategic goals through defining both financial and non-financial measures. The PMM is a relatively simple framework, the BSC may be considered an improvement of the PMM.

The BSC focusses on managing the strategy of an organization through the four areas of *finance, customer, internal processes, and learning & growth*. Kaplan and Norton create perspectives through these four areas to create a balance between financial and non-financial performance measures. Particularly relevant for this research is the process perspective, as is should be measurable in what way internal processes participate *efficiently* in achieving strategic goals.

The vision of an organization shapes its strategy. Subsequently, objectives can be generated in the four BSC areas. To determine if an organization is successfully achieving these objectives, measures need to be formulated that can be used to determine this. These measures should be *small in numbers (relevant), easy-to-understand,* and *rapidly answered* (IntrafocusUK, 2012). Measures in the four BSC areas should include leading- and following measures. Following measures are the result of management, and cannot be directly influenced. An example, one cannot directly influence a test-grade (following measure) but through managing the number of lectures attended (leading measure) grades may be influenced.

The performance prism considers an almost radical deviation from the commonly used BSC by conducting a stakeholder analysis before determining the strategy of an organization. When stakeholders are identified, all of them are assessed on their importance to the organization. The performance prism proposed by Neely et al. (2002) involves measures that indicate how well an organization is meeting stakeholder-requirements; which as a result can be regarded to as the general strategy of the organization: to keep the stakeholders content.

Summarizing, KPIs should be *small in numbers (relevant), easy-to-understand,* and *rapidly answered.* A PMS should include both leading- and following measures, as well as both non-financial and financial measures. More importantly, the organizational strategy should manifest in the PMS. This may be done by formulating strategy-based organizational goals, subsequently formulating KPIs that measure the degree to which these goals are achieved.

The second subsection discusses PMS in the specific context of purchasing, where (organizational) strategy plays an important role as well.

4.4.2 | Purchasing Performance Measurement Systems

Three of the most common PMS are described in the section above. The PMS can be applied to the organization as a whole when formulating KPIs, including purchasing departments. However, measuring the performance of specifically a purchasing department is an art in itself. Recall the BPM of chapter 2, even purchasing processes can quickly become relatively complex. This section discusses frameworks to measure the performance of purchasing departments (PPMS), which is increasingly discussed in the literature because of its complexity (Knudsen, 1999).

Procurement Maturity and Cost-Saving

KPIs are not always used to determine how well an organization is performing, and certainly not for purchasing. For purchasing, a complete overview that covers the structure and processes in combination with generic measures make a complete PPMS. Solely metrics on their own are not even worth mentioning in an appendix (Knudsen, 1999). Schiele (2007) developed a metric-less auditory approach for determining the performance of a purchasing department by assessing its maturity based on five dimensions: *planning; organisational structure; process organization; HR and leadership; purchasing control*.

> *"Maturity is the level of professionalism in the purchasing function"*
> *(Rozemeijer, Weele, & Weggeman, 2003, p. 7).*

Ultimately, the result of the maturity audits are compared to the cost-saving ability of the purchasing department. Cost-saving is preferred over other measures such as stock price, because savings are expected from the purchasing department and savings are to a lesser degree impacted by external, possibly unknown, factors (Schiele, 2007). Savings in the maturity-study by Schiele are assessed through seven sourcing levers, given in Appendix K.

Procurement Maturity and Supplier Relations

Cost-saving capabilities of the purchasing department are one indication of the maturity of the department. The ability to work together with suppliers is another, as Van Weele (2009) argues. Van Weele assesses purchasing departments on their ability to integrate into the value chain. Maturing departments shift from a purely operational/transactional focus to a more commercial focus. Lastly, the organization realizes its suppliers are stakeholders not to neglect and suppliers are involved in process improvement- and product development projects. Furthermore, suppliers are continuously challenged to improve the performance of an organization by actively supporting its strategies.

Concluding, purchasing performance may be expressed in terms of the maturity of the purchasing department. This maturity is correlated with the degree of participation of the purchasing department to the cost-savings of the organization (Schiele, 2007). Cost-savings are not directly addressed by Van Weele (2009), in Van Weele's model the maturity of the purchasing department lies in its ability to participate in- and strategically exploit the value-chain. Therefore, for KPIs to accurately measure the performance of the purchasing department, these should take into consideration cost-savings and possibly the extensiveness of supplier relations.

Another PPMS and the Telgen-Box

The procurement performance measurement system (PPMS) discussed by Knudsen (1999) in his licentiate thesis starts by indicating that, generally, the importance of operational purchasing is diminishing. The commercial dimension gets the greatest attention. Secondly, the strategic dimension is given increasing attention. Both are proactive concepts, compared to administrative tasks. Indicating that the PPMS should measure how well an organization can save costs (commercial), and how well its souring strategy is performing (strategic procurement). Clearly, a good sourcing strategy and a well-performing sourcing department allow for greater cost saving. If the strategy is about cost-saving, then commercial focus and strategy are intertwined.

Measuring adherence to the contracts that are created based on a sourcing strategy may be done by utilizing the Telgen-Box alfa (Schotanus, 2018) (see e.g. Telgen & Cobben-Mulder, 2005).

Knudsen refers to the performance-model of Van Weele (1994) that stipulates purchasing performance initially ramifies into two branches. The performance of the purchasing department, in the broadest terms, is measured through *effectiveness* and *efficiency*. First, effectiveness is defined as the degree to which the purchasing department meets predefined goals and/or standards. Second, efficiency is defined as the differences between planned and actual sacrifices made to achieve these predefined goals.

This indicates that performance goals for purchasing could be classified in these two perspectives, as a logical consequence the KPIs should be selected such that these can adequately measure both effectiveness- and efficiency as defined above. This may be translated to leading- and following measures (recall the BSC). Following measures may measure effectiveness, and leading measures efficiency because resources invested for achieving goals (efficiency) may be influenced, the degree to which goals are achieved itself (effectiveness) may not be directly influenced; especially if the effectiveness KPIs describe supplier-performance, as is currently the case at VMI.

4.4.3 | Analysing PMS and PPMS to find KPI criteria

Summarizing the PPMS findings, solely metrics (KPIs) are not enough. Knudsen (1999) argues that a PPMS consists of structure and processes in combination with generic measures make a complete PPMS. Schiele (2007) links performance (maturity) directly to the ability of a purchasing department to save costs, maturity can be measured through *planning; organisational structure; process*

organization; HR and leadership, and *purchasing control* indicating that for a PPMS to be complete its KPIs should measure the performance of at least those five aspects.

More generally, Knudsen (1999), based on Van Weele (1994), argues a simplistic PPMS that measures performance through effectiveness and efficiency is best. In such a PPMS commercial and strategic focus is of greater importance than transactional focus Knudsen (1999). This is in-line with the maturity model of Van Weele (2009) where a low-maturity is an organization with a transactional focus, intermediate maturity equals commercial focus and a mature organization has successfully integrated its purchasing department in the complete value chain.

Therefore, for a PPMS to be complete it should take into consideration performance through both effectiveness and efficiency. Secondly, the PPMS should take into consideration the ability of the purchasing department to save costs; an increase in cost-savings indicates increasing maturity. Lastly, the ideal PPMS indicates the extent to which suppliers are participating in reaching organizational goals, thereby supporting corporate strategy.

From assessing the general PMS, these goals should be formulated such that these are in-line with the strategy of the organization. Therefore, when formulating and selecting KPIs the stakeholders responsible for the performance of the process must have a clear strategy in mind. The organizational strategy may be based on both in- and external organizational stakeholders.

4.5 | Summarizing Selection Criteria

The sections above discuss KPI theory (4.2), KPI selection methods (4.3) and (purchasing) performance measurement systems (4.4). All are assessed on their theory to find aspects of good KPIs and/or good performance measurement. This section summarizes the findings.

Finally, without overlap, the findings are 22 unique criteria. These are the NIST criteria supplemented by manipulability. However, the SMART criteria should be given greater importance due to their ability for reformulation by stakeholders. Furthermore, the SMART criteria are more heavily used throughout literature and are less abstract than the NIST criteria. The NIST criteria, however, may be proposed to management to serve as a source of inspiration when formulating selection criteria. See Appendix I and Table 8 | *SMART Criteria* for NIST & SMART respectively.

From the aspects of PMS, it can be concluded that the final KPIs should be *small in numbers, easy to understand,* and *relevant (quickly acted upon)*. Furthermore, a complete PMS has leading- and following measures. Secondly, a complete PMS has both financial- and non-financial metrics. Most importantly, for a PMS to be relevant it should be in-line with the strategy of an organization by formulating clear organizational goals. When formulating the organizational strategy, both in- and external stakeholders may be considered. The selected KPIs should measure how well an organization is achieving its goals indicating that a criterion for a set of KPIs could be its *ability to measure reaching organizational goals*. KPIs and measurement of reaching goals is further addressed by purchasing specific PMS (PPMS).

Some PPMS have a rather simplistic design that measure just the *effectiveness* and *efficiency* of the purchasing department. Effectiveness is the degree to which the purchasing department reaches pre-determined goals. Efficiency is the degree to which is adhered to the resource-planning whilst doing so. In order for the purchasing department to measure its effectiveness, clear goals should be formulated. These goals should be the result of an organizational strategy. Secondly, the PPMS should measure the cost-savings made by the purchasing department; as by some authors, this is set to be the main goal of a purchasing department. Furthermore, the ability of the purchasing department to save costs may indicate the overall maturity of the department. Lastly, if an

organizational goal, for whatever reason, is to make use of framework contracts then the Telgen-Box alfa is an unambiguous metric to quantify how well departments are doing so.

4.6 | Verification Interviews & Stakeholders

Before the identified literature criteria can be used in the next chapter these need verification/validation by VMI professionals. All criteria were presented to the P&L managers. Note that, ideally, higher management such as the VP of global purchasing and logistics should participate in selecting, formulating and verifying criteria because his participation may ensure that corporate strategy shows itself in the selection criteria. Which is an important aspect of PMS and thus for a set of KPIs.

Before the presentation, the SMART and NIST criteria were provided to the managers as a list, asking the managers to rate all criteria on a scale from 1 to 5. During the meeting, these results were presented and discussed. From the discussion, *three* criteria are formulated and selected for further use in this research. Clearly, these criteria are based on both literature and VMI preferences. These verified criteria may be found in Table 9 | VMI Verified & Formulated Selection Criteria in section 4.8.

Aspects of PMS were not explicitly addressed, as the findings are general and should anyhow be taken into consideration when formulating and selecting KPIs (not criteria) in the next chapter. For example, it should be clear that the corporate strategy is somehow manifested in the selected KPIs.

These selection criteria now need a method for giving them values. This is discussed in the next section, where value focussed thinking is addressed to highlight KPIs on their excellence.

4.7 | Determining Criteria Values

The verified criteria that should be used in the KPI-selection methodology should be given scores. Rather basic methods exist to score options on criteria, more sophisticated options exist for weighing criteria. This section discusses Value Focussed Thinking (VFT) for scoring criteria.

Interval Thinking

Most authors discussed in the sections above simply state that stakeholders score KPIs on how well these perform on criteria within a range from a to b. Stakeholders are given e.g. the following statement: *"The value of the KPI is adequately measurable in your organization and can be numerically specified."* Followed by a question: *"Please score the KPI on how well you think the KPI meets the given statement."* If you, the reader, have ever participated in a questionnaire you are probably familiar with such questions.

In KPI selection this is a dull approach where excellent KPIs are potentially not given adequate attention to. When using the SMART criteria, for example, a KPI that is *measurable* but *irrelevant* is useless to a PMS; even though its average score might be decent.

Therefore, a scoring method that identifies flaws in KPIs and adjusts the relative value of that KPI on a criterion increases the probability of selecting excellent KPIs for implementation through selection criteria.

Value Focused Thinking

Value focused thinking (VFT) was already briefly discussed in section 4.3.1 by Hester et al. (2016), an intuitive question may be to ask what value can a KPI have to a (P)PMS. As discussed, KPIs that score both excellent and poor on different criteria may be useless. The idea of VFT was first described by

Ralph L. Keeney as a method to keep focused on what we want to achieve with the decision (see e.g. Keeney, 2008).

A method to distinguish excellent KPIs via their scoring *x* on selection criteria, is by utilizing value functions. The value function ensures higher contrast between values of poor and excellent scorings on criteria, if shaped like e.g. a normal sigmoid curve: $V(x) = \frac{1}{1+e^{-x}}$

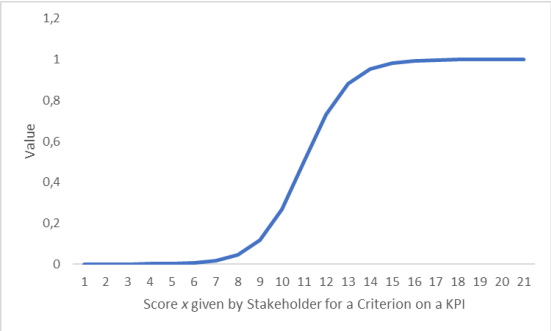

Figure 10 | A Sigmoid Function

The shape of such a value function is given in Figure 10 and highlights poor scores. Note that, particular excellence of a KPI on certain criteria is useless. The KPI should excel in all the selection criteria in order for the KPI to add relevancy to the PMS.

This concludes the last subsection of new information, the research question formulated at the start of this chapter can now be answered. Therefore, the next section concludes chapter 4.

4.8 | Concluding Chapter 4

This section answers the sub-questions and main research question of phase 3. Recall, the goal of this chapter is to find selection criteria for KPIs. Three tracks (Figure 8) are assessed, now a conclusion to the main question of phase 3 is formulated, supported by sub-questions regarding stakeholders and valuing criteria.

Sub Questions

- *What aspects does a good KPI have and how can these be used as selection criteria?*

In short, KPIs may be selected based on the three VMI-verified selection-criteria. When designing a selection methodology for KPIs that together have to form a PPMS, the following should be at least discussed: In the formulation and selection of KPIs the goals of an organization should be clearly formulated and translated to purchasing-goals, because KPIs should measure how effective and efficient the purchasing department reaches its goals. Organizational goals should be in line with organizational strategy, and may be determined by taking both in- and external stakeholders into consideration.

Additionally, the KPIs for the PPMS should indicate a degree of cost-saving and supplier-relationships. Lastly, both leading- and following metrics are ideally included in the PPMS as the purchasing department may want to contribute to bigger organizational KPIs set by chief officers that cannot be directly influenced, this may also be covered by complying to using both effectiveness and efficiency metrics, as discussed.

- *Which of the identified stakeholders to take into consideration when determining criteria?*

Ideally, higher management is present when formulating selection criteria. This may ensure that corporate strategy is manifested in the selection criteria.

- *How to determine the value of the identified criteria?*

Excellent KPIs could be highlighted utilizing adequate value functions. KPIs that score poorly on one criterion should be discarded because these are useless in a final system of KPIs.

Main question

From answering the sub-questions the main question of this phase is answered:

What selection criteria should be taken into consideration when selecting suitable KPIs for the supply process at VMI and how to give these selection criteria a value?

The following VMI-verified selection criteria and their definitions (Table 9) should be taken into consideration when selecting suitable KPIs for the purchasing process at VMI and these should be given scores by using adequate value functions to highlight the particular excellence or poorness of KPIs on particular criteria.

Table 9 | VMI Verified & Formulated Selection Criteria

	Criterion	**Description**
1	Clear	The definition and calculation of the KPI is clear, understandable, and unambiguous. Ideally, the definition and calculation are based on scientific/industry standards.
2	Measurable	Measuring the value of the KPI is easy, and the measurement is accurate. The value of the KPI cannot be manipulated to an adequate degree.
3	Useful	The KPI can be used to increase the performance of the process and/or business in the organization. The KPI has buy-in to the degree that managers are willing to work towards the goal-value of that KPI; and know how to do so.

The next chapter aims at designing a KPI-selection methodology such that the findings listed above are taken into consideration.

Chapter 5 | KPI Selection Methodology

The goal of this chapter is to find KPIs that are most suitable for VMI. Because corporate strategy can be the foundation for selecting KPIs (chapter 4), an introduction to translating strategy to KPIs is given in the first section (5.1). Secondly, a decision methodology for selecting KPIs is proposed (5.2). Lastly, this methodology is put into practice at VMI (5.3). After which the chapter is concluded (5.4).

The following research question is formulated:

What are the most suitable KPIs, specifically for VMI, based on the selection criteria, the value of these criteria and the decision-making method?

5.1 | From Strategy to KPIs

Chapter 4 has yielded the insight that strategy should shape goals, and that KPIs should be able to measure performance in terms of effectiveness and efficiency regarding these goals. For example, if your strategy is cost-leadership then a goal may be to provide your product at the lowest cost. For purchasing this could mean that the cheapest suppliers are selected by the operation of e.g. requesting discounts; the total discount achieved may describe the performance in terms of the effectiveness of the purchasing department. The number of quotation and/or discount requests sent may indicate the efficiency of this operation.

But how is corporate strategy determined, and how does this impact purchasing? This section explores the theory of translating corporate strategy to purchasing strategy, which is later used in the KPI-selection methodology.

5.1.1 | Corporate Strategy

Competitive strategy at the corporate level is about enhancing the performance of an enterprise by deciding how to organise major resources such that competitive advantage in the market is gained (Boddy, 2014). So, strategy determines how to invest limited resources. But what determines strategy? Clearly, the literature on this topic is extensive. Therefore, we solely give an introduction that allows for a link to purchasing strategy.

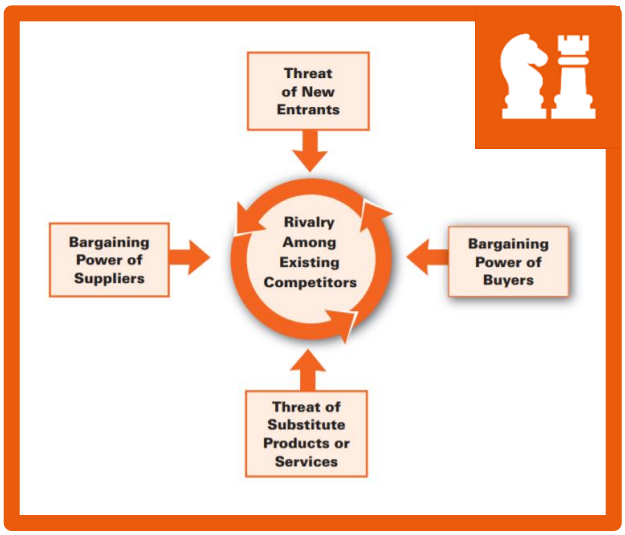

Figure 11 | Porter's Model (Porter, 2008, p.80)

According to Porter (2008) strategy is determined by competition, and that competition is shaped by four forces. Figure 11 visualizes this revolutionary idea, which was first developed in the late 1970s.

Porter addresses that, commonly, the model is faulty used to work towards a conclusion that determines if a market is profitable or not and then the analysis ends. According to Porter, the goal of the model is to understand *why* an industry is profitable and what the foundation of the industry's competition is. Therefore, if an organization is good at e.g. making machines it should not discontinue its business if an analyst, based on Porter's model, says the industry not profitable. On the contrary, the organization should formulate a strategy based on the competition in the industry to gain a competitive advantage and become more profitable.

Clearly, over the past decades, a lot has changed our world in terms of digitalization, globalization, and technology in general. However, Porter's model is still relevant because these terms affect the

five forces and do not require changing the model (Dälken, 2014). Therefore, a modern organization such as VMI may still be able to effectively use Porter's model to shape her strategy. Note that, the model of Porter requires an organization to think about what these forces will do in the near future; which is in essence what a corporate strategist does. The strategist must look at how the industry is expected to evolve over the coming three to five years, which is then used to shape a strategy (Schoemaker, 2019).

Three generic strategies for achieving competitive advantages are discussed by Porter (1980) and require an organization to differentiate itself through *costs, differentiation,* or *focus (niche)*. Roughly speaking that is: be the cheapest, be perceived as unique, or make actual very specific products. Treacy & Wiersema (1993) argue that for an organization to be successful, it should be number one in the industry in terms of *innovation*, *customer intimacy,* or *operational excellence*. According to Porter, choosing *one* strategy is key. However, growth-strategies by Ansoff (1988) may be used in the short-term to achieve long term strategic goals (Schoemaker, 2019). For example, investing heavily on developing new cheap products to become an established cost-leader thereafter.

Concluding, before selecting KPIs corporate strategy may be determined by making use of Porter's five-forces model. Which is then used to determine procurement strategy based on, at least, the (bargaining) power of suppliers (Figure 11).

5.1.2 | Procurement Strategy & The Kraljic Matrix

Aligning the purchasing strategy with the corporate strategy increases the success of an organization. Recall Porter's model (Figure 11), and note that one of the five forces is the bargaining power of suppliers. The power of suppliers may be summarized by how heavily an organization depends on its suppliers. This subsequently shapes a purchasing strategy; which means that either different goals for different types of suppliers should be formulated, or the goals should be generalized such that these apply to the complete purchasing department.

In a way, the work of Kraljic (1983) may be used to extend the method of determining a purchasing strategy. Kraljic's model classifies suppliers based on *market complexity* and *financial impact*. A market is complex if supply is difficult. Financial impact is described by the extent to which a raw material affects profit, e.g. voluminous or expensive materials.

Figure 12 | The Kraljic Matrix

For a complex organization that requires many different parts, it seems unfair not to distinguish between the performance of purchasers that work in different quadrants of the Kraljic matrix. After all, their objectives differ. For example: for the performance of non-critical items a KPI may be *order cycle time,* while the performance for orders concerning bottleneck items the *Telgen-alfa* may be a better metric. Therefore, differentiating on product-level may be necessary when formulating KPIs. Contrarily, different norms for the same KPIs may be determined; this, however, still requires differentiating on product-level.

Knudsen (2003), based on the work of Mahoney & Pandian (1992); Grimm & Smith (1997); and Powell (2001), distinguishes three types of strategic logic: monopoly, Ricardian and entrepreneurial. In essence, all of which strive to make profit through competitive advantage; just like Porter's competitive forces method. However, *how* this advantage is achieved may shape the purchasing strategy. Table 10 by Knudsen (2003) gives an overview of this phenomenon. Therefore, on a more general level, differentiating between the nature of firms is necessary before formulating a general purchasing strategy; and thus before formulating KPIs.

Table 10 | Procurement Strategies (after: Knudsen, 2003, p.728)

Strategic Logic	Monopoly (establish & fortify)	Ricardian (Scarce Resources)	Entrepreneurial (Innovate)
Competitive-advantage	Exploit market power according to Porter	Develop/maintain inimitable resources.	Act quickly on the discovery of new information.
Procurement Strategy	"Maintain or enhance power over suppliers, refrain from long-term relationships as this might reduce power advantage. Reduce cost of the total procurement process"	"Matching and finding suppliers with resources complementary to one's own resources. Development of close supplier relationships that become idiosyncratic, valuable and hard to imitate"	"Scanning, finding and materialising on new suppliers and new, innovative products and services; being alert and ready to act quickly"

5.1.3 | Formulating and Measuring Goals

After formulating a purchasing strategy, there is a need to formulate goals. These goals should be formulated on how well the purchasing department is adhering to her strategy. As discussed, from these goals should follow KPIs; these KPIs should, amongst others, measure how effectively and efficiently the organization/department is achieving the formulated goals. Clearly, this needs to be placed in a specific organizational context because goals may be anything. Note that, general objectives such as those presented in chapter 3 exist. Recall, KPIs can be classified along the objectives of cost, time, quality, etc.

These objectives may be summarized by the perspectives of the Kaplan & Norton balanced scorecard. Using the four balanced scorecard perspectives ensures a balanced PPMS. Furthermore, its perspectives are easily understood by management and the BSC is expected to be most suitable for purchasing (Komatina, Nestić, & Aleksić, 2019). Lastly, the BSC formulates questions such that its perspectives are excellently understandable for decision-makers. This is later visualized in section 5.3.

The next section discusses a methodology for formulating and selecting KPIs. This involves formulating a purchasing strategy based on, amongst others, corporate strategy.

5.2 | Decision-Making Methodology

All components of good PPMS are defined, now these should be translated to a decision-making methodology such that the final KPIs live up to the defined standards. First, these components are discussed (5.2.1). Secondly, decision making is discussed (5.2.2). Lastly, the methodology is introduced (5.2.3).

5.2.1 | Components of the Methodology

The output of chapter 4 is not limited to selection criteria for KPIs. General aspects of good performance measurement are additionally found. By considering these aspects when formulating a methodology for KPI-selection, we expect a more complete PPMS because different theories are integrated. The following table gives an overview of the findings on PPMS requirements. Note that, a PPMS in this research is considered a set of carefully selected KPIs. When designing the KPI-selection methodology later in this chapter, the table below is considered. This table is but a summary of chapter 4; we present the essential findings below (Table 11).

Table 11 | Considerations of PPMS

Requirement of the KPI Selection Method	**Description**
Corporate strategy shapes goals (PMS; Knudsen, 2003)	The KPIs in the PPMS should be aligned to corporate strategy by e.g. using purchasing strategy as a link.
Effectiveness, and efficiency in achieving goals (Van Weele, 1994; Knudsen, 1999)	Goals should be formulated from purchasing strategy, the effectiveness and efficiency of the purchasing department in achieving these goals should be measurable using the PPMS.
Measuring maturity of supplier relationships (Van Weele, 2009)	Extensiveness of supplier relations, e.g. degree of value-chain integration, is an indication of the maturity of the purchasing department. Ideally, the PPMS can measure the goodness of supplier relations with KPIs.
Measuring cost-saving (Schiele, 2007)	The ability of the purchasing department to save costs indicates the maturity of the purchasing department. Therefore, ideally, the PPMS can measure costs saved by the purchasing department.
Leading- and following KPIs (BSC)	According to the balanced scorecard, related leading- and following KPIs should be present in the PPMS to determine *how* managers can take actions. Traditionally, financial metrics are following and non-financial are leading.
Balanced-ness (NIST, 2015-2016)	The set of KPIs should make sense. The NIST method defines balanced-ness by referring to the BSC of Kaplan & Norton. That is, the perspectives of *customer, financial, processes*, and *learning/growth* should be considered in the set of KPIs.
KPI-Selection Criteria (Chapter 4)	The selection methodology should use the selection criteria from chapter 4. These ensure VMI-verified high-quality KPIs.
Few KPIs (BSC, NIST)	Throughout literature, there is consensus that KPIs should be few-in-numbers. Five to nine seems a good indication.

5.2.2 | Decision Making with Criteria

Before implementing the findings listed in the table above, we explore the theory of decision-making. Greater attention is given to how the identified selection criteria of chapter 4 may be used because there are numerous ways to implement selection criteria in a selection methodology.

Multi-Criteria Decision Analysis

Recall, section 4.3 retrieves criteria from KPI-selection models but no further assessment of these selection models is given. Commonly used approaches for selecting KPIs involve the AHP and successors such as the ANP or the fuzzy-AHP. As discussed, these tools are commonly used combined with stakeholder-expertise by e.g. letting stakeholders score the KPIs on criteria.

However, successors of the AHP such as the ANP are not applicable for industry-use due to their complex mathematical nature (Hester et al., 2016). Moreover, solely scoring KPIs on selection criteria may result in decision-fatigue due to its time-consuming nature (Hester et al., 2017) (Baumeister & Tierney, 2011). Therefore, a more straightforward, simplistic and less time-consuming model is preferred.

The use of linear models, such as the destination-model of the AHP, is considered a strategy for improved decision making by Bazerman & Moore (2013) because of the model's ability to reduce the deficiency between the decisions that managers intuitively make, and objectively rational decisions. Bazerman & Moore continue, human 'experts' do not make the same decision at different trials given the same data; models do. Therefore, Bazerman & Moore argue, models are capable of capturing the underlying policy that experts use without the error of the human-expert.

However, when scoring KPIs on selection criteria the input for a linear model requires decision making by humans. Therefore, the outcome of a simple linear model is likely to be irrational and random-error sensitive. Furthermore, a regression to find optimal weights for selection criteria is impossible because the goodness of a KPI may be considered as immeasurable.

For example, determining the probability of default on a loan based on criteria such as income, age, loan amount, and educational attainment can be very accurate because the criteria are exceptionally measurable. Furthermore, given data-availability, the model can be trained because the defaults and input-data of earlier applicants are known. On the other hand, determining the goodness of a KPI based on the value of selection criteria is different because the value of selection criteria is based on human intuition.

Therefore, the part of a decision methodology that involves scoring KPIs based on criteria may be considered superfluous. The input is based on human intuition, while the goal of the model was to counter irrational human intuition. Models such as the fuzzy-AHP take into consideration input-uncertainties but these are too complex for industry use (Hester et al., 2016). Therefore, a simple, straightforward use of selection criteria may be a checklist that is used to check if KPIs meet the required selection criteria when these KPIs are proposed. This checklist idea is adopted in the next section.

5.2.3 | Methodology for formulating and Selecting KPIs

We now have explored the theory on defining purchasing strategy and decision making. Recall, chapter four provided us the insight of what a PPMs should consider (Table 11). We shortly address these topics below.

Corporate Strategy & Purchasing Strategy

The first step of formulating and selecting KPIs is to define strategy. Corporate strategy can be used to define a purchasing strategy (Knudsen, 2003). The performance prism by Neely et al. (2002) stipulates that this strategy is defined by identifying stakeholders and keeping these content. Furthermore, the power of suppliers shapes the industry (Porter, 2008) and therefore the power of suppliers should be considered when formulating a purchasing strategy. This is in line with the work of Kraljic (1983) where different purchasing strategies can be formulated for different types of suppliers.

Supplier Relationships & Cost Savings

Secondly, suppliers in itself should be assessed. The previous chapter reviewed the literature on PPMS. In a way, Schiele (2007) links the ability of the purchasing department to save costs to the maturity of the department. Kraljic (1983) shows us that *how* costs can be saved depends on the

type of supplier. For example, the strategy for leverage items is to negotiate low prices; while order efficiency for non-critical items is stressed. Clearly, both result in cost-savings. On top of that, Van Weele (2009) defines that a mature purchasing department has valuable supplier-relationships.

Clearly, supplier-relationships define how the organization is dependent on that particular type of supplier and therefore how costs may be saved. Independently of costs, supplier relations may be the basis of purchasing goals by e.g. allowing suppliers to participate in product development projects. The goal here is to let suppliers actively support organizational strategy (Van Weele, 2009).

Miscellaneous

Thirdly, the remainders of Table 11. The balanced scorecard (BSC) is made such that leading- and following-metrics are defined. In a way, this may be achieved by defining both metrics for effectiveness and efficiency; given that efficiency metrics resemble resource utilization that may be influenced by managers, and effectiveness is the logical result of the resources spent.

The BSC is balanced because both financial and non-financial metrics are included in the PMS, also stressed by the NIST method. After formulating the KPIs, managers should *check* if the set is adequately balanced. A simple framework proposed in section 5.3 may aid in doing so.

When formulating KPIs, managers should take into consideration the KPI-criteria from chapter four. Lastly, KPIs should be few in numbers. According to Collins et al. (2016), a good example of human cognitive abilities is 'the magical number seven, plus or minus two' by Miller (1956). Therefore, the goal-range of the number of goals is set as $[5, \dots, 9]$. Given goals needs measures of effectiveness and efficiency, this would imply that KPIs are at least double the amount of goals. Therefore, good structure is required, as presented in the next section (5.3).

Overview of Selecting & Formulating KPIs

For the convenience of both the reader and the team of KPI-selectors, an overview of the model is given below (Figure 13).

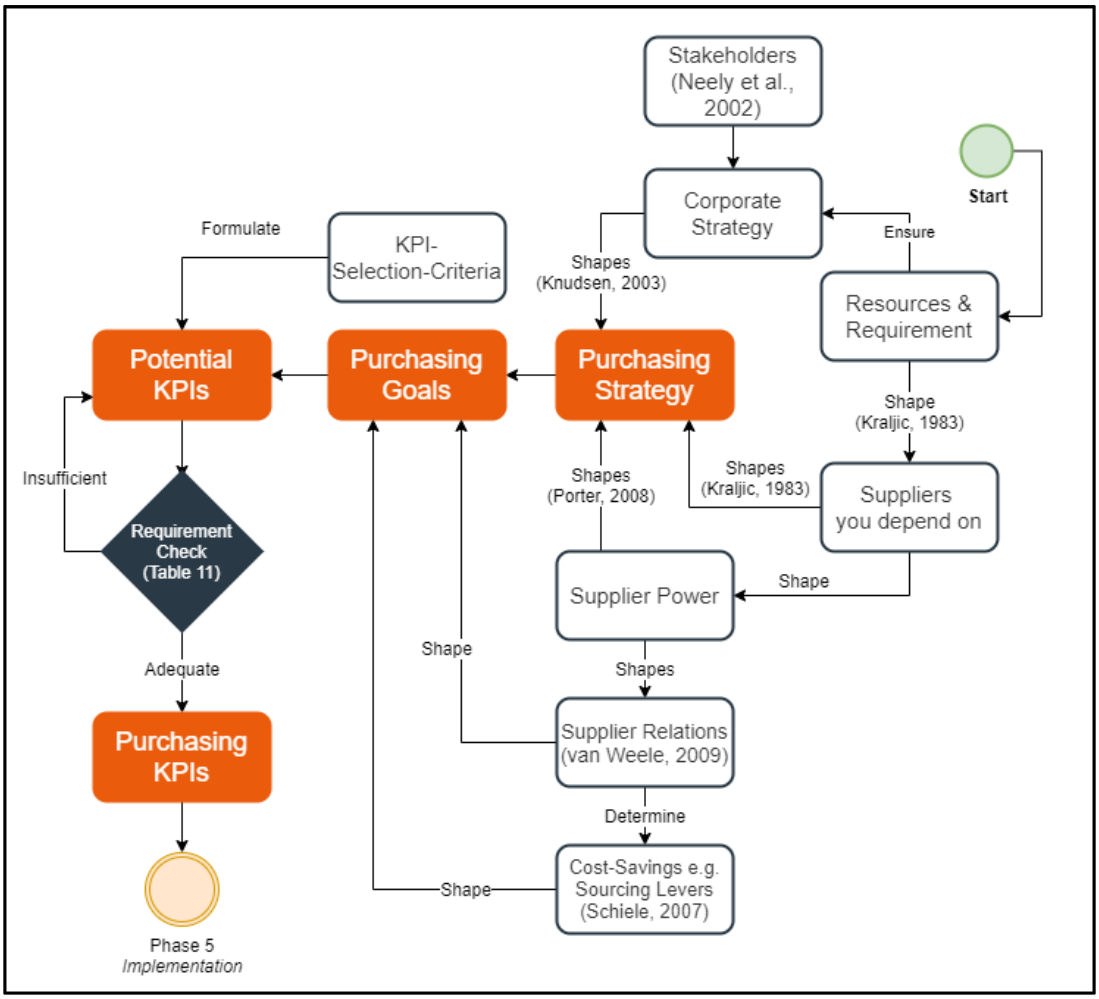

Figure 13 | Overview of the KPI Selection

5.3 | Selecting KPIs

A working model for structuring KPIs is proposed below in Table 12 on the next page. This table considers the BSC perspectives, such that proposed performance measurement systems may be easily verified on their balanced-ness. Implementing the model (Figure 13 and an empty Table 12) at the *supply* department of VMI yielded the KPIs in the table below.

These KPIs are discussed in the next chapter, as well as why these were selected. The KPIs consider solely supply at VMI. That means, other KPIs may be necessary across the purchasing department; but these are considered out-of-scope for our solution. Furthermore, the efficiency KPIs can never be all-encompassing regarding the real-world, because the supply department is required to solve extremely divergent in- and external failures. Therefore, to be concise, we have chosen to mostly express efficiency in the number of projects initiated; as project-based working is in-line with the practical business execution at VMI.

Table 12 | Structured KPIs for VMI

Objective	Effectiveness KPI (Following)	Efficiency KPI (Leading)
Financial* | "How do we look to shareholders?"		
- Survive	*Profit*	*Because all KPIs listed below affect total costs in any way, these affect the 'big' financial KPIs. Therefore, all are 'efficiency' KPIs in the context of the financial perspective.*
- Succeed	*ROA*	
- Prosper	*Annual Growth for Profit and ROA*	
*Survive, succeed & prosper is taken from the ECI case-study by Kaplan & Norton (1992)		
Customer | "How do (internal) customers see us?"		
- Delivery Reliability	*Material Completeness*	*Hours of Supply Buyers planned and realized in a week*
- Product Quality	*NCP_T + NCP_L*	*Yearly number of supplier quality projects towards sourcing initiated*
- Continuous Production	*NCP & Showstopper Solving Time towards Production*	*Yearly number of supplier relation projects initiated due to external NCP failures*
NCP: Non-Conforming-Parts. These are parts that are either damaged by logistics (L) or parts that are technically (T) unfit for the machine.		
Processes | "What must we excel at?"		
- Efficient Processes	*STP*	*Yearly number of process-efficiency projects realized*
- Cost Savings (Schiele, 2007)	*Total Costs Saved*	*Yearly number of cost related task-force projects initiated.*
Learning & Growth | "How can we continuously improve and create value?"		
- Supplier Flexibility/Relations (Van Weele, 2009)	*RLIP if < Leadtime*	*Time planned & realized time for contacting suppliers to improve supplier reliability.*

5.4 | Concluding Chapter 5

As the title suggests, this section concludes chapter 5 by formulating answers to the research questions below.

What are the most suitable KPIs, specifically for VMI, based on the selection criteria, the value of these criteria and the decision-making method?

Concluding, based on the KPI selection model presented in Figure 13 the KPIs presented in Table 12 should be included in the PPMS at VMI.

This conclusion is based on answers to the following sub-questions:

- *Which KPI(s) from the phase 2 list, must be included in the final system, no matter the outcome of the decision-making method?*
- *According to VMI, what KPIs are missing/superfluous from the phase 2 list?*

KPIs in itself have a managerial utility of close to none. If KPIs are implemented just because these KPIs are present in the literature, chances are that the PPMS is worthless because the metrics are nonsensical. KPIs need to be carefully selected, and carefully formulated along the specified selection criteria.

No matter what, the KPIs must be in-line with the strategic objectives of the organization by letting the KPIs measure how effectively and efficiently goals are reached. Therefore, we cannot say what KPIs must be in the final system; because the presented decision-making model involves specifying strategy. Any KPIs that are both on the theoretical list (Appendix H) and the final result (Table 12) may be considered an answer to the first sub-question. Any KPIs that are present in Appendix H and not in Table 12, may be considered superfluous. Any new KPIs in Table 12, that are not in Appendix H, may be considered missing from the phase 2 list. Thereby answering the second sub-question.

- *What is the (relative) value of each selection criterion?*

Criteria are not given values, they act as fixed requirements during formulating KPIs. Therefore, the value of each selection criterion for each KPI in Table 12 may be considered ‘Adequately yes’ or ‘1’ in binary.

- *What is the correct decision-making method to determine the KPIs for VMI?*

KPIs should be determined such that these are aligned to purchasing- and corporate strategy. Furthermore, good purchasing performance measurement has numerous requirements, as presented in *Table 11 | Considerations of PPMS.* A structured overview of the KPI selection methodology is given in Figure 13.

- *How to cope with criteria-value-uncertainty?*

Biases in human-decision making affect the performance of the decision-maker. Linear models, or advanced decision-making models, are a strategy for debiasing judgement (Bazerman & Moore, 2013). However, because the aspects of good KPIs are immeasurable these models are not suitable for selecting KPIs. Therefore, criteria for good KPIs must act as standards for the KPI. As the model (Figure 13) depicts.

- *Where to draw to a cut-off line in selecting the most suitable KPIs?*

Would a hierarchic methodology be proposed that ranks a list of KPIs based on their scores of criteria, a cut-off value (e.g. best 20 per cent) aids the decision-making. However, due to the above

answer, the criteria in our model act as requirements. If a KPI does not meet the requirements of the chapter four criteria, it is discarded. Therefore, incompliance to the criteria is the cut-off line.

Chapter 6 | Purchasing Performance Measurement System

The KPIs are obtained, but these are only available on paper. In order for us to complete this performance measurement project, an organizational implementation plan is proposed in this chapter. First, the result of chapter five is discussed (6.1). From this, implementing the new PPMS is discussed (6.2). Lastly, the chapter is concluded (6.3).

Starting, the final research question is given:

What performance measurement system(s) can be advised to VMI?

6.1 | Assessment of the PPMS to-be

Chapter five yields us the KPIs, but how certain are we about this set of KPIs? Even though managers are trained to make decisions, their decisions may be sub-optimal. Uncertainties, biases and random-error may influence the outcome of the final decision (Bazerman & Moore, 2013). Given that a PPMS could dictate the operations in the office, the PPMS should be carefully assessed before implementation.

6.1.1 | Biases & Uncertainties

Recall, the KPI-selection methodology from chapter five discusses how (linear) mathematical decision-making models can be used to strategically counter bias. These models, however, are only relevant when the input-data is absolutely measurable. For scoring KPIs on criteria, this is not the case and thus the output-data would still be subject to human bias.

And yet, we have presented a structured, balanced, well-considered set of KPIs using a methodology that is free from any mathematical wizardry. No numbers are used when selecting KPIs, so a formal sensitivity analysis cannot be done. Therefore, we cannot quantify the robustness of our solution: the set of KPIs. Another method of solution-analysis should be formulated.

Threats to validity and reliability can be assessed by discussing any known uncertainties of the decision. For example, knowing the flaws of the set of KPIs may result in better, more refined, management. In decisions such as selecting KPIs, it is likely that suboptimality of the decision (i.e. an irrational outcome) stem from biases in decision making. Biases, according to Bazerman & Moore (2013), stem from decision-making heuristics. And these heuristics are the result of *system 1 thinking*. Or, your intuitive thinking system. Concluding, suboptimality of the result of our KPI-selection model may stem from irrational intuitive thinking. This is discussed in the next section.

6.1.2 | Coping with Biases & Uncertainties

Thinking Fast and Slow by Kahneman (2011) distinguishes between two types of thinking. System 1 thinking is the system we use for most decisions. This system is easy, automated, and steadfast (Bazerman & Moore, 2013). It is, however, also emotional. System 2 thinking is not emotional, and we use it for difficult and important decisions. We take our time to slowly, consciously and logically reason our way through the problem.

Our KPI-selection methodology is structured such that there is room for discussion, different strategies must be formulated; goals must be carefully defined thereafter. The discussions should minimize the risk of system 1 thinking. Different heuristics, not algorithms, are used in system 1 thinking; all of which may result in biases. For an overview of heuristics and their corresponding biases, see e.g. Bazerman & Moore (2009) p.41. There are numerous techniques to improve decision-making. The following paragraphs discuss the findings of Bazerman & Moore (2013).

First, experience is expected to increase your ability to make decisions. However, experience is passive learning and abundant evidence indicates that managers routinely make sub-optimal decisions due to biases (Bazerman & Moore, 2013). Therefore, debiasing judgement by being aware of potential biases in combination with experience is a strategy for better decision making.

Another method for debiasing judgement, according to Bazerman & Moore, is analogical reasoning. That means, rather than reflecting on one event for getting insight it is better to generalize the learning-message to an abstract form based on multiple events. This decreases the risk of focussing on irrelevant features of the situation, as a result, the lesson can be applied to new situations.

Asking for the opinion of outsiders may spark new insights regarding the problem at hand. To reduce bias, accept that an inexperienced outsider may have a fresh and more accurate view of the problem due to your biases originating from e.g. the availability heuristic (Bazerman & Moore, 2013).

Concluding, using managerial/operational experience while reflecting on past events and considering the input of lesser-experienced individuals should be incorporated. This can simply be done by allowing discussions in the selection model. Decision-makers (managers) should be allowed to discuss the problem (KPI-selection) at hand with operational workforce; as both have different types of experience, and may therefore be considered inexperienced relative to the other party.

The result of our KPI-selection methodology (Table 12 | Structured KPIs for VMI) was assessed by the supply manager, and an internal advisor. To avoid confusion, the researcher did not explicitly mention biases. Rather, discussions were stimulated through gathering stakeholders with different types of experience; this reduces the risk of biases in decision making (Bazerman & Moore, 2013).

An important shortcoming of this research is that one PPMS may be insufficient for the purchasing department. Due to the complexity of VMI as an organization and the wide variety of ordered parts, different strategies for different 'purchasing teams' may be considered; resulting in partially different PPMSs across the office. This is discussed in the next section.

6.2 | Implementing a PPMS

Neely & Bourne (2000) discuss reasons for failing performance-measurement projects. These were briefly discussed at the start of chapter 4, where we argue that proper selection-criteria reduce the risk of bad KPIs. Moreover, good KPIs should be easier to implement due to the willingness of the organization to try hard on implementing a set of carefully selected KPIs.

Assuming the set of KPIs proposed in the previous chapter makes sense, we have successfully side-stepped the risk of nonsensical KPIs. Now, we'd like to implement these. However, according to Neely & Bourne, this is the other half of the total risk: the implementation phase. This sub-section discusses a strategy for implementing the formulated PPMS.

6.2.1 | Strategies Across the Purchasing Department

First and foremost, it should be stated again that purchasing is a complex profession. Kraljic (1983) visualizes this with his matrix. We have discussed, the result of the matrix dictates the strategy for that particular product/supplier pair. Therefore, different sub-departments at VMI may have to use different versions of the PPMS presented in chapter five. Purchasers that work in different quadrants of the Kraljic matrix may reach the objective of e.g. cost-saving in different ways. E.g. improving purchasing non-critical items should be through increasing efficiency. While improving purchasing bottleneck items should be through proper contracting, and securing delivery. Therefore, for each activity in the purchasing process different *efficiency KPIs* may be necessary for each quadrant of the Kraljic matrix. This, however, would make the PPMS unfavourably complex.

6.2.2 | Change Management & PPMS

PPMS Implementation Failure

Neely & Bourne (2000) distinguish three types of implementation-failure. First, the PMS is likely to fail if its outcome is used to punish management and/or operational workforce. If this is the culture within the organization, Neely & Bourne propose that employees get access to the performance-reports before the managers do. This way, the only reasonable question managers may ask is how the employees are trying to improve the performance.

Secondly, the lack of IT infrastructure is addressed by Neely & Bourne. Data to compute the value of KPIs are stored anywhere in the organization, assuming that the organization even stores the required data. The key to success here is to not underestimate the task of re-engineering the IT infrastructure because this is an enormous task. Especially for an organization such as VMI, with hundreds of employees and different (sub-) departments working towards the same goal, while all possibly generating useful data for other departments.

Thirdly, Neely & Bourne observe that performance-measurement projects are fail due to loss of motivation. The project takes too long, restructuring the IT infrastructure was underestimated in difficulty. Obviously, not completing the project results in failure. Neely & Bourne stress once more, the endeavour of implementing a PMS must be considered as a long march instead of a quick hike. People get tired during the march, but its benefits may be everlasting.

Lastly, as an additional remark, it should be noted that when managers do not use the PPMS, the whole project of performance measurement (the march) must be considered a waste (Neely & Bourne, 2000). Therefore, actions need to be defined to increase the effectiveness of reaching the goals by management; as seen in the *leading efficiency* column of the final set of KPIs presented in chapter five. Consistently using the PPMS might require restructuring the organization of management, e.g. through adequate change management discussed hereafter.

Unfreeze

A widely known change-management strategy, is designed by Lewin (1947) and involves unfreezing, changing, and refreezing the behaviour of people. If for the better, we should be motivated and willing to change. Those that need to implement and use the new PPMS should at least believe that the new PPMS will e.g. increase the ease of work because better performance with the same effort could be achieved. This example holds because the PPMS presented in chapter five requires managers to define *efficiency KPIs* which indicate how much resources are consumed to focus on increasing the performance of the *effectiveness KPI*.

Clearly, the appropriate method of unfreezing (i.e. generating motivation) depends on the organizational culture and should be determined by managers. Note that at least, those who implement the PPMS must be aware of the challenging endeavour of the performance-measurement project; while still being motivated for change.

Change

The greatest part of a performance measurement project takes place in the *change* phase. Here, the new PPMS is implemented and subsequently used. The sections above discuss the pitfalls of implementation, and the greatest loss: not utilizing the new PPMS. Generally speaking, we do not like change. The new PPMS however, is expected to increase the performance of the purchasing department. Therefore, the department should be willing to utilize the new PPMS. Using the new PPMS should be stimulated by appropriate organizational techniques suitable to VMI. For example,

initiatives to increase the performance of KPIs could be discussed each morning during the Task-Force meeting.

Freeze

The rewards of performing well are addictive. The simplest form of rewarding good performance is to visualize the performance. For example, select an important department-wide metric such as *total costs saved* and visualize the trend. If the new PPMS yields better performance, employees are likely to accept the new PPMS and keep using it to improve on the said metric.

6.2.3 | A new Set of supply KPIs

The first chapter promises a simple deliverable, a description of each selected KPI including explanations to the aspect listed below in Table 13. Finally, we deliver. In the following paragraphs, each KPI from chapter five is briefly discussed. Efficiency KPIs are not discussed in detail, as these are actions and how frequently these actions are performed; and may therefore also be regarded to as a proposed reaction strategy, which is part of the deliverable below. Furthermore, known-to-VMI KPIs that are already in use are not addressed in detail as these are already known to the client-company VMI.

Table 13 | Generic Final Deliverable

Name of the KPI selected specifically for VMI's Purchasing Process.	
Aspect	Explanation
Manager	Stakeholder responsible for KPI value management
Description	A description of the KPI
Measurement method	How the KPI is measured (formula explained in words)
Formula	The formula of how the KPI is measured
Method of implementation	Description of a method of implementation.
Frequency of evaluation	Frequency of evaluating the value of the KPI
Norm indication	An indication of the norm should be the value to strife for
Proposed reaction strategy	What can management do if the KPI deviates from the norm?

The Financial Perspective

Survive, succeed, prosper. This trilogy is taken from the ECI case-study by Kaplan & Norton (1992), and we have assigned the following KPIs to express how well VMI is doing this. This research does not go into further detail on these KPIs, as this is out of *supply* scope. To survive, profit is necessary. Succeeding is expressed in ROA (Return On Assets), as business should be done as efficiently as possible: thereby maximizing the return on assets. To prosper is to grow, improvements in the survive and succeed KPIs could therefore be a financial indication of prospering.

The Customer Perspective

The purchasing department serves the production department. Therefore, the main goals are: delivery reliability, product quality, and continuous production. Effectiveness KPIs are, respectively: material completeness, NCP_T & NCP_L, and NCP & Showstopper Solving Time towards Production. NCPs are 'non-conforming-parts' that were delivered. Ultimately, the LMT management team are the KPI managers because the complete purchasing process affects these KPIs.

As these KPIs are currently known within VMI, the measurement method, formula, method of implementation, frequency of evaluation and an indication of the norm are known. For the supply manager specifically, the reaction strategy for these KPIs concerns the numbers of operational

supply buyers, and projects initiated regarding supplier quality & - relations. Now we move to the process perspective, where a new KPI is introduced.

The Processes Perspective

From interviews with the supply manager and a supply chain engineer, the purchasing department should excel at operational efficiency and cost savings. The effectiveness KPIs are therefore, respectively, STP and Total Costs Saved. The latter is known to VMI, and is not further discussed in this report.

STP stands for *straight-through-process* and gives an indication of the degree to which the supply process is adhering to the defined STP in chapter two; where a business process model is visualized. STP is a new KPI and is therefore presented as follows:

STP	
Aspect	Explanation
Manager	Ultimately, LMT is responsible for the purchasing STP value. The supply STP value should be managed by the supply manager.
Description	The degree to which the supply process is adhering to the defined STP.
Measurement method	If an order deviates from the ideal, this is considered a non-STP order. The order should be marked as such.
Formula	$STP = \frac{TotalOrderLines - NonSTP}{Total\ Order\ Lines}$
Method of implementation	This KPI is yet in a draft-phase, and the implementation should be done minimally at first. VMI is advised to continuously find reasons for why an order is Non-STP, which may be done by e.g. an annual Failure Mode and Effects Analysis (FMEA). The findings from such an analysis may be used as input for projects regarding increasing process efficiency; these projects should be counted because this is the corresponding efficiency KPI.
Frequency of evaluation	Daily - and Weekly averages.
Norm indication	Cannot yet be determined, as the current STP value is unknown and therefore it may be anything. As VMI is advised to conduct a yearly FMEA, the STP value should increase each year, because resources are consumed to increase this KPI.
Proposed reaction strategy	Initiating the required process-efficiency projects, after researching reasons for failing to adhering to a yet to be determined norm.

The Learning & Growth Perspective

Supplier flexibility is a high priority at the purchasing department. For example, internal production reschedules make up for a lot of extra work for the supply department. Whenever such an exception occurs, VMI would like suppliers to be flexible and adjust to specific requests. Therefore, any order or any adjustment to an order-line such that the supplier is required to deliver in a time that is shorter than contractual lead-time is analysed on its performance. Requested Line Item Performance (RLIP) if VMI requests a supplier to deliver in a timespan which is shorter than the contractual lead-time is therefore selected as a KPI. This is a KPI currently used by VMI, and is not further discussed in this report.

6.3 | Concluding Chapter 6

We have assessed the result of chapter five, which is the PPMS for implementation. Thereafter, a strategy for implementing the new PPMS based on change-management is discussed. Lastly, we conclude chapter six and answer the following research question:

What performance measurement system(s) can be advised to VMI?

The previous section (6.2) discusses the new set of KPIs for implementation. We see that a set of KPIs is only half the work, implementation is likely to fail if the process of implementation is not given adequate attention by both management and operational workforce responsible for change. In short, we conclude that VMI may implement the PPMS consisting of the KPIs from chapter five; because this PPMS is carefully assessed by the VMI professionals, it is ready to be implemented at VMI. This answer is formulated based on the following sub-questions:

Sub Questions

- *What is the result of phase 4?*
- *What are the threats to the validity and reliability of the conducted decision-making method?*
- *What sensitivity analysis is to be conducted, and what is its result?*

The result of phase four is listed in chapter five. The KPIs are carefully selected and structured along the perspectives of the balanced scorecard. As with all decision making, the decision-maker risks suboptimal outcomes due to e.g. biases. As discussed, linear models are a way to counter this bias but those show no added value in KPI selection. The threats to validity and reliability of the outcome (the KPIs) must, however, still be considered suboptimality of the outcome. Due to the lack of quantifiability, these cannot be addressed through a formal sensitivity analysis. Therefore, the outcome (the KPIs) should be discussed by both managers and operational workforce. Additionally, an 'outsider' such as internal advisors may participate in this discussion to 'debias' judgement of the decision-maker.

- *How can VMI implement the identified KPIs?*

VMI can implement the selected KPIs by conducting the performance measurement project in three phases: unfreeze, change, and freeze. The key throughout the whole project is to make sure managers ensure motivation of all who are involved. Moreover, understanding that the project will be a 'long march' rather than a 'quick hike' should make the participants aware that this project may be difficult to complete. Therefore, before the start of the project participants should be well aware of the benefits of a new PPMS; as this is expected to motivate the department for change.

Additionally, the PPMS should be 'frozen in place' when the implementation is successful. That means, the PPMS should be used to dictate operations on the work floor. Furthermore, to stimulate the use of the new PPMS, good performance may be visualized in the department; as this may be considered a reward for performing well. As Neely & Bourne (2000) state, the biggest sin is not using the PPMS after going through the full endeavour of implementing one.

Chapter 7 | Conclusion, Discussion and Recommendations

The final chapter of this thesis concludes the research by answering the main research question. Thereafter the research is discussed, and recommendations for further research are proposed. Lastly, a formal recommendation to VMI is proposed.

7.1 | Conclusion

We started this research because, at VMI, management finds it difficult to steer purchasing operations. After researching this problem we concluded that the performance measurement system at VMI purchasing is incomplete. Therefore, the following research question was formulated:

What is the correct performance measurement system for VMI Holland to monitor and steer purchasing operations?

The answer to this research question lies in KPIs, their structure, and how to implement these. We conclude that the correct performance measurement system for VMI Holland to monitor and steer purchasing operations consists of the KPIs presented in chapter five of this document, together with the plan of implementation (change-management) presented in chapter six of this document. Our solution solves the problem adequately, because it proposes adequate KPIs to the supply manager.

Key considerations involve the strategic alignment of the KPIs. That means, we start at defining corporate strategy and analysing supplier power. From this, purchasing strategy is defined. Furthermore, the VMI-criteria need to be considered when formulating KPIs. Lastly, a balanced set of KPIs may be achieved utilizing the presented framework; which is after the balanced scorecard. Additionally, this KPI framework must be assessed by sub-departments within purchasing because efficiency KPIs may differ due to different working-strategies given a product-supplier pair. Which yet is the main shortcoming of our solution, and is further discussed in the next sections.

7.2 | Discussion & Further Research

The main shortcoming of this research, which may be solved by further research, is the fact that our presented framework for KPIs may not be generalized enough for VMI. Because purchasing is a sophisticated task, multiple strategies may be required at different supply sub-departments. The Kraljic matrix stipulates that each supplier-part pair should be assessed, and a strategy for that particular pair may be formulated. This research tries to mitigate this shortcoming by deeming it necessary to use general purchasing-goals for the supply department to use; but still, the *efficiency* KPIs may require differentiating across the supply sub-departments at VMI.

Further research may be done on generalizing and aligning purchasing strategy at VMI such that clear KPI differentiation across sub-departments is possible.

Furthermore, purchasing is only part of the value chain. We have tried to align purchasing strategy to corporate strategy; but this is only one of many factors that may shape purchasing strategy. Further research can be done on aligning warehousing strategy and purchasing strategy, because of their direct interlinkage. Further further-research may be done on aligning at least these strategies to the corporate strategy such that these departments work towards the same goal, creating synergy across multiple departments.

Lastly, further research on implementing the KPIs may be done such that these are available via a dashboard for the supply manager. Currently, based on the observations of the researcher, visualization of performance may be improved by the right graphs, e.g. distributions of late-deliveries and their lateness, RLIP versus days left to order compared to the ultimate order date, etc. Better graphs allow for better decision making, because patterns may be more easily recognized.

7.3 | Recommendations to VMI

Based on the conclusion and its shortcomings, the following recommendations may be proposed to VMI:

What	Why	Who
Assessing the new set of supply KPIs once more (chapter 5 & 6), including their corresponding goals.	To establish the KPIs to implement with great certainty, before starting the implementation phase.	The supply manager and at least one experienced knowledge worker. LMT should be responsible for determining the final goals for the purchasing department. These goals, ideally, should be verified by the Vice President of the department.
Unfreezing the supply sub-departments.	After formally establishing goals and supply KPIs, all supply sub-departments should be motivated to implement the KPIs.	The supply manager.
Implementing the KPIs from chapter six.	If we want to use the new set of KPIs, we need to implement these.	Implementing KPIs involves fixing the IT requirements, this should be done by the SCI department. Throughout this phase, both supply- and SCI management should try to keep the workforce motivated for change.
Using the KPIs.	The supply KPIs are there for the supply manager to monitor and steer purchasing operations. This is expected to increase purchasing performance.	The supply manager may use the new set of KPIs to dictate the operations in the office. Operational workforce should have input in how to perform the tasks; and at least should be aware of why these tasks are expected to increase performance.
Complete the PPMS across the whole purchasing department, using the presented framework for KPIs, or a better one.	Purchasing is not solely supply, it involves multiple sub-departments such as sourcing, quality, and innovation. For a harmonized department: implement KPIs for each department; which are ideally based on the same purchasing-goals.	The vice president may coordinate on a more general level. The LMT managers could be responsible for KPIs for their own department. KPIs may be established with corresponding experienced knowledge workers, and 'external' SCI supply chain engineers.

All taken together, this may be completed over the course of at least a full year. Unfreezing is expected to take approximately a month and concerns step one and two of the table above. Changing the current system by implementing the new set of KPIs is expected to take six months, and involves step three in the table above. Getting used to using the KPIs, if correctly implemented, is expected to take a month. This is the fourth step in the table above. Lastly, to complete the PPMS, if IT infrastructure is available and the purchasing department has learned from the supply department, may be done in, at the very least, four months. Which is the final step in the table above.

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Appendices

Appendix A: Detailed Plan of Approach and research Design

With the research goal, the deliverable and draft problem approach defined the detailed problem approach is formulated as well as the knowledge problems. From these two concepts, the research design is formulated. Lastly, limitations, reliability and validity of the research designs are discussed.

Phase 1 | *Gathering information about the current supply process*

The goal of this phase (chapter 2) is to gain insight into the current Supply process. The following research question is defined:

What does the business process model of the supply process look like and what data is available to analyse this process?

Sub Questions

- Within the scope, what are the flowcharts of the procedures within the supply process?
- Who are the stakeholders involved in the supply process?
- Within the defined scope, what are the IT systems used in the process?
- What data is available on the IT systems to analyse the process?

Deliverable

A BPM flowchart representing the supply process of VMI delimited to the scope of this research that also shows the available data that is currently available in this process. Furthermore, a list of stakeholders and their defined role in the supply process.

Problem Approach

First, the scope of the Supply process is set. This is done by defining where the process starts, ends and what procedures to take into consideration. Secondly, the internal procedures are mapped out through analysing the available procedures, flowcharts and work instructions gathered from the applicable internal information system. These documents are verified by conducting interviews with employees. Furthermore, the interviews and observations (work-along) allow for more detail in the deliverable. The stakeholders of the process are defined by observing the process.

Research Design

I wish to gain knowledge about the supply process of VMI and the available data by doing qualitative descriptive research. The supply process and data are described and no sample is taken. Data is gathered by analysis of primary sources, interviews and observation. The sources are the available documentation of the process available with the company, the supply manager and employees are interviewed, and the work of supply employees is observed. This method of data gathering is chosen because the VMI employees know most about the supply process. The data is subsequently processed by describing and summarizing what I have seen.

A possible limitation to this research design is that the available documentation does not match reality, which threatens the validity of this research. This risk is mitigated by doing both analyses of the company documents and interviews/observation. Any gaps are addressed in the interviews to ensure reliable results. Any discrepancies are discussed in the reporting as well. The reliability of results is addressed by interviewing and observing multiple employees.

Operationalization

Variable (output)	The business process model and the data available to analyse this process.
Research population	The available documents and knowledge within VMI and their IT system.

Relationship	The available documents and knowledge within VMI describe the variable.

Phase 2 | *Searching for KPIs in the literature*

The goal of this phase (chapter 3) is to generate a list of potential suitable KPIs for VMI.

What are potential suitable KPIs to measure the performance of a purchasing process according to the literature?

Sub Questions

- According to the literature, along which dimensions should KPIs be classified?

Deliverable

The deliverable for this phase is a list that shows identified potential KPIs to measure the performance Supply process of VMI.

Problem Approach

This research question is answered by conducting a systematic literature review (SLR), procedures and way of working is according to Noort (2019).

Research Design

I wish to gain knowledge about the potential suitable purchasing KPIs by doing qualitative descriptive research. The potential KPIs are described and the sample is determined by inclusion and exclusion criteria. Data is gathered through conducting a systematic literature review because a lot of information/evidence on one question can be systematically assessed. Data is subsequently processed using a concept matrix, to visualize the ideas of the papers reviewed.

A possible limitation of this research design is that the best articles are not found by the searching protocol due to poor search strings. This reduces, but not destroys, the validity of the research. Moreover, the validity of results is partly unknown because others wrote the papers, hence papers from renowned journals are preferable. The reliability of the research is ensured by documentation of search strings and explaining the choice of scholarly libraries.

Operationalization

Variable (output)	Potential suitable KPIs for VMI.
Research population	Literature on purchasing and logistic processes.
Relationship	The research population describes the value of the variable.

Phase 3 | *Determining KPI Selection Criteria*

The goal of this phase (chapter 4) is to have suitable selection criteria for the found potential KPIs and understand how to give these a value.

What selection criteria should be taken into consideration when selecting suitable KPIs for the purchasing process at VMI and how to give these selection criteria a value?

Sub Questions

- What aspects does a good KPI have and how can these be used as selection criteria?
- Which of the identified stakeholders to take into consideration when determining criteria?
- How to determine the value of the identified criteria?

Deliverable

The deliverable is a list of the identified potential KPIs suitable for the supply process (phase 2) supplemented with selection criteria. Secondly, a methodology for scoring the criteria is delivered.

Problem Approach

If we do not know on which criteria to select the most suitable KPIs, how are we going to select the KPIs? Selection criteria need to be defined. This is a difficult thing to do for KPIs, as they do not have a price tag or a quality indicator attached to them.

First, a literature study is conducted to find theoretical aspects that define a good KPI. Then, interviews with stakeholders are conducted to find the aspects of KPIs they deem important. The value of the selection criteria is based on the nature of the criteria; important is that for each criterion lists are generated to determine the value of the criterion using the same list for each KPI. This is done by creating score-lists based on the nature of the criterion, these are to be based on literature and VMI preferences.

Examples of criteria are: the ease of implementing the KPI based on the available data, or the visualization-ability of the KPI (Kaizen theory).

Research Design

I wish to gain knowledge about selection criteria for KPIs by doing qualitative descriptive research. The selection criteria are described, no sample. Data is gathered through literature reviews and interviews. This method is chosen because the literature review gives the research its broadness, while the interviews with VMI stakeholders ensure the selection criteria are along the wishes of the problem owner. Data is subsequently processed by structurally describing the findings, such that these can be used in the next phase of the research.

A possible limitation to this research design is unreliable selection criteria because of misunderstanding of the concept of selection criteria by the interviewees, thereby making the outcomes of the interviews unreliable and invalid. To mitigate this risk, the structure of the interviews must be known beforehand, including a clear definition and explanation of what I wish to know from the interviewee.

Operationalization

Variable (output)	Selection criteria for good KPIs for VMI
Research population	Literature and process stakeholders.
Relationship	The descriptive qualitative value of the variable in the research population

Phase 4 | *Generating the most suitable KPIs for the supply process*

The list from phase 3 is the complete list of identified suitable KPIs. However, no priority has been given to specific KPIs. The goal of this phase (chapter 5) is to determine the most suitable KPIs for VMI. The following research question is defined, along with X sub-questions.

What are the most suitable KPIs, specifically for VMI, based on the selection criteria, the value of these criteria and the decision-making method?

Sub Questions

- Which KPI(s) from the *phase 2* list, must be included in the final metric, no matter the outcome of the decision-making method?
- According to VMI, what KPIs are missing/superfluous from the phase 2 list?
- What is the (relative) value of each selection criterion?
- What is the correct decision-making method to determine the KPIs for VMI?
- How to cope with criteria-value-uncertainty?
- Where to draw to a cut-off line in selecting the most suitable KPIs?

Deliverable

The deliverable is the list from phase 3, extended with the extra column that gives a priority number to each identified KPI. This priority number may then be used in the next phase, where the final advice to the problem owner is written. Secondly, a decision-making-methodology is proposed.

Problem Approach

First, KPIs that must be included in the final system are determined, no matter the outcome of the decision-making method. I am not fully eligible to determine this; semi-structured interviews are conducted to find the stakeholder preferences. Literature may lead us to new insight on selection criteria, but it is only a helping hand as they are secondary sources.

Secondly, the correct decision-making method is selected from the literature. This method is influenced by the nature of the selection criteria, which are yet to be determined.
Uncertainty in criteria values for some selection criteria are addressed, this is to discuss the validity and reliability of the outcome of the decision-making method.

A cut-off criterion may be determined through stakeholder interviews, to filter out undesirable and sub-optimal KPIs. Examples: top 10 KPIs are selected, or the best *x percentage* are selected.

Research Design

I wish to gain knowledge about the most suitable KPIs for VMI by doing qualitative descriptive research, possibly extended by a quantitative decision-making method. The preference of the KPIs are measured and no sample is taken. Values for selection criteria are gathered through interviews with stakeholders because VMI stakeholder preferences must determine how good the KPI is.
The decision-making methodology is found by doing a literature study on the topic of (multi-criteria) decision-making methodology. The most suitable KPIs follow from the output of the selected decision-making methodology. The list of most suitable KPIs is processed by summarizing its results, as we need these in the next phase.

A possible limitation of this research design is that we are unable to find reliable values for selection criteria because the level of cooperation in interviews was poor. Furthermore, if the criteria-scoring methodology from the previous phase is poor, the results can be invalid if the methodology is wrong and unreliable, if the questions are multi-interpretable for example.

Operationalization

Variable (output)	The most suitable VMI KPIs based on the selection criteria and their values.
Research population	Process stakeholders and literature on decision-making methodology.
Relationship	The value of the selection criteria are determined by stakeholders. The selection criteria and their value then are input for determining the variable value.

Phase 5 | *Creating the performance system*

Now that we know the final list of KPIs to be used in the system to be delivered to SCI, the final measurement system may be designed. This is the goal of the phase (chapter 6): designing an adequate measurement system.

What performance measurement system(s) can be advised to VMI?

Sub Questions

- What is the result of phase 4?
- What are the threats to the validity and reliability of the conducted decision-making method?

- What sensitivity analysis is to be conducted, and what is its result?
- **How can VMI implement the identified KPIs?**

Deliverable

A chapter/section where the measurement system is described to the SCI department. The measurement system consists of the selected most suitable KPIs, described in terms of the needs of the problem owner (see Final Deliverable).

Problem Approach

For each relevant KPI its definition an implementation strategy is determined based on the previous phases of the research, and semi-structured stakeholder interviews. Threats to validity and reliability identified in the previous phase are addressed and potentially solved or mitigated by means of a sensitivity analysis.

First, threats to validity and reliability of the outcome are discussed. These threats may have to be mitigated by employing a sensitivity analysis. If so, the sensitivity analysis is to be described, and subsequently analysed on its outcome. Lastly, each selected KPI is listed and described along the lines of the Final Deliverable, which requires semi-structured interviews with VMI stakeholders.

Research Design

I wish to gain knowledge about an adequate performance measurement system for VMI by doing qualitative descriptive research. The most optimal KPIs are described along the lines of the proposed deliverable, and no sample is taken because the selected KPIs are all relevant.

Data on the KPIs and their aspects, as described in the proposed deliverable, is gathered through stakeholder interviews to make the measurement system VMI specific. Data is subsequently processed by describing the findings as an advisory report, because then VMI has a starting point to implement the measurement system.

A possible limitation to this research design is that the implementation of the proposed measurement system cannot be adequately discussed, because the researcher lacks VMI expertise. Interviews are therefore crucial. The final measurement system is the result of many interviews, if the interviews are invalid because the interview did not measure what the researcher intended to measure then the proposed system may be sub-optimal or invalid. In the previous phase, a sensitivity analysis may have been conducted that shows the robustness of the solution.

Operationalization

Variable (output)	Performance measurement system for VMI.
Research population	The result of phase 4.
Relationship	The value of the variable in the research population.

Appendix B: Systematic Literature Review Protocol

Search Strings

Set keywords are *("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator")* in every string, as the KPIs need to be suitable in a purchasing environment. Further keywords resemble the performance-management and -measurement perspective.

Table 14 | Overview of the search protocol

Search String	Scope	Date	Date Range	#Articles
Search protocol Scopus				
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator")	TITLE-ABS-KEY	25-3-2020	Until present	156
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator")AND ("Performance Management")	TITLE-ABS-KEY	25-3-2020	Until present	14
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator")AND "Performance Measurement"	TITLE-ABS-KEY	25-3-2020	Until present	24
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator") AND ("Performance Management" OR "Performance Measurement")	TITLE-ABS-KEY	25-3-2020	Until present	35
Search protocol Web of Science				
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator")	Topic, Title	25-3-2020	Until present	29
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator")AND ("Performance Management")	Topic, Title	25-3-2020	Until present	4
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator")AND "Performance Measurement"	Topic, Title	25-3-2020	Until present	5
("Purchasing" OR "Procur*") AND ("KPI" OR "Key Performance Indicator") AND ("Performance Management" OR "Performance Measurement")	Topic, Title	25-3-2020	Until present	7
Total (EndNote)				274
Removing articles based on exclusion criteria				-138
Removing duplicates				-100
Removed after reading abstract				-27
Removed after reading full article				-6
Included articles recommended by professionals, after reading.				+2
Included articles from reference lists of selected articles, after reading.				+1
Total articles for reviewing (*listed in the References*)				**6**

Databases & In- and Exclusion criteria

Databases used to find the academic literature are Scopus and Web of Science.

Table 15 | Inclusion and exclusion criteria

Inclusion Criterion	**Reason**
Articles discussing relevant KPIs for purchasing and/or procurement processes.	The goal of the SLR is to find potential KPIs for such a process.
Articles discussing performance measurement and – management systems in a purchasing & logistics environment.	These systems may be used for the same purpose as KPIs.
Exclusion Criterion	**Reason**
Articles discussing solely the KPI selection process.	The goal of the SLR is to explicitly find potential KPIs for a purchasing process.
Articles discussing solely KPI hierarchy of predetermined KPIs	The goal of the SLR is to explicitly find potential KPIs for a purchasing process.
Keywords: “Selection Process”, “Hierarchy”	These keywords are not in line with the goal of answering the knowledge question.
Non-Dutch and Non-English articles	Articles written in other languages require too much time (max. 10wks) for me to understand.
Articles where via UT the full text is unavailable	The resources for paid articles are unavailable.

Appendix C: An overview of business process stakeholders (Weske, 2012)

Stakeholder	**Description of responsibility or role**
Chief Process Officer	Harmonizing and evolution of different processes.
Business Engineer	Business experts responsible for defining strategic goals of organizational processes.
Process Designer	Resonsible for modelling business processes.
Process Participants	Operational workforce in the enactment of the business process. During modelling, the information that process participants have is modelled.
Knowledge Worker	Knowledge workers make use of information systems in the process.
Process Owner	Each BPM is assigned to the process owner, who is responsible for correct execution and improvement of the process.
System Architect	Responsible for the IT systems to be able to be used to manage the business process.
Developers	Software professionals who create software required to implement the business process, e.g. interfaces.

Appendix D: PPMs Structure by Caniato et al. (2012)

Table 3. PPMS structure in the sample.

		Aero	Retail	Station	Pharma	Switch	Oil	Wash	Candy	Steel
Purchasing performance	Cost	Budget vs. actual and saving	Sales and margins and cash flow	Sales and margins and inventory	Budget vs. actual and saving	Saving and cash flow	Saving	Price variance and saving	Budget vs. actual	Price variance
	Time						Purchasing throughput time		On time delivery	Total throughput time
	Quality	Conformance	Suppliers variety		Internal customer satisfaction		Customer satisfaction, qualification and standard contracts	Supplier performance	Conformance	Conformance and customer satisfaction
	Flexibility									
	Innovation									
	Sustainability									
Internal processes	Cost	Spending via e-auctions		Supplier reduction	Orders through e-catalogue		Cost of purchasing function, spending consolidation and use of e-procurement	Supplier number, low-cost country suppliers, use of e-procurement, self invoice and VMI	Cost of purchasing function	Inventory level and use of e-procurement
	Time	Order emission LT				Order emission LT	Order emission LT			Purchasing throughput time
	Quality		Supplier management	Long term, collaborative relationships		Supplier management	Supplier management			Customer satisfaction
	Flexibility									
	Innovation								Supplier turnover	
	Sustainability									Payment terms compliance
Suppliers	Cost	Purchasing price	Purchasing price and supplier profitability	Purchasing price	Purchasing price	Purchasing price	Purchasing price	Purchasing price		Purchasing price and total cost
	Time	On time delivery		On time delivery	On time delivery	On time delivery	On time delivery	On time delivery	On time delivery	Supplier throughput time
	Quality	Conformance	Conformance	Conformance and certification	Conformance and customer service	Conformance	Conformance	Conformance	Conformance	Conformance
	Flexibility	Reactivity to change		Customer responsiveness						
	Innovation	Contribution to NPD		Innovativeness	Innovative proposals	Time to market		Innovativeness		
	Sustainability			Social and environmental responsibility				Social sustainability		

Appendix E: Procurement Performance Indicators by Habibi, Kermanshachi & Rouhanizadeh (2019)

Table 4. Procurement Phase Cost and Schedule Performance Indicators.

Group	Procurement Performance Indicators		P-Values	
			Schedule Performance	Cost Performance
Material	PP.1	Material quality	0.021 **	0.321
	PP.2	Material shortage	0.079 *	0.804
	PP.3	Transportation delays	0.094 *	0.711
	PP.4	Imported material	0.288	0.215
Labor	PP.5	Imported labor	0.039 **	0.087 *
	PP.6	Shortage of skilled and technical personnel	0.253	0.245
Management	PP.7	Construction site layout problem	0.855	0.619
	PP.8	Slowness in decision making	0.086 *	0.049 **
Contractor	PP.9	Contractor experience	0.734	0.549
Equipment	PP.10	Equipment shortage	0.645	0.048 **
	PP.11	Imported equipment	0.743	0.054 *
	PP.12	Equipment quality	0.846	0.084 *

** denotes significant differences with 95% confidence; * denotes significant differences with 90% confidence.

Appendix F: KPIs by Nabelsi (2011)

Table 5 Common KPIs for the procurement department and purchasing organisation groups ($n_3 = 31$)

Performance dimensions and corresponding KPIs		*Procurement department n = 23* Rank	*Purchasing organisation n = 8* Rank
Reliability			
REL3	% of suppliers meet the service conditions	1	7
REL5	% of procurement requests, purchase orders, bids, mandates and call for tenders emitted without intervention and without error	8	9
RL8	Quality of technical specifications, reflecting product reliability	6	1
Cost			
COST1	Dollar savings comparing the previous prices paid with the new prices	3	4
C1	Dollar savings negotiated on the tenders signed	4	2
Time			
TIME2	Delay in the treatment of bids, mandates and call for tenders	9	6
Quality			
QUAL1	Quality of supplies	2	5
Quantity			
QUANT 1	Number of procurement requests, purchase orders, bids, mandates and call for tenders	5	8
QT1	Number of tenders to be renewed or renegotiated	7	2

Appendix G: Bibliographical Notes on SLR Literature

Article	Main Takeaways
Caniato, F., Luzzini, D., & Ronchi, S. (2012).	The authors discuss purchasing performance management systems (PPMS) used by nine major companies. Their conceptual framework, describing the PPMS, is filled by conducting interviews with purchasing managers. The conceptual framework structures the PPMS in three parts, each with its own research question: *structure* (measurement), *process* (management), and *architecture.* The findings on structure stem from the research question: "According to the presented PPMS framework (Figure 14) what are the KPIs actually measured by companies?" Notice that purchasing performance is expressed through **cost, time, quality, flexibility, innovation and sustainability** which is based on an extensive literature review that, amongst others, takes into consideration Porter's five forces that shape strategy (Porter, 1980). Interestingly, the PPMS takes into consideration the internal processes, based on the literature of Day and Lichtenstein (2006). The authors answered the question by giving an overview of the structure (performance indicators) of the PPMS by means of a table, given in Appendix D: PPMs Structure by Caniato et al. (2012). These KPIs are adapted for further research in this theoretical framework.
Habibi, M., Kermanshachi, S., & Rouhanizadeh, B. (2019).	The authors, as the title of their research suggested, conduct their research in the field of construction. Procurement involves the delivery of goods here as well, to the construction site. The authors measure procurement performance along two constructs: schedule performance (*time*) and cost performance (*cost*). The performance indicators were formulated through the perspective of material, labor, management, contractor and equipment. Most important findings, is that the performance is assessed on the constructs of **time and cost** only; after which, the perspectives are assessed on these constructs. The list of performance indicators is given in Appendix E: Procurement Performance Indicators by Habibi, Kermanshachi & Rouhanizadeh (2019).

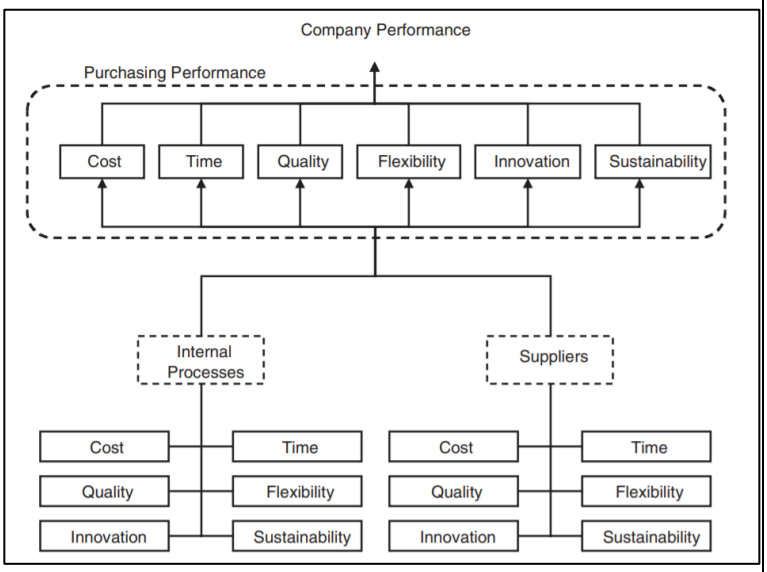

Figure 14 | PPMS (Caniato et al., 2012)

Nabelsi, V. (2011)	Nabelsi (2011) stresses the importance of performance management based on, amongst others, the work of Jobin et al. (2004), who states that PM allows managers to operationalise the organisation's strategy, which improves the process because actions can be oriented. Notice that strategy plays a key role in the system of Nabelsi. This is found back in the 8 dimensions Nabelsi uses to classify KPIs according to strategic objectives. These are: **Reliability**, Flexibility, **Cost**, **Time**, **Quality**, **Quantity**, Availability, and Satisfaction. However, the KPIs listed for specifically the procurement department and purchasing organisation groups involve only the **bold** dimensions. Satisfaction and flexibility are, arguably, important dimensions as well: as urgent-deliveries may be expressed through flexibility and *internal-customer-satisfaction* (which can, for example, be based on surveys taking into consideration how well the procurement department performs according to internal customers) through satisfaction. Nabelsi first formulates potential KPIs, after which these KPIs are given hierarchy. The hierarchy is not given explicit attention to, as VMI is not a hospital. However, the classification system of KPIs according to different groups allows for specific KPI adaption. KPIs involving the performance measurement of the procurement department and purchasing organisation groups are adapted in Table and are listed in Appendix F: KPIs by Nabelsi (2011)
Van den Heuvel, W.-J., & Papazoglou, M. P. (2010).	As the title of the research suggests, this article focusses on transactions. Which is part of the operational purchasing function (Van Weele, 1988). The authors describe measure requirements for a smart transaction-management system. Quoted: "• Has the supplier acknowledged the order? • Has the supplier and logistics service provider committed to a ship date? • Will the supplier start manufacturing on time? • Will the supplier be able to get the order shipped on time? • Does this order meet on-time delivery goals and other KPIs? • If the order the logistics provider shipped doesn't arrive on time, how should we proceed? • Does it affect other partners if the logistics service provider can't deliver the order? How do we compensate for this problem?" (Van den Heuvel & Papazoglou, 2010, p.74) Assessing these, it can be concluded that **time** and **reliability** are the key constructs of measurement.
Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001)	The authors from this paper assess specifically metrics for performance evaluation of planned order procedures. Which entails purchasing. A wish from an (internal) customer is transformed into a planned order, generally speaking. An important metric given is *Total Order Cycle Time.* Furthermore, *Degree of Sharing Information* is listed; which is in-line with the work of Van den Heuvel & Papazoglou (2010). Interestingly, the summary of metrics include a classification system of metrics along the levels of control by Anthony (1965) which are often used in manufacturing planning & control (Hans, Van Houdenhoven & Hulshof, 2011). Furthermore, metrics are only classified in terms of **cost** (financial) and **other** (non-financial). The critical reader finds, however, that metrics include several dimensions: listed in the concept matrix of objectives in chapter 1.6.3.

Hans, E. W., van Houdenhoven, M., & Hulshof, P. J. H. (2011).	This paper was assessed as it discusses a framework for operations control, which may be regarded to as operations management. The use for this thesis is that the authors distinguish three levels of control: *strategic, tactical, and (online/offline) operational.* Where the strategic level involves the structiral decision making (Hans, Van Houdenhove & Hulshof, 2011) of the company. The operational level involves short term decision making. Tactical is an in-between, it forms an adequate bridge between the strategic and operational levels: allowing for strategy to be put into practice by means of control. This thesis uses the three classic levels of control for classifying KPIs.

Appendix H: List of theoretical KPIs

KPI Name	**Description**	**Comments**
Total cash flow time	The time it takes for the supplier to be paid after placing the order.	
Order lead time	The actual time it takes for an order to reach the correct warehouse after placing the order.	
#Times supplier started manufacturing too late.	#Times supplier started manufacturing too late.	
Supplier performance	The perceived supplier performance.	Not a metric, examples of metrics are RLIP, CLIP and Delta; which are already available.
Flexibility of service systems to meet particular customer needs	The degree to which specific orders can be processed by the IT systems of the organization.	Not a metric, this may be measured through employee satisfaction.
Cost of purchasing function	The average cost per time unit of one purchasing function.	
Purchase order cycle time	The time it takes for an order to be processed by the purchasing department starting at notification of the internal customer.	
#Orders shipped too late	The number of orders shipped too late by the supplier.	
Transportation Delays	The number of late deliveries that are the result of transportation delays.	
Supplier ability to respond to quality problems	The ability of suppliers to sufficiently and adequately solve NCPs, can be expressed in the costs an organization has due to NCPs or as a number that states the number of NCPs solved by the responsible supplier.	Not a metric, needs to be quantifiable before implementation through discussion with processionals.
Material Quality	Quality of supplied materials.	Not a metric, needs to be quantifiable before implementation through discussion with processionals.

Cost per operation hour	Costs of keeping the purchasing department operational for one hour.	May be averaged.
Total throughput time	Total throughput time of an order.	Metric may be implemented on different phases of the purchasing process.
Purchasing throughput time	The time it takes for the purchasing department to process an order.	
%Orders meeting on-time delivery goals	%Orders meeting on-time delivery goals	
Quality of delivery documentation		Not a metric, needs to be quantifiable before implementation through discussion with processionals.
Quality of delivered goods		Not a metric, needs to be quantifiable before implementation through discussion with processionals.
Process KPIs by Van Sinderen (2018)		
Capacity	Maximum output rate, measured in units produced per unit of time.	
Capacity utilization	Fraction of the maximum capacity that is being used at any time, or on average during a time-interval.	
Throughput rate	The rate at which units flow pass a point in the process.	
Throughput time	Average time for a unit to be processed by the full process.	
Cycle time	Time between successive outputs: $cycle_{time} = 1/throughput\ rate$	
Idle time	Time during which no work is done.	
Inventory	From Little's Law: $inventory = througput\ rate\ *$ throughput time	

Appendix I: Horst (2015) pp.7-9 KPI effectiveness criteria Comparison (fully adopted)

Criteria	Definitions	NIST (2015-2017)	SM-ART	WIN-NING Parmenter (2010)
Balanced	"The KPI is *balanced* to the degree to which the KPI is balanced (Kaplan and Norton, 1996) (Fraser, 2012) within a fixed set of other KPIs. For example, a set of KPIs should be balanced in terms of both lagging and leading type KPIs."	X		
Aligned	"The KPI is *aligned* to the degree to which the KPI affects improvement in relevant higher-level KPIs, where alignment implies a high ratio of the percent improvement (assuming positive impact) in important higher-level metrics to the percent improvement in a KPI (or KPI set), given no other changes in the system."	X	X	X
Standardized	"The KPI is *standardized* to the degree to which a standard for the KPI exists and that standard is correct, complete, and	XXX		

	unambiguous; the standard can be plant-wide, corporate-wide, or industry-wide."			
Valid (Verified)	"The KPI is *valid* to degree of the syntactic and semantic compliance between the operational definition of the KPI and the standard definition. If no standard exists, then validity is zero."	XXX		
Quantifiable	"The KPI is *quantifiable* to the degree to which the value of the KPI can be numerically specified; there is no penalty for the presence of uncertainty, as long as the uncertainty also can be quantified."	XXX	X	
Accurate	"The KPI is *accurate* to the degree to which the measured value of the KPI is close to the true value, where a departure from the true value can be affected by poor data quality, poor accessibility to the measurement location, or the presence of substandard measurement devices and methods."	XXX		
Timely	"The KPI is *timely* to the degree it is computed and accessible in real-time where real-time depends on the operational context"	XXX	X	
Predictive	"The KPI is *predictive* to degree to which a KPI is able to predict non-steady-state operations."	XXX		
Actionable	"The KPI is *actionable* to the degree to which a team responsible for the KPI has the knowledge, ability, and authority to improve the actual value of the KPI within their own process."	XXX	X	X
Trackable (Traceable)	"The KPI is *trackable* to the degree to which the appropriate steps to take to fix a problem are known, documented, and accessible , where the particular problem is indicated by particular values or temporal trends of the KPI."	XXX		
Relevant	"The KPI is *relevant* to the degree to which the KPI enables performance improvement in the target operation, demonstrates real-time performance, allows the accurate prediction of future events, and reveals a record of the past performance valuable for analysis and feedback control."	XXX	X	
Correct	"The KPI is *correct* to the degree that, compared to the standard definition (if one exists), the calculation required to compute the value of the KPI compared	X		

	to the standard definition (if one exists), has no errors with respect to the standard definition."			
Complete	"The KPI is *complete* to the degree that, compared to the standard definition (if one exists), the definition of the KPI, and the calculation required to compute the value of the KPI, covers all parts, and no more, of the standard definition."	X		
Unambiguous	"The KPI is *unambiguous* to the degree that the syntax (grammar) and semantics (meaning) in the definition of the KPI lacks ambiguity or uncertainty."	X	X	
Automated	"The KPI is *automated* to the degree that KPI collection, transfer, computation, implementation, and reporting are automated."	X	X	
Buy-in	"The KPI has *buy-in* to the degree that the team responsible for the target operation, as well as teams responsible for both upper and lower level KPIs, are willing to support the use of the KPI and perform the tasks necessary to achieve target values for the KPI; includes difficulty of obtaining official approval by management for the KPI."	XXX		X
Documented	"The KPI is *documented* to the degree that the documented instructions for implementation of a KPI are up-to-date, correct, complete, and unambiguous, including instructions on how to compute the KPI, what measurements are necessary for its computation, and what actions to take for different KPI values."	XXX	X	
Comparable	"The KPI is *comparable* to the degree that means are defined to reference supporting measurements over a period of time, and a normalizing factor to express the indicator in absolute terms with appropriate units of measure."	X		
Understandable	"The KPI is *understandable* to the degree that the meaning of the KPI is comprehended by team members, management, and customers, particularly with respect to corporate goals."	XXX		
Inexpensive	"The KPI is *inexpensive* to the degree that the cost of measuring, computing, and reporting the KPI is low."	XXX		
Independent (Added in 2016)	"The degree to which the KPI collection, transfer, computation, implementation, and reporting are performed	XX		

	independently from process stakeholders.”			

Appendix J: SMART Comparison of Authors by Podgórski (2015)

Table 1
The meaning of SMART criteria and their references to other sets of criteria.

Criterion	Meaning of the criterion	Respective criteria by Kjellen (2009)	Respective criteria by Carlucci (2010)
Specific	The name of the indicator should precisely define the phenomenon under research, and should be comprehensive to all users The indicator should be appropriate for the measurement of effectiveness of the implementation of specific goals for a given action	Indicators should be comprehended by those in charge with the responsibility of using them	Understandability and representational quality: concise and unsophisticated
Measurable	It should be possible to technically measure the indicator's value based on a properly selected unit	Quantifiable and permitting statistical analyses	Comparability and consistency: the possibility for comparison of the indicator's value between enterprises, and of the values measured at different times
	Data for the measurement should be identifiable, and relatively readily available	Sensitive to change in environmental or behavioural conditions	
	The indicator should provide appropriate accuracy and repeatability of the measurement	Provide minimum variability when measuring the same conditions	Reliability: the indicator is fault-tolerant, and reliably measures what is to be measured; data for the measurement are available without high costs
	The indicator's values may be used for comparisons between enterprises or organizational units		
Achievable	The indicator's values should be achievable under given conditions and in the foreseeable period of time The resources (human, technical, information, etc.) necessary for the collection of data for the measurement should be sufficient	Cost of obtaining and using measures is consistent with the benefits	Not addressed
Relevant[a]	Measurement using the indicator should contribute to accomplishing the general objectives of a given system, process or action The indicator should be relevant to the operation of an enterprise or organizational unit, as well as for its users The results of the measurement using the indicator should be appropriate for fulfilling relevant requirements concerning documentation of the actions	Valid and representative of what is to be measured	Relevance: the indicator provides information which allows a proper adjustment of actions being carried out, or a proper forecast of the results of those actions in the future
Time-bound	It should be possible to determine the period in which a given value of the indicator may be achieved The time for achieving a given value of the indicator may be divided into successive stages	Not addressed	Not addressed

[a] Occasionally, in the literature the letter R represents the criterion of Realistic or Rational, by which it is understood that the indicator should represent the goal which the user is going to pursue, and that the goal is going to be achievable. According to the author, such a meaning of this criterion is included in the criteria of “Achievable” and “Relevant”.

Appendix K: Seven Sourcing Levers taken from Schiele (2007)