DESIGN OF A PERFORMANCE MEASUREMENT SYSTEM WITH A DATA COLLECTION APPLICATION FOR DECOR SON

B.F.N. (Bas) Bemelmans

BSc Industrial Management and Engineering
Student ID: 0534954

TU/e Supervisors:
dr. ir. J.J.M. Trienekens
dr. L.J.A.M. Somers

Company Supervisor:
ir. J.M. Verlaan

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Abstract

This master’s thesis project describes the design of a performance measurement system for Eurostrip, a production unit of Decor Son where decorative stone strips are produced. The performance measurement system consists of a set of metrics that can give the management of Decor Son a better insight in the performance of Eurostrip. A data collection application was built to collect the data needed for the performance measurement system.
Executive Summary

Decor Son is a supplier of DIY (Do-It-Yourself) products and operates on the European market. Their activities include trading, production and logistics. The focus of this project is on Eurostrip, a production unit of Decor Son where decorative stone strips are produced. Eurostrip features five production lines, with different degrees of automation. A broad range of stone strip products is produced on these production lines. The management of Decor Son expressed that they were unsatisfied with the current measurement system that was in use at Eurostrip. This led to the main problem definition for this project:

*The current measurement system used for measuring the performance of the Eurostrip production unit is not performing as desired*

This project should contribute to a solution for this problem. The project goal for this project is:

*Design and implement a performance measurement system (PMS) for the Eurostrip production unit*

To better understand the background and the context of the problems, the current situation was analyzed based on the 7S model. The structure, strategy and systems of Decor Son and Eurostrip were described in a top-down fashion.

A literature review was carried out to get a better understanding of performance measurement and related concepts. Methodologies describing how performance measurement systems can be built were studied. This resulted in a five-step performance measurement system design plan, which consisted of a static and a dynamic part. The static part was based the Performance Pyramid (Lynch & Cross, 1995), a conceptual framework which offered guidance on how to look at the performance of a production unit such as Eurostrip. The dynamic part of the design plan was based on the Goal Question Metric approach (Basili, Caldiera, & Rombach, 1994). This methodology was used to translate strategic objectives into measureable metrics.

The performance measurement system design approach was then followed to construct a measurement system for Eurostrip. Strategic objectives were defined in each of the four performance dimensions located at the bottom of the performance pyramid: quality, delivery, cycle time & waste. The Goal Question Metric approach was used to translate these strategic objectives into measureable metrics. This process resulted in a list of in total nine metrics. For each of the metrics we defined which data was needed and how they should be calculated. These metrics altogether give the management insight in the performance of Eurostrip.

To facilitate the collection of data for these metrics, a data collection application was designed in Microsoft Access 2007. This application was aimed at collecting data for the two internal performance dimensions of the performance pyramid: cycle time and waste.

In total, three different types of front-end applications were designed: the production lines, the expedition warehouse and the front office. Different functionalities are present in each of these applications. The first and most important functionality is the collection and storage of data. Secondly, the application can be used to generate reports based on the collected data. These reports contain information on the metrics of the performance measurement system and should be
periodically reviewed by the management. Because the data is now stored in a relational database, aggregation of data becomes much easier.

A minimal validation of the proposed solution was carried out because the actual implementation of this application was postponed to a later moment.

Based on this project, the following conclusions were drawn:

- The PMS designed during this thesis gives the management a better insight in the performance of Eurostrip
- The data collection application that was developed, is an improvement compared to the current situation
- A structured approach towards designing a performance measurement system is essential
- Proper measurement of performance is an essential basis for improvement

The following recommendations were given:

- Optimal cycle times should be used instead of normative times
- Launch improvement initiatives aimed at improving the overall performance
- Keep the performance measurement system and the data collection application up to date
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1. Introduction

1.1 Introduction to the project
This master thesis is based on a project that was executed at Decor Son. This report is part of the final stage of the master Business Information Systems at the Eindhoven University of Technology (TU/e).

The goal of this project was:

Design and implement a Performance Measurement System (PMS) for the Eurostrip production unit

The Decor Son management was unsatisfied with the measurement system that was currently in use at one of their production units, Eurostrip in Den Bosch. This project is aimed at improving the possibilities for measuring the performance of this production unit.

1.2 Company Description
Decor Son is a family business founded in 1973. The company has made through a vast growth in the last decades and currently employs over 200 employees, mainly in the Netherlands. Decor Son is a supplier of DIY (Do-It-Yourself) retail outlet chains. They supply A-branded products and are active in several European countries, such as the Benelux-area, Germany, France and Italy. Customers include Gamma, Praxis, Leroy Merlin and lots of others. About 30% of the sales volume is generated from in-house production, the rest comes from trade products.

Apart from their trade and in-house production activities, Decor Son also has its own truck fleet. Together with their trade and production activities, the logistic part is the third of three pillars that together form the strong foundation of Decor Son: Trade, Logistics and Production.

The scope of this project is limited to one of the two production locations, named Eurostrip. This plant was acquired about a decade ago and is located in Den Bosch. The in-house production of stone strips takes place here. Stone strips are concrete and plaster stones that resemble natural stones. They are used to decorate wall segments. Several types of stone strips are produced in various colors at Eurostrip.

1.3 Structure of the report
This report follows the regulative cycle as described by (Aken, Berends, & van der Bij, 2004). The regulative cycle is a standardized approach to solve a business problem in a five step process. The regulative cycle starts with a problem mess. This is the set of problems every problem solver is confronted with at the beginning of the process.

Part I – Problem Definition (Chapter 2). From the original problem mess, one problem is chosen which will be solved in this thesis. The construction of the problem mess and the definition of the main problem is described in chapter 2: Problem analysis.
Part II – The analysis and diagnosis phase (Chapter 3 & 4). The situation in which the chosen problem has to be solved is described here. In chapter 3, a literature review is described that was executed to develop understanding of the background of the problem and to find a suitable method to solve this type of problem. In chapter 4, the current situation is analyzed and described in more detail. By the end of this phase, a thorough understanding exists of the problem itself, the context of the problem and the approach that will be taken to solve the problem.

![Figure 1 - The regulative cycle (Aken, Berends, & van der Bij, 2004)](image)

Part III – Solution and implementation design (Chapter 5 & 6). In chapter 5, a conceptual design of the performance measurement system is made based on the theoretical background from chapter 3. In chapter 6, the design of a data collection application is described. This data collection application is built to collect and store the data required for the performance measurement system.

Part IV – Implementation. The actual implementation of this data collection application will not be carried out during this thesis.

Part V – Validation. The designed solution was validated by discussing the proposed data collection application with stakeholders. This validation phase is described in chapter 7.

This report will be concluded with a list of conclusions and recommendations. The appendix contains several supporting documents.
2. Problem Analysis

2.1 Introduction
In this chapter, the analysis of the business problem is described. In paragraph 2.2, the initial project description is given. In 2.3, the problem area has been explored and in section 2.4, a final problem definition is given. Following on this problem definition there are several research questions, which are discussed in 2.5. In paragraph 2.6, a problem delineation is given based on the PCI framework. In the final paragraph of this chapter, the goal for this project is described and the consistency of this goals is validated against the initial project goals as they were issued in the initial project description.

2.2 Initial project description
The initial project description formulated by Decor Son contained three goals;

- Describe the production process including the supply of raw materials, their processing and the resulting drain of waste material and end products
- Determine which elements in this process should be registered
- Automate these registrations

These goals are quite clear and unambiguous; they however signal that there is an underlying problem. By simply trying to fulfill these goals we cannot guarantee that the underlying problem is solved. Therefore, in the remainder of this chapter a problem mess, problem definition and research questions will be given and the problem will be delineated.

2.3 Problem Exploration
At the start of this project, no clear set of problems was given. Following the regulative cycle, we first have to explore the problems currently existing in the organization. A problem solver is usually confronted with a problem mess instead of a clearly defined single problem (Aken, 2002). This was also the case at Decor Son and Eurostrip. Although a clear set of project goals was given, we have taken a broader view and started looking for problems currently existing within the company.

This paragraph has been split up in three sub-paragraphs. First, the methodology is described that was used to identify the existing problems. Secondly, these problems are classified and described in more detail. In the third sub-paragraph, all the problems that were found have been placed in relation to each other, forming a problem mess. This problem mess is then decomposed into a set of key problems which eventually leads to a problem definition for this thesis, which is elaborated in paragraph 2.4.

2.3.1 Methodology
At the start of this project, there was no knowledge of the actual problems. Since these problems were not documented anywhere, the best way to retrieve the needed information was by interviewing several employees. In general, interview types can be classified into three categories (Corbetta, 2003), (David & Sutton, 2004):
- **Structured interviews**: Often referred to as ‘standardized’ interviews. In structured interviews, all respondents are asked the same questions with the same wording and in the same sequence.

- **Semi-structured interviews**: These interviews are non-standardized and are frequently used in qualitative analysis. The researcher has a list of key themes and issues to be covered. This type of interview gives the researcher opportunities to probe for views and opinions of the interviewee.

- **Unstructured interviews**: The most casual interviews. There is no detailed interview guide and each interview is different. Interviewees are encouraged to speak openly and give as much detail as possible.

In this research, both semi- and unstructured interviews were used. At first, an unstructured interview was held with the managing director (AD), the Eurostrip production team leader (TLPB) and the information analyst (IA). The acronyms used here refer to the job names as used within Decor Son. For more information on these acronyms see the organizational scheme in Appendix A. These first few sessions were aimed at getting acquainted with Decor Son and Eurostrip and to develop understanding of the organization.

As opposed to the first interviews, the goal of the next round of interview sessions was aimed at uncovering the problems in the company. The interviewees during these sessions were the same three persons as before (AD, TLPB and IA). The goal of these sessions was to construct the problem mess from different viewpoints. This is where semi-structured interviews proved to be useful. Using semi-structured interviews, the interviewer can explore, probe, and ask questions on particular subjects. A conversation can be built in which questions can be asked spontaneously, while keeping the focus on a particular subject that has been predetermined (Patton, 2000). This underlines that these types of interviews are well-suited for exploratory research, just like what is needed here. Each of the interviewees was asked which problems were currently experienced in Decor Son, especially surrounding the Eurostrip production location. Each of the interviewees could freely express their opinions and viewpoints due to the free and open nature of the interviews. There was also enough room during the sessions to elaborate on certain issues that came up during the interview. This helped greatly in understanding the problems in and around the Eurostrip production location.

### 2.3.2 Existing problems

As noted before, the first interview sessions were aimed at identifying existing problems around Eurostrip. It is important to note that there is no single universal truth regarding these problems. As the problems are identified through interviews, they can be biased, based on wrong assumptions or result from an interviewees’ viewpoint. The goal here was to neutrally describe the problems as they exist to the best extent possible.

The various problems have been classified in three different groups:

- **Surfacing problems**: the problems that are currently surfacing, the visible problems
- **Core problem**: problem that lies at the heart of the organization
- **Underlying problems**: problems that are barely visible

All of these problems will now be shortly explained in the next sections.
2.3.2.1 Surfacing problems

Three surfacing problems have been identified:

- **Ad hoc problem solving**
  At this moment, too much problems are solved ad hoc. Solving problems this way means that problems are solved on an individual basis without looking at the bigger picture. Therefore, no sustainable solutions are created to prevent these problems from reoccurring. This situation is described by interviewees as ‘putting out fires’. An example here is that agreed production schedules get overruled by top management from time to time to be able to serve new customers’ needs, this was mentioned by TLPB during one of the first interviews.

- **Not meeting strategic goals**
  All the interviewees noted that several strategic goals have been defined for the production unit Eurostrip, but achieving these goals in practice becomes more and more difficult. These strategic goals for example include production amounts and product quality.

- **Sub-optimal planning and scheduling**
  The production planning and scheduling at Eurostrip is not optimal at the moment. This is apparent from the interviews and personal observations. The production planning as well as the schedule is created manually, issues such as line balancing or batch sizes are not taken into consideration at all. The production manager of Eurostrip (TLPB) signaled that he knows about the sub-optimal nature of the planning and scheduling, but that there is currently no expertise or know-how how to improve or automate this. This is also noted by (Stoop & Wiers, 1996): “…practitioners in production planning and control are often convinced that much can be improved with regard to manual scheduling.”

The three problems described above are the problems that are currently surfacing. It is important to note that up until now, none of these problems have led to critical situations yet. This however does not mean that these problems are not important. Given the fact that the company keeps on growing, these problems must be recognized and dealt with before they can really evolve into critical problems.

2.3.2.2 Core Problem

The three problems above have one important cause, which has been identified as the core problem:

- **The complexity of control**
  Controlling and managing the Eurostrip plant is experienced as a complex task, this is mentioned by all the interviewees. Finding a proper definition of complexity seems to be difficult. An interesting definition is given by (Edmonds, 1999): “That property of a system or model which makes it difficult to formulate its overall behavior, even when given complete information about its atomic components and their inter-relations”. This definition describes the complexity of control as it is experienced around Eurostrip. Despite of the fact that there is a lot of knowledge about the production processes within Eurostrip, the management finds it difficult to control the plant and its operations.
The next step to take now is finding out which issues are really causing the experienced complexity around and within Eurostrip. This is described in the next paragraph below.

### 2.3.2.3 Underlying problems

In this paragraph, each of the problems causing the experienced complexity will be shortly described. This paragraph is split up in four parts:

- **Common causes of complexity in literature**
- **Causes directly influencing complexity**
- **Causes of complexity related to company growth**
- **Causes of complexity related to the measurement system**

#### Common causes of complexity in literature

Since complexity is such an abstract term, the real issues causing this complexity cannot be tracked down by simply asking interviewees for the causes. Therefore we need some kind of reference on common causes of complexity. As a guideline we have looked at literature on this subject, and found seven main components that generally influence the experienced control complexity in manufacturing environments (Calinescu, Efstathiou, Schirn, & Bermejo, 1998), (Wiendahl & Scholtissek, 1994):

1. *The product structure*: the number of different items, lead and cycle times, lot sizes, type and sequence of resources required to produce it;
2. *The nature of the production process*: the way in which the process is set up (structure) or the way in which it should be executed (procedures);
3. *Structure of the plant*: the number of resources required for production, layout, set-up times, maintenance tasks, idle time, performance measures;
4. *Planning and scheduling functions*:
   - The planning & scheduling strategies
   - The number, content, timing and priority of the documents used for planning and scheduling
   - The decision making process
5. *The information flow*: internal (during the decision-making process), intra-departmental and external (with other plants, suppliers and customers);
6. *The dynamics, variability and uncertainty of the environment* (customer changes, breakdowns, absenteeism, data inaccuracy and unreliability, scrap/rework, etc.);
7. *Other functions within the organization* (training, political information, etc.)

This list of common causes of complexity was then used as a reference while building the problem mess. This was helpful, as finding causes of the experienced complexity within Eurostrip was not very easy without any guidance.

#### Causes directly influencing the complexity

Below, each of the sub-problems that were identified through the interview sessions is shortly described. Where applicable, it is also indicated to which of the seven main sources of complexity from literature the problem can be attributed. The sub-problems causing the experienced complexity of control around Eurostrip are:
- **Bigger product assortment (relates to: 1)**
  The range of products produced by Eurostrip was increased in the last couple of years. A bigger product assortment influences the complexity of control, since more different product types have to be produced. The production planning becomes more complex, as well as the day to day operations.

- **Increased product complexity (relates to: 2)**
  New products that have been introduced are increasingly complex to produce. An example here is the Odyssee stone strip series. This stone strip requires different sorts of paint to be injected in the mould before it is filled with concrete mixture. This increased product complexity also influences the complexity of control since more planning is required and the production process itself becomes more complex.

- **Wrong forecast models (relates to: 6)**
  Using wrong forecast models inevitably leads to an increase in control complexity. The environment is uncertain, that is a fact. But the fact that wrong forecast models are used leads to data inaccuracy and unreliability, which increases the complexity. This is supported by the findings in literature. The wrong forecast models result from the fact that the demand pattern is not fully understood. In this context, the ERP system ‘ACP’ is partly to blame. This system uses several routines for forecasting with evident shortcomings. Apart from the system itself, also the people using it are partly to blame, as they blindly rely on the system.

*Causes of complexity related to company growth*

Another set of underlying problems that increase the complexity of control, have one common cause; *company growth*. As noted before, Decor Son has experienced a significant growth in the last decade. Problems that were caused by the company growth include:

- **Insufficient communication between departments (relates to: 5)**
  Over the years, each department became more and more isolated from the others. During interviews we found that employees experienced that the different departments were in fact on ‘islands’ and that the communication between the different departments suffered from this. Eurostrip’s production manager noted that this was mainly noticeable in the communication between the sales department and Eurostrip. The sales department sometimes fails to signal new big sales promotions and does not actively participate in production planning meetings. Their input however can be very valuable for Eurostrip to support their planning activities. This is supported by literature as well; ineffective information flows, in this case intra-departmental, can contribute to complexity.

- **Responsibilities not clear (relates to: 3)**
  This applies to individuals as well as departments. Since the organization is structured in a functional manner, there are strong functional boundaries in between departments and individuals working there. Through the growth, new tasks inevitably arise. This in itself should not be a problem, but when these new tasks fall outside of all functional boundaries, they are completed by the wrong people, or they are not completed at all. Examples of this issue are numerous; it is for example not clear who is really responsible for maintaining enough stock of Eurostrip products in the Son warehouse.
- **Increased resource utilization**
  Company growth obviously leads to increased utilization of certain resources. On the other hand, the fact that increased resource utilization also leads to increased control complexity is also obvious and therefore does not need further explanation here.

Just about every single problem listed here can be matched to the one of the common causes of complexity that have been listed in the previous paragraph. But are these problems so severe that they should be seen as the main causes of the complexity? The answer is no. In the end, Eurostrip produces ‘simple’ stone strips in a ‘simple’ production process. The experienced complexity therefore cannot be caused only by the problems mentioned above.

**Causes of complexity related to the measurement system**

The larger a company and the more varied its range of tasks, the more difficult it is for management and other decision-makers to obtain all the relevant performance related information (Ansoff, 1979). This statement is particularly interesting when looking at the problems experienced by Decor Son and Eurostrip. The company has made a significant growth and the management on various levels struggles to obtain the information they need. A system for measuring the performance of Eurostrip is in place, but it appears that it is not delivering the desired results. Each of the interviewees confirmed the existence of this problem.

It is argued that insufficient information supply has a negative influence on experienced control complexity of managers, this is stated by various authors in the area of performance measurement, see for example (Kaydos, 1998), (Maskell, 1991) & (Lynch & Cross, 1995). This is also underlined in the shortlist of complexity causes from literature at the beginning of this paragraph (see issue 5).

The next problem directly underlying the experienced control complexity is:

- **Measurement system not performing as desired**
  This issue strongly influences the control complexity, as proper control cannot be executed without good and trustworthy information. Management in general is very dependent on reliable information about the performance of business processes they control. This is not strange; how can a manager improve a process without having information on the actual performance of the process?

Several causes for the fact that the measurement system is not performing as desired are identified:

- **Wrong assumptions**
  The validity of the assumptions that lie at the base of the current measurement system is unclear. There is no documentation supporting the current measurement system so we cannot find out why certain assumptions have been made. This problem influences the soundness of the measurement system in place. One example here is that in the current measurement system, each of the concrete mixers used for production accounted for less weight of raw materials than what is actually in them. This was a wrong assumption, therefore it became very hard, if not impossible, to calculate input/output ratios.
- **Information need not clear**
  Up until now, it has not been properly documented which information is needed for which employees to execute their jobs. Complaints here include receiving too much, too little or not the right information at a certain management level. For example, the managing director complained that he received a lot of information on a weekly basis in the form of a management report. After some discussion, it became apparent that he was only really interested in a small number of ratios to base his decisions on.

- **Collected data not accurate**
  The data that is currently collected is not accurate enough. The measurement activities are currently aimed at a limited set of data, which results in inaccuracy in the measurement results. For example, it is currently hard to measure the performance of individual employees of the packaging department because only highly aggregated data is collected here.

- **Insufficient systems integration**
  At the moment, up to four different types of IT applications are used at Eurostrip, all used to support different measurement activities. These systems are not integrated at all and in some cases paper prints from one application are entered manually in another application. This is for example the case with data on production amounts. Needless to say is that these practices cause a lot of redundant work and thus inefficiency.

- **Existing systems not updated**
  The measurement system that is currently in use is based on an MS Excel sheet that was custom made by a former employee. It has a quite complicated set-up and on the other hand MS Excel is simply not equipped for certain functions. Because of these reasons, the system has not received any updates to improve its quality. This results in the fact that the current system used for measurement has become uncontrollable.

The fact that there is insufficient integration of different systems and that the existing systems are not upgraded properly, are caused by:

- **Insufficient technology adaptation**
  During the last 10 to 15 years, IT systems became more and more capable. The company also experienced strong growth during this period. However, new IT systems were only implemented on a small scale and old systems were retained too much. This created the situation of today; the company is quite big now, whereas the supporting IT systems lag behind. In fact the IT systems have not grown in parallel with the rest of the company.

This concludes the discussion of the problems that were identified during the exploratory interview sessions. The next paragraph continues with the construction of the problem mess diagram.
2.3.3 The problem mess

All the problems and causes that have been identified in the previous paragraphs will now be placed into perspective in a problem mess diagram (Aken, 2002). This way a good overview can be given of the different problems with their causal relations. The problem mess diagram can be found in Figure 2 below. As noted before, there is no unambiguous truth here and this also goes for this problem mess. It is meant as an integrated view of the problems currently surrounding Eurostrip and since it is constructed from different viewpoints, it can be somewhat subjective.

As can be seen, the complexity of control is located at the center of the problem mess. Complexity of control is the cause of all three surfacing problems; these are located on the right of the diagram. On the other hand, the complexity of control has various causes; these are located all around the diagram.

According to the regulative cycle, we have to select a problem from this problem mess and formulate a problem definition. Therefore, we will now analyze the problem mess from Figure 2 and try to select a problem to focus from there on. The most straightforward and obvious problem to select would be the core problem, ‘complexity of control’. This problem is however immensely complex, as it is the result of a lot of sub-problems.

Another issue to note here is that not all causes of ‘complexity of control’ are real problems. Some of these causes are in fact desired, even though they lead to increased control complexity. Examples here are company growth, increased resource utilization, increased product complexity and bigger product assortment.

The goal here is to select the problem that will contribute the most towards reducing control complexity, so that the best result can be obtained in the end. From the interviews with the top management as well as the management of Eurostrip, it became apparent that the performance of the current measurement system, or actually the lacking of it, has the biggest negative influence on the control complexity at the moment. This problem is therefore elected from the problem mess as
the main problem. The other causes of the complexity of control will therefore not be considered in this research.

2.4 Final problem definition
Based on the foregoing problem exploration, the construction of the problem mess and discussions with stakeholders, the final problem definition is stated as:

The current measurement system used for measuring the performance of the Eurostrip production unit is not performing as desired

For clarity, the selected problem with its causes is highlighted from the problem mess and can be found in Figure 3.

The different sub problems which cause the main problem have been explained in the previous paragraph. The goal is to solve the main problem, in order to do this we have to solve the underlying problems.

The problem defined here cannot be solved without studying the background and the context in which this problem exists. This is done based on a set of research questions, which will be elaborated in the next paragraph.

2.5 Research Questions
Four different research questions have been defined:

1. What is performance measurement?
2. Which concepts are related to performance?
3. Why do managers want to measure performance?
4. How should a performance measurement system (PMS) be designed?

Each of these research questions will be answered in chapter 3; Literature Review. The first two questions are aimed at understanding the background of the problem. The concept of performance measurement and related concepts will be researched and discussed based on literature.

The third question is also answered by studying literature. Purposes of performance measurement in general are listed. Developing understanding of the reasons for measuring performance is an important first step towards improving the system.
The fourth question is concerned with the actual redesign of the system. An approach is designed based on conceptual frameworks from literature how to redesign the performance measurement system for Eurostrip. The chosen approach will also be pursued throughout the remainder of this project.

2.6 Problem Delineation

In this paragraph, the problem area is delineated. Delineation is important here so that different expectations can be avoided.

The problem delineation can be properly described by the PCI framework (PBI in Dutch), developed by (Bemelmans, 1991). The thought behind the PCI framework is that each primary business process (P) is controlled by another process (C). The control process should be tuned to the primary process. The information supply process (I) forms the connection between the other two functions, and as such it should be tailored to both the control and primary process. In Figure 4 below, a schematic overview of the PCI framework can be seen.

![Figure 4 - The PCI framework (Bemelmans, 1991)](image)

The problem can now be delineated using the PCI paradigm. In other words, we will select where the problem is in this situation. It can be in either of these three areas, or maybe in a combination of these areas.

From the initial exploration of the problem area, we say that the main focus of this problem lies in the area of information supply (I). As noted before, the original project proposal was aimed at improving and automating the registration functionalities within Eurostrip. Registration (or measurement) is obviously concerned with information supply. Apart from this, the management has explicitly underlined that the information supply should be improved and that the primary and the control processes fall outside the scope of this project.

Information supply is concerned with “which information is produced, for whom and under which conditions” (Bemelmans, 1991). This is still a broad definition, which is not strange because information is a very broad concept in itself. To narrow this focus some more, the PCI framework is slightly modified. This is done to further delineate the problem. In the original PCI framework, the relation between the P, C and I concepts is that the control should be tuned to the primary process and the information supply should be tuned to both the control and the primary process.

In the modified version, we say that the information supply is in fact the ‘glue’ between the primary and the control process. This is a circular relationship, and the concept of information supply here is split up in three different concepts: performance measurement, enhancement and management. These concepts are further explained in the literature review. The modified framework can be found.
in Figure 5. Simply put; the information supply coming from the primary process to support the control process is concerned with performance measurement. Information coming from the control function towards the primary process is concerned with performance enhancement. Performance management in this context can be seen as the complete, circular relationship here: the measuring and enhancing of the performance of the primary process. In fact, performance management lies at the core of the control process.

This modified PCI framework enables us to further delineate the problem area. In the original PCI framework, we limited the scope to the information supply process, whereas now we limit it somewhat further to the concept of performance measurement only. This delineation complies with the original project definition as well as the wishes of the management. The management wants to improve the quality of the measurement information coming from Eurostrip. This underlines that the focus should be on performance measurement only. This thesis will describe which information is needed from the primary process and how it can be measured. We will not describe how the management should act on this information; this is performance enhancement.

2.7 Project Goal

Based on the considerations in the paragraphs above, the main goal of this thesis is stated as:

Design and implement a performance measurement system (PMS) for the Eurostrip production unit

Designing and implementing a PMS for Eurostrip is consistent with the initial project goals as stated in paragraph 2.1. By fulfilling this goal, the following two initial project goals will be fulfilled:

- Determine which elements in this process should be registered
- Automate these registrations

The initial first goal, describing the production process, is not a goal in itself but a means to achieve the two goals noted here. By designing process models, a comprehensible overview of the production processes can be given.
3. Literature Review

3.1 Introduction
This chapter describes the literature review that has been conducted to answer the set of research questions that have been defined in paragraph 2.5. These questions resulted from the initial exploration of the problem area. The following four questions are answered in this literature review:

1. What is performance measurement?
2. Which concepts are related to performance?
3. Why do managers want to measure performance?
4. How should a performance measurement system (PMS) be designed?

These questions are answered in paragraphs 3.2 to 3.5, paragraph 3.6 contains the conclusions for this chapter.

3.2 What is Performance Measurement?
The answer to this question is not straightforward. Leading authors in this field state that “…performance measurement is often discussed but rarely defined” (Neely, Gregory, & Platts, 1995). This is true; a lot of work is done in this field, but a clear and commonly accepted definition of the concept does not exist. Most authors simply assume that the concept of performance measurement is understood and do not explicitly define the meaning in their work. The three authors mentioned above give the following definition of performance measurement: “The process of quantifying the efficiency and effectiveness of an action.” In this sense, we can say that the process of quantification refers to measurement, and the efficiency and effectiveness of an action refers to performance. The concepts efficiency and effectiveness are fundamental here, as they can be seen as two dimensions of performance. These concepts will be elaborated in the section ‘related concepts’ below.

Looking up ‘performance’ in the Oxford dictionary gives us the following definition of performance: “a task or operation seen in terms of how successfully it is performed”. This is in line with the earlier definition of performance. However this implicates that performance is a broad concept, as a task or operation can be performed successfully in many different ways. Other authors confirm this, for example (Sink & Tuttle, 1988) state that the performance of an organization is a complex interrelationship between seven performance criteria:

- Effectiveness
- Efficiency
- Quality
- Productivity
- Quality of work life
- Innovation
- Profitability / Budgetability

Looking at these seven criteria, we can say that the definition by (Neely, Gregory, & Platts, 1995) has a too narrow focus, as there is more to performance than just effectiveness and efficiency.
Another author notes that performance measurement is “...complex, frustrating, difficult, challenging, important, abused and misused” (Sink, 1991). Apart from these drawbacks, the author notes that “measurement at the individual, group and organizational levels has tremendous problems, as well as opportunities associated with it.” This poses the question; is performance measurement worth the effort? This question is therefore also a literature research question. *(Why do managers want to measure performance?)*

The concept of performance measurement has now been clarified, but there are two terms that also need explanation here;

- **Performance measures**
  These are the concrete metrics used to quantify the efficiency and/or effectiveness of an action (Neely, Gregory, & Platts, 1995). Another author gives a similar description; “performance measures are the vital signs of the organization, which quantify how well the activities within a process or the outputs of a process achieve a specified goal” (Hronec, 1993). Other authors use different names for performance measures; most common are performance metric and performance indicator. (Fortuin, 1988) defines a performance indicator (PI) as “…a variable that expresses quantitatively the effectiveness or efficiency or both, of a part of or a whole process, or system, against a given norm or target.” This definition is also in line with the definitions of performance measures given before.

- **Performance measurement systems (PMS)**
  These are often defined as the set of metrics used to quantify both the efficiency and effectiveness of actions (Neely, Gregory, & Platts, 1995). In other words, the PMS is nothing more than the collection of all performance measures according to these authors. This definition seems incomplete; a PMS does indeed consist of performance measures, but there is more to it. A PMS also serves as a framework ensuring that the right measurement information is delivered to the right people in the company. This is an essential part of a PMS and it is what makes the difference between it being a system or just a bunch of performance measures. A review of other literature confirms this conclusion, a PMS is described by other authors as “…a tool for balancing multiple measures (cost, quality, and time) across multiple levels (organization, processes and people)” (Hronec, 1993). Other authors describe a PMS as “…a system (software, databases and procedures) to execute performance measurement in a consistent and complete way” (Lohman, Fortuin, & Wouters, 2004).

### 3.3 Which concepts are related to performance?

Apart from the concept of performance measurement itself it is useful to clarify concepts that are closely related to performance measurement. The following four concepts are elaborated in this paragraph:

- Effectiveness
- Efficiency
- Profitability
- Productivity
As stated before, **effectiveness** and **efficiency** should be seen as two dimensions of performance. Efficiency is a measurement of the extent to which a firm utilizes its resources in an economical matter. The focus here is on the internal manufacturing process, so it is not concerned with external performance such as customer satisfaction. Effectiveness on the other hand refers to the extent to which customer requirements are met. Thus, the focus here is at the external performance of the manufacturing process under consideration (Neely, Gregory, & Platts, 1995).

A simple definition of the terms efficiency and effectiveness is given by (Sink & Tuttle, 1988): effectiveness is usually in simple words described as “doing the right things”, while efficiency means “doing things right”. This definition of these terms is, although often cited, too simplistic and does not explain the terms good enough. The same authors also provide a visual representation of the concepts efficiency and effectiveness, which can be found in Figure 6 below. The definitions used in this figure for efficiency and effectiveness are clear and unambiguous. As can be seen, efficiency is placed right at the start of the transformation process (*internal performance*), whereas effectiveness is located at the end of the transformation process (*external performance*). This is in line with other authors in this area.

The terms productivity and profitability are, just like efficiency and effectiveness, closely aligned with performance. First we will discuss the concepts of productivity and profitability, after which these will be aligned in a conceptual framework together with performance, efficiency and effectiveness.

The term productivity is, just like all of the other concepts, defined by multiple authors in different ways. A very straightforward definition of the term productivity is given by (Chew, 1988): “Productivity = units of output/units of input”. This is the general view of productivity that is shared by most researchers, albeit some of these researchers place some nuances here. A more elaborated definition of productivity is given by (Bernolak, 1997): “Productivity means how much and how well we produce from the resources used. If we produce more or better goods from the same resources, we increase productivity. Or if we produce the same goods from lesser resources, we also increase productivity. By “resources”, we mean all human and physical resources, i.e. the people who produce the goods or provide the services, and the assets with which the people can produce the goods or provide the services.”

From these definitions it becomes apparent that productivity is in fact nothing more than the ratio in which inputs in a process are transformed into outputs, and as such the concept of productivity has a limited scope.

The concept of profitability is closely related to productivity. This is illustrated by the fact that companies tend to ignore the importance of productivity because they often see productivity and
profitability as one single issue. This might be true from an accounting perspective, but from an industrial engineering perspective it certainly is not. In his work, (Bernolak, 1997) elaborates the differences between productivity and profitability by giving formulas for both productivity and profitability:

\[
\text{Productivity} = \frac{\text{output volume}}{\text{input volume}} \quad \text{Profitability} = \frac{\text{output volume} \times \text{output unit price}}{\text{input volume} \times \text{input unit price}}
\]

Looking at these two formulas, we can say that profitability is in fact the result of productivity in combination with the input/output product prices. Obviously profitability will generally show a causal relationship with productivity but it is important to note that this is not always the case. The ‘price gap’ between productivity and profitability is called ‘price recovery’ (Tangen, 2005).

Since we have clarified four important concepts related to performance by now, we can place these concepts in a conceptual framework with the concept performance itself. We can say that performance is in fact an umbrella concept, including profitability and productivity, but also other important performance criteria such as quality, delivery, speed and flexibility. The so-called ‘Triple P’ model (Figure 7), developed by (Tangen, 2005) is an understandable model, placing the concepts performance, profitability and productivity, effectiveness and efficiency in relation with each other.

3.3.1 Performance measurement and performance management

The concepts of performance measurement and performance management are often mentioned together. In this context it is important to distinguish these concepts as they are obviously interrelated but the differences should be depicted here. Interesting work in this area is done by (Lebas, 1995), who states that performance measurement and management are not separable from each other. This author also notes that “measurement and management follow each other in an iterative process” and “performance management is a philosophy which is supported by performance measurement.”

In other words: Performance management is concerned with managing business processes while targeting a certain level of performance. Performance measurement is the discipline concerned with providing managers the information and insights they need to manage the processes. Therefore this is a circular relationship; measurement provides managers results of their management actions but measurement also serves as a basis for deciding on new management actions. A graphical presentation of this relationship can be found in Figure 8.

Concluding this research question, several concepts related to performance and performance measurement have been elaborated and placed into perspective in this paragraph.
3.4 Why do managers want to measure performance?

Since we have now explained the concept of performance measurement, the next step is to understand why it is useful to companies. The importance of measurement through the eyes of an expert in this field:

“Measurement is the first step that leads to control and eventually to improvement. If you can’t measure something, you can’t understand it. If you can’t understand it, you can’t control it. If you can’t control it, you can’t improve it.” (Harrington, 1991)

Several business functions for which measurement is important can be found in literature:

- **Improved control.** The feedback provided by performance measures gives managers better control over their areas of responsibility, whether it is a department, a plant or a division (Kaydos, 1998). Improved control implicates a reduction in control complexity. This supports our findings in chapter 2; the control complexity can be reduced by using good measurements.

- **Improvement of business processes.** The fact that measurement is an important prerequisite of improvement is noted by several authors, for example (Lohman, Fortuin, & Wouters, 2004) state that “the ability to measure the performance of operations can be seen as an important prerequisite for improvement.” Other authors note that “perhaps the only really valid reason for measuring performance is to support and enhance improvement” (Sink & Tuttle, 1988).

- **Measurement as a motivational tool.** Apart from solely providing managers with insights, performance measurement can also affect the motivation of individuals. Early research by (Locke, Shaw, Saari, & Latham, 1981) shows that performance improves if individuals are given targets, and is maximized if targets are seen as challenging but achievable. Of course some type of measurement should be executed to support the use of target and goal setting in practice. This is also supported by (Pritchard, 1990), who states that a beneficial use of measurement is that it is a source of motivation for increasing productivity.

There are more reasons for which measurements are used but the three reasons mentioned here are the most important ones during this research. Another author argues that each reason for measuring is providing an answer to one of the following questions (Lebas, 1995):

- Where have we been?
- Where are we now?
- Where do we want to go?
- How are we going to get there?
- How will we know we got there?

These questions are of a rather diverse nature as they are generally asked from different perspectives and with different goals in mind. For example, using measurement as a basis for a reward system is strongly related to the first question, with a focus on past achievements. On the other hand, when management wants to use its measurement system as an input for planning and budgeting activities, they want to answer the fourth question (How are we going to get there?). This indicates that the purpose of the measurement system should determine the design and set-up of
the system. Concluding, we can say that performance measurement is used for various reasons in organizations.

Performance measurement might sound like a vague management concept, but the opposite is true. Almost every manager worldwide uses performance measurement, either implicitly (e.g. way of thinking) or explicitly (e.g. through measurement protocols). Measurement simply cannot be separated from management. The relation between these two concepts is also confirmed by (Sink, 1991), who states that “measurement is an integral and important part of our management systems”. The question “Why do managers want to measure performance?” thus has a quite straightforward answer: Managers are simply dependant on all kinds of measurement to be able to execute their job successfully.

3.5 How should a performance measurement system be designed?

3.5.1 Cost driven performance measurement

Methodologies that describe how to design a performance measurement system have been widely discussed in literature by a broad range of authors from different disciplines. In the 90s, the shortcomings of traditional, purely cost driven performance measurement systems were recognized in industry. Various disadvantages of the traditional cost driven PMS have been discussed in literature, some examples are (Bitichi, 1994), (Maskell, 1991):

- Cost driven PMS encourage short-termism, which is not desirable in some situations. There are for example strategies that require sacrificing today’s profits for profits in the long run.
- Financial measures are not able to quantify the costs and benefits of some important aspects of performance such as quality and flexibility.
- Financial indicators are per definition lagging, reports are usually produced monthly and reflect the results of decisions that were made a couple months earlier.
- They induce reactive instead of proactive management.

More reasons can be found in literature why the traditional cost driven measurements are not suitable anymore for today’s businesses. It is sufficient here to recognize that they are lagging behind too often and that they are not able to capture all aspects of performance properly.

These shortcomings have led to the development of several ‘new style’ PMS frameworks, starting in the mid-nineties. These new approaches to performance measurement took a broader view towards performance and thus included more non-cost related measures.

3.5.2 Designing our own PMS

In this project, a PMS has to be developed which is based solely on non-cost measures, because the management wishes to keep all the financial information private. With this consideration in mind, the new style performance measurement frameworks prove to be useful because they are generally aimed more at the non-financial characteristics of performance.

In the remainder of this paragraph, we will construct a methodology that will be used during this project to construct a PMS for Eurostrip. We will first define three characteristics that the to-be designed performance measurement system should possess. With these characteristics in mind, we
will describe several methodologies and conceptual frameworks that can be useful when designing a performance measurement system. In the end, each of these will be rated against the three characteristics, and a step-wise design plan will be constructed.

Three characteristics that our measurement system should possess are:

1. The measurement system should have a **strong conceptual basis**
   A strong conceptual basis ensures that the measurement system to be developed is based on existing theories. After all, there is no need to reinvent the wheel here. This way we can also minimize the risk of overlooking important issues in the development process.

2. The measurement system should **incorporate performance indicators**
   Performance indicators are currently used within Decor Son already. This is the result of a professionalization effort that was started several years ago. By incorporating performance indicators into the to-be designed measurement system, the understandability and the level of acceptance can be improved.

3. The measurement system should have a **limited scope**
   The system to-be developed is aimed at measuring the performance of a production location (Eurostrip) using purely non-financial measures. This is a limited scope for a measurement system, as most approaches aim at measuring companywide performance on financial as well as non-financial aspects.

A total of six methodologies and frameworks that can be used when designing performance measurement systems will be discussed here:

- The Balanced Score Card
- Critical Success Factors
- The Performance Pyramid
- ProMES
- The Goal Question Metric method
- The Overall Equipment Effectiveness

Each of these frameworks will now be described in more detail.

### 3.5.3 The Balanced Score Card

When talking about Performance Measurement Systems, the Balanced Score Card (BSC) cannot be ignored. It is probably the most widely used ‘new style’ PMS around since it was introduced by (Kaplan & Norton, 1992). Since its introduction, balanced scorecards have been implemented by big consultancy firms in thousands of industries worldwide successfully. The basic idea underlying this method is that a company should use a balanced set of performance measures. These measures
allow top managers to take a quick but comprehensive view of the business from four different perspectives: Financial, Customer, Internal business and Innovation. The idea is that good performance in each of these areas, drive the performance of the company as a whole. The balanced scorecard methodology is often criticized for having several shortcomings. (Neely, Gregory, & Platts, 1995) argue that there are two main shortcomings of the balanced scorecard method:

- There is little guidance on the design of the performance management system, as the balanced scorecard is merely a framework. However, there must be noted here that this deficiency in the methodology was recognized by Kaplan & Norton and they published a step-by-step method describing how to implement a balanced scorecard in a company.
- The second shortcoming is the fact that, although the method claims to take a balanced view, not all relevant perspectives are captured. In this framework there is no notion of the so-called ‘competitor perspective’ (what are our competitors doing?)

In general, we can say that the balanced scorecard is certainly an innovating way of looking at performance measurement. But due to its set-up it is mainly useful for companywide implementation instead of implementation at a small functional business unit.

### 3.5.4 Critical Success Factors & Key Performance Indicators

A critical success factor (CSF) is a variable that is of critical importance in realizing the corporate strategy. A CSF is a **qualitative** description of an element of the corporate strategy in which the company has to excel to be successful. A key performance indicator (KPI) on the other hand is a unit for measuring a critical success factor. The KPI provides information about the CSF and it is always expressed as a number (Waal, Mijland-Bessem, & Bulthuis, 1998).

This is not so much of a conceptual framework as the other approaches discussed here. In fact, key performance indicators are often used in each of these frameworks, they represent the actual performance measures or metrics of the system.

---

**Critical success factor:** Customer Service  
**Key Performance Indicator 1:** Repeated purchases  
**Key Performance Indicator 2:** Satisfied Customers  
**Key Performance Indicator 3:** Complaint handling duration

![Figure 10 - Example of a CSF with corresponding KPIs](image)

The idea of this approach is that an organization should determine their key objectives (the CSF) at all levels in the organization. When the list of critical success factors is chosen, a set of KPIs should be constructed for each CSF. The problem here is that one cannot know whether the list of CSFs is complete, it is possible that either too much or too few CSFs are chosen. When too few CSFs have been chosen, success of the business is not ensured in certain areas. In the case of too much CSFs the attention of employees is spread too much and sub-optimal results will occur. Therefore it would be
useful to have some more guidance when implementing CSFs and KPIs as to when the list is complete.

### 3.5.5 Performance Pyramid

This approach to performance measurement was developed by (Lynch & Cross, 1995). These authors note that there must be a clear link between performance measures at the different hierarchical levels in a company, in such a way that each employee strives towards the same (corporate) goals. Following this reasoning, it is not strange that the authors drew a pyramid reflecting an organization. At the top level is corporate vision, expressing the ultimate goals of an organization. As can be seen in Figure 11 below, the objectives are translated in a top-down fashion, whereas the measures are translated from the bottom of the organization (e.g. the factory floor) to the top. Going down from the top, purely strategic goals shift gradually into operational goals at the bottom. Another distinction that is depicted here is the distinction between external and internal performance.

![Figure 11 - The performance pyramid (Lynch & Cross, 1995)](image)

External performance is performance that the customer experiences. The customer sees the quality of products or services, and whether they are delivered in time. The internal performance is all the performance inside the company, which is not visible from the outside.

The advantage of the performance pyramid framework is that it is useful for operational performance measures, as it clearly shows how operational measures should be consistent with the higher level performance measures and vice versa. This way the measurement of the operational activities can be strategically aligned with the strategic goals of the company.

It can be said that this framework presents an appealing overview of different sorts of performance measures within an organization. This brings us to the biggest disadvantage of this method, as there is not really much more to it. Apart from it being a nice looking conceptual framework, there is no guidance on how metrics should be selected to populate this framework. Also, not much guidance is given on how to implement this framework in a practical setting. This makes the performance pyramid, albeit the best conceptually oriented framework around, also the least practical.
3.5.6 ProMES

The Productivity Measurement and Enhancement System (Pritchard, 1990) is the most different framework compared to the others discussed here. The author states that “ProMES is a way of measuring productivity and feeding productivity information back to personnel”. By feeding back this productivity information to the personnel, the goal is to improve the productivity by actually involving the employees in this measurement process. This is why the term “enhancement” is included in the name of this method.

As we know by now, the concept of productivity has a smaller focus than performance, as productivity is said to be the ratio of outputs divided by inputs. This is indeed true in the ProMES approach, the main focus is on productivity ratios. However, the author also suggests measuring ratios such as ‘demand met’ and ‘quality’, of which we said that they belonged more to the concept of performance instead of productivity. This confirms the fact that the terms productivity and performance are often used interchangeably for the same things. Nevertheless, the ProMES approach focuses on productivity measures more than anything else so by no means this approach can be said to take a balanced view of performance such as most other methods.

The idea behind ProMES is illustrated in Figure 12. The process starts by identifying the objectives of the organization. From these objectives, a productivity measurement system is developed that is consistent with the objectives. Next, the data resulting from the measurement is fed back to the employees through a feedback mechanism in the form of feedback reports. These feedback reports then serve as a basis for discussing how to improve productivity among employees. This process should lead to increased productivity and thus meeting the organizational objectives stated at the start of the process.

![Figure 12 - The ProMES approach (Pritchard, 1990)](image)

The author states that ProMES is primarily designed “to improve productivity through the activities of the personnel in the organization” (Pritchard, 1990). This is the main issue that makes ProMES different from the other approaches presented here, as most other approaches stop after stage two (the actual design of the measurement system), ProMES starts here.

3.5.7 The Goal Question Metric

The Goal Question Metric (GQM) approach is based upon the assumption that for an organization to measure in a purposeful way it must first specify the goals for itself and its projects, then it must trace those goals to the data that are intended to define those goals operationally, and finally provide a framework for interpreting the data with respect to the stated goals (Basili, Caldiera, &
Rombach, 1994). Although this approach was originally designed for software engineering, it can be applied to other situations as well.

After applying the goal question metric approach one should end up having a specification of a measurement system targeting a particular set of issues. The resulting measurement model has three levels:

1. The Conceptual level (Goal): A goal is defined for an object, for a variety of reasons, with respect to various models of quality, from various points of view, relative to a particular environment. Objects of measurement include products, processes and resources.
2. The Operational level (Question): A set of questions is used to characterize the way the assessment/achievement of a specific goal is going to be performed based on some characterizing model.
3. The Quantitative level (Metric): A set of data is associated with every question in order to answer it in a quantitative way. This set of data can be either objective or subjective, based on the source and the nature of the data.

The hierarchical structure of the model with its three levels can be seen in Figure 13 below.

![Figure 13 - The hierarchical structure of the GQM model (Basili, Caldiera, & Rombach, 1994)](image)

Reasons for implementing goal-oriented measurement using GQM are to ensure adequacy, consistency and completeness of a measurement plan (Briand, Differding, & Rombach, 1996). These seem like valid reasons, but some remarks should be made here. The fact that GQM is a very helpful and structured approach in translating goals into metrics is clear. However, the completeness of the measurement system cannot be fully guaranteed, since there is no real guidance on how to select the goals to start with. Since there is no guidance on the selection of goals, we can never ensure the completeness of the measurement system as a whole. The GQM approach ensures that the selected goals can be properly measured, but how can we know if we have selected the right goals to start with? This is an important drawback and it should be taken into account when using this approach.

When looking at the CSF/KPI and to the Goal Question Metric approaches, it occurs that these two methods are actually roughly the same. Both approaches state that a set of strategic goals (or critical success factors) should be chosen and that a set of metrics (or indicators) should be used to monitor the progression towards these goals. The only difference is that the Goal Question Metric approach more explicitly describes the way in which these goals should be translated into the metrics.

### 3.5.8 The Overall Equipment Effectiveness

Most managers would like to have one single performance metric that could tell them how their production processes are performing in a blink. Sadly, this ultimate metric does not exist. A concept that approaches this ultimate metric does exist though. It is called the Overall Equipment
Effectiveness (OEE). It is a composed metric that describes the overall effectiveness of a manufacturing operation. It is thus concerned with the operational performance of a production line or machine. This concept is different from the other concepts discussed in this paragraph, because it is not a design method. In fact, it is nothing more than an easy and understandable way of measuring the effectiveness of a process. As we know from the foregoing, effectiveness is only one of the many dimensions of performance.

The OEE measure is a composed metric that breaks down into three independently measurable components (Ljungberg, 1998):

- Availability
- Performance rate
- Quality rate

The formula for calculating the OEE is:

$$\text{OEE} (%) = \text{Availability} (%) \times \text{Performance rate} (%) \times \text{Quality rate} (%)$$

Each of these components will be shortly explained below based on (Dal, Tugwell, & Greatbanks, 2000).

The availability ratio represents the percentage of scheduled time that the production line is available to operate. Thus, this is the fraction of uptime of the production line in the scheduled uptime.

$$\text{Availability} (%) = \frac{\text{Actual operating time}}{\text{Scheduled operating time}} \times 100\%$$

The performance rate is a measure of the actual speed compared to the ideal speed. For example, if the ideal cycle time of a certain product is 1 minute, and we have produced 45 of these products in a run that took 60 minutes, the performance rate will be 75%. (De Groote, 1995) suggests that the performance rate can simply be calculated for a fixed time interval, as the ratio of the actual produced amount to the maximum possible production amount for that time interval. The maximum production amount in a time interval is reached when producing in an optimal cycle time.

$$\text{Performance rate} (%) = \frac{\text{Actual amount produced}}{\text{Maximal production amount}} \times 100\%$$

The quality rate is the ratio of the amount of good products to the total amount of products produced.

$$\text{Quality rate} (%) = \frac{\text{Total no. produced} - \text{No. scrapped}}{\text{Total no. produced}} \times 100\%$$

Multiplying these three rates gives us the OEE ratio. This ratio is the percentage relating the current performance of a production process against the optimal performance of that line. An OEE performance of 100% will most likely never be reached in practice, but it is a goal that should be pursued.
3.5.9 Discussion of the methods

The performance measurement methodologies and frameworks that have been discussed in this chapter are quite different from each other. As said before, reviewing these frameworks was done with a purpose in mind. In the end, a methodology has to be developed that can assist us in designing the performance measurement system for Decor Son, or more specific, Eurostrip.

Each of the six approaches to performance measurement discussed in the foregoing will now be rated against the three criteria that were mentioned in 3.5.2. This way, we can find out which of the concepts are useful in our situation.

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<tr>
<td>Balanced Scorecard</td>
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<td>CSF &amp; KPI</td>
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<td>Performance Pyramid</td>
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<td>Goal Question Metric</td>
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<td>Overall Equipment Effectiveness</td>
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Table 1 - Comparison of the PMS approaches

As can be seen in Table 1, the Balanced Scorecard approach scores good on its conceptual basis and the fact that it incorporates performance indicators. However, since it is aimed so much at companywide performance, it is not suitable to be used in such a limited scope as we require here. Therefore this approach will be discarded and will not be used in this project.

Critical success factors and key performance indicators lack a strong conceptual basis but score well on the other two criteria. As discussed before, this methodology is roughly the same as the GQM approach, but it is less explicit in explaining how to translate critical success factors (goals) into performance indicators (metrics). Therefore the GQM approach is preferred above the CSF/KPI approach here.

The performance pyramid has the strongest conceptual basis of all the other frameworks, but does not contain any practical guidance for implementation. It is therefore very useful as a ‘static’ framework in the sense that it can help us to explain and understand the dimensions of performance and the way in which they are related through the various levels within a company.

The ProMES approach is mainly focused at the way in which a measurement system can be used to improve employee performance by feeding back measurement data to the workforce. Although this approach offers interesting insights, the real power of this method lies in the post-implementation stage. Since this project is aimed only at the design phase of the measurement system, the ProMES approach will also not be used in this thesis. It might be useful to keep this theory in mind for when the implementation phase is completed.

The Goal Question Metric approach is suitable for deriving metrics from strategic goals. Therefore this approach can be used as a ‘dynamic’ framework because it offers us a step by step plan to translate strategic goals into measurable metrics. The resulting metrics can also be called performance measures or performance indicators, because these are three different names for the same concept, this was already discussed at the beginning of this chapter. For consistency, we will
use the term ‘metrics’ during the remainder of this thesis. The major drawback of the GQM approach is that it does not give enough guidance on selecting the goals to start with.

Finally, the OEE metric is a very different concept in the sense that it is only a simple method to present an easy overview of the effectiveness dimension of performance. It lacks a strong conceptual basis. The OEE metric can be used in a limited scope, but it can only be used for rating the effectiveness. Because of this, the OEE metric will not be included in our design methodology. The concept will not be fully discarded because it might be useful in a post-design phase.

3.5.10 Construction of our methodology

Based on the discussion of the approaches above, we will construct our own methodology here. We will develop a step-wise method based on the approaches discussed in the previous paragraph.

In order to successfully develop a PMS for the Eurostrip production unit, we will follow a five step process:

1. Define a strategic objective in each of the four performance dimensions at the 2\textsuperscript{nd} layer in the performance pyramid (Quality, Delivery, Cycle time & Waste) from (Lynch & Cross, 1995). This way we can ensure that we start the design of the measurement system with a complete and integrated view on performance. Also, the performance pyramid proves to be a useful visual aid in explaining the relation of the several performance concepts.

2. Apply the Goal Question Metric methodology (Basili, Caldiera, & Rombach, 1994) to translate each of these goals into measureable metrics. This way we can ensure that each of these goals can in fact be measured. Also, the consistency and completeness of the set of metrics can be guaranteed when the GQM approach is successfully followed.

3. For each of the metrics, clearly define the input parameters and the way in which the metric should be calculated. Also document additional information about the metrics.

4. Design a data collection system able to collect the parameter data, to aggregate and calculate the metrics on a periodical interval, and to present the data.

5. Implement this system at Eurostrip.

Figure 14 below shows a modified performance pyramid describing the first two steps of our measurement system design. On the right side of the pyramid, we can see that the three upmost layers of the pyramid are the responsibility of Decor Son, whereas Eurostrip is responsible for the
two lowest layers. For this project we are primarily interested in the Eurostrip production unit and therefore the lowest two layers of the performance pyramid. Strategic goals will be defined for each of the four performance dimensions for which the Eurostrip production unit is responsible. Then, using the Goal Question Metric approach, these strategic goals will be translated into measurable metrics.

The execution of the first three steps of this five-step methodology will be described in chapter 5: the design of the performance measurement system. Step four is described in chapter 6: the design of the data collection system. The actual implementation, step 5, will not be completed during this thesis.

3.6 Conclusions

In this chapter, the results of a literature review have been described, providing answers to the four literature research questions that were defined in chapter 2. In paragraph 3.4, a five step method has been constructed that will be used in the remainder of this project to construct a performance measurement system for Eurostrip.
4. Analysis of the current situation

4.1 Introduction
In this chapter, the current situation at Decor Son and Eurostrip is described in more detail. In section 4.2, the framework that is used as a guideline for describing the company is explained. In section 4.3, the Decor Son and Eurostrip structure, strategy and systems are described in more detail.

4.2 Methodology

4.2.1 Description of the 7S framework
The current situation is described in this chapter based on the McKinsey 7S framework, originally developed by (Waterman, Peters, & Phillips, 1980). The framework was created as a recognizable and easy to remember model. Since then it has been widely used by practitioners and academics in the analysis of thousands of organizations. This model is also often referred to as the McKinsey 7S model, as both authors were McKinsey employees. The idea behind the model is that each organization can be broken down into its component parts by covering seven elements that make up an organization: Structure, Strategy, Systems, Skills, Style, Staff and Superordinate Goals (later renamed to Shared Values in (Peters & Waterman, 1982)). The seven components should be seen in relationship to one another. This means that a change in one of these elements always influences the other elements.

The 7S model can be divided in three ‘hard’ elements and four ‘soft’ elements. ‘Hard’ elements are easier to define or identify and management can directly influence them. The three hard elements are located at the top of the framework; strategy, structure and systems. The other four elements are called the ‘Soft’ elements, they are more difficult to describe, less tangible and are more influenced by culture. Both the soft and the hard elements are equally important for the organization to be successful.

4.2.2 Narrowing the scope
As stated, the McKinsey 7S framework will be used here as a guideline for analysing the current situation of Decor Son and Eurostrip. We will however not describe the organisation on all of these seven aspects, as this would be too elaborate here. The choice is made to describe the current situation based on the three ‘hard’ elements described above: Structure, Strategy and Systems. This is done because these factors are easier to identify in the organisation and they are normally well documented in the form of reports such as strategy statements and organisational charts.

Figure 15 - The 7S framework (Peters & Waterman, 1982)
4.3 Organization description

The organization is described in this paragraph from three different angles; Structure, Strategy and Systems. The following paragraphs will describe the organisation from each of these perspectives.

4.3.1 Structure

Structure is concerned with the way in which people and work are organized, it often dictates the way it operates and how well it performs (Waterman, Peters, & Phillips, 1980). The Decor Son structure will be described here in a top down approach.

4.3.1.1 Decor Son structure

The organisation structure of Decor Son can be seen in the figure below. In the Decor Holding B.V. there are a number of independent companies. Each of these companies operates under the collective name ‘Decor Son’.

Decor Son profiles itself as a company that is based on three core activities: Trade, Logistics and Production. These can be distinguished from the organisational structure here:

- **Trade** (Decor Handelsmaatschappij BV)
  Decor Son Trade supplies A-branded products to DIY retailers, mainly the Benelux and Germany. The assortment includes about 5,000 different articles. Products are shipped from the main compound in Son, where they are stocked on the 75,000 square meter storage space of which 30,000 square meters is roofed.

- **Logistics** (Nico Witlox Transport BV)
  Within Decor Son Logistics, activities include the management of the stocks in Son, but also the operation of the privately owned truck fleet.

- **Production** (Decor Productiemaatschappij BV and Eurostrip BV)
  About 35% of the total sales result from in-house production. These products are manufactured either in Son (Decor Productiemaatschappij BV) or in Den Bosch (Eurostrip BV).

An organizational chart can be found in appendix A. It can be seen that the organization is functionally oriented and that there are two to three management levels, depending on the department. The scope of this project is Eurostrip B.V., the production unit located in Den Bosch where the stone strips are produced. All the other companies in the holding are located at the main compound in Son.
4.3.1.2 Eurostrip structure

We will now zoom in on the Eurostrip production unit to describe its structure. In Figure 17, the organizational structure of Eurostrip can be seen. The top manager of Eurostrip is the operational manager (OD), second in rank is the production manager (PM). This is the organizational structure on paper. In practice however, both the functions of operational director and production manager are executed by the general manager (AD). The day to day operations at Eurostrip are the responsibility of the production team leader (TLPB). He is assisted by an administrative employee (APm) and a technical service coordinator (cTD).

At Eurostrip, around 50 employees carry out the actual manufacturing activities at the work floor. The production employees are divided in so called production cells. One employee is the team leader of all the production cells (PLC). Within each production cell, there are production cell coordinators (CCo), machine operators (MO) and regular production employees (Pm). Apart from the employees in the production cells, there are several employees that perform supportive functions, such as internal logistics. These are called the expedition employees (Em).

4.3.2 Strategy

A company’s strategy is designed to transform the firm from the present position to the new position described by objectives, subject to constraints of the capabilities or the potential (Ansoff, 1979). In this paragraph, we will describe the business-level strategy of Decor Son. Business-level strategy involves issues that define how the organization will compete in its market. Typical business-level strategies include (Hatch, 1997):

- Expansion into new sales territories
- Building new plants or offices
- Cost reduction programs
- Product or service differentiation
- Quality enhancement

Insight in Decor Son’s business-level strategy was gained during an interview session with the human resource manager (MPO). The strategy is explicitly described in the annual reports, but these are kept confidential and could therefore not be used as a resource here.

Each of the typical strategies mentioned above is more or less present today at Decor Son. In one word, Decor Son’s corporate strategy is built around growth. The goal is to keep growing faster than the competition. In the past ten years, Decor Son managed to achieve a turnover growth of about 10% above the market average. Decor Son aims at maintaining this steady growth in both turnover and net profit. While doing so, the existing customer base has to be kept satisfied. In this perspective, the quality of both products and processes has become an important issue in Decor Son’s strategy. Decor Son has been certified according to ISO 9001 since 2000. This way, external parties can see that quality is important at Decor Son.
Considering the growth, the aim is to yearly increase the turnover together with the net profit. Since Decor Son is a trading company, turnover growth can be obtained by increasing sales volumes. Decor Son aims at increasing the sales volumes by applying a mix of two strategies:

- **Broadening the assortment:** selling a larger product assortment to the existing customers
- **Acquiring new customers:** contracting new customers in existing countries and entering new markets

Which strategy is chosen depends on several issues. Let’s take the Dutch market for example. Decor Son supplies the majority of the DIY retail chains that are active on the Dutch market (Gamma, Karwei, Praxis, Formido and several others). In this particular market, no real growth can be achieved anymore by acquiring new customers. Therefore the strategy for the Dutch market is to broaden the assortment for the existing customer base, instead of aiming at growth through acquisition. In other countries, such as Germany and some Southern European countries, the strategy is aimed more at the acquisition of new customers to get a larger market share there.

To increase the net profit, Decor Son aims at increasing sales volumes which was mentioned before, but also by increasing the profit margin on the sold products. To increase the profit margins, Decor Son aims at increasing the fraction of sales that comes from in-house production, and thus expand their production activities. Acquiring other (smaller) manufacturing companies is part of the strategy here. At the same time, the goal is to guard the efficiency of the current manufacturing processes. Toward this goal, cost reduction is an important part of the strategy for both production locations.

This concludes the discussion on Decor Son’s business-level strategy. Summarizing, Decor Son wants to continue the growth of the last decade by broadening the assortment and acquiring new customers. At the same time, high quality products and processes are important. Also, expanding their in-house production activities is an important part of their strategy. Finally, cost reduction initiatives are implemented at both production locations.

### 4.3.3 Systems

Systems are all the procedures, formal and informal, that make the organisation go, day by day and year by year (Waterman, Peters, & Phillips, 1980). The systems aspect of the 7S model is described here in terms of business processes. A business process is defined here as a set of logically related tasks performed to achieve a defined business outcome (Davenport & Short, 1990). Building process models proves to be helpful in understanding the processes and it is also useful to explain the processes to the reader who is not familiar with Decor Son and Eurostrip.

#### 4.3.3.1 Methodology

For building process models, we have used IDEF0 models combined with flowcharts. IDEF0 models are often used as a tool in systems development because they can be used to model complex systems in a simple graphical way. Apart from this, these models have a hierarchical set-up and processes can be decomposed into sub-processes while retaining the hierarchical structure. A top-down approach is taken here to describe the processes; we will start at the highest level and ‘zoom in’ on sub-processes that are of interest for this project. For more information on the IDEF0 modelling method, see the Appendix. Apart from IDEF0 models, we will use simple flowcharts to clarify certain processes at the lowest hierarchical levels, which in this case are the physical production processes.
In the next few sub-paragraphs, several business process models will be presented and described. The goal of this paragraph is twofold; we want to develop understanding of the business processes while at the same time gather insight on the context of the business problem at hand.

All models that have been constructed are based on both employee interviews and company procedures. The employees that were interviewed here were the general manager (AD), the production team leader of Eurostrip (TLPB) and the information analyst (IA). These three employees were also interviewed during the problem analysis phase of this project. The written company procedures that were studied are part of the internal quality system (‘KMA Systeem’). This system is a document repository shared over the internal network and contains a broad range of documents such as internal procedures, templates and instructions. The most interesting documents for building process models were the internal procedure documents. These documents describe various processes in terms of tasks, employee responsibilities and qualifications. We have however taken a somewhat skeptical approach towards these internal procedures, as they document how things should be done, whereas employees tell the story of how things are actually done.

The next sub-paragraphs will describe the relevant business processes at Decor Son in more detail, in a top-down fashion.

4.3.3.2 A0: Overall business process
The first IDEF0 model described here is the A0 process: the overall business process. This is the highest level business process, describing the complete business process of Decor Son.
As can be seen in Figure 18, the process starts with a customer order, which is processed in activity A1. The order then gets scheduled (A2) so it can be picked some time later. In parallel, the stock at the main warehouse gets replenished frequently (A6). The goal of replenishing the stocks is to prevent lost sales from occurring. Sometime after the orders have been scheduled, they are picked at the warehouse (A3). The ERP system generates picking schemes for the warehouse employees. The goal here is to combine various customer orders into one truck load such that truck capacity can be used to its full extent. The result of the pick order activity is a loaded truck, which is then dispatched to the customer. After the goods are delivered, an invoice is sent to the customers by the finance department (A5).

As said earlier, about 35% of the turnover comes from in-house production. This production takes place in the activity ‘produce’ (A7), which runs in parallel to all the other processes. The goal of the production departments is to produce sufficient products to stock. Controls for the ‘produce’ activity are the actual and projected stock quantities at the Son warehouse, the strategic production planning and the updated sales quantities.

In Figure 18, we have shaded the part of the A0 process that is performed at the Eurostrip production unit. Not surprisingly this is the sub-process ‘Produce’, referred to as A7 here, and it will be further decomposed into sub processes. The other sub-processes (A1 to A6) will not be further elaborated here as they fall outside the scope for this project.

4.3.3.3 A7: Produce
This sub-process is a decomposition of the A7 process and consists of three different activities; these are named A71 to A73 according to the IDEF0 standards. The complete IDEF0 diagram for A7 can be seen in Figure 19 below. First, the production has to be scheduled; this is done in activity A71 and will

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**Figure 19 - Activity A7: Produce decomposed into sub-processes**
be further described in paragraph 4.3.3.4. The output of this activity is a production schedule. This schedule steers the ‘Execute Production’ activity A72, where raw materials are transformed into both products in stock and waste material. This takes place at several different production lines, which will be described in paragraph 4.3.3.5. During and after the production activities at the various production lines, data is collected about these processes in the activity ‘Collect and Process Production Data’ (A73). This production data is eventually used to create several reports, containing information on the performance of the production processes. The next three paragraphs will now discuss each of these sub-processes in more detail.

4.3.3.4 A71: Schedule Production
The activity ‘Schedule Production’ is the first sub-process of the A7 process. As can be seen in Figure 19, the controls for this process are stock quantities, strategic planning and updated sales. Eurostrip is a production unit of Decor Son and their planned production quantities are determined by Decor Son’s needs. The process that ultimately leads to a production schedule will be elaborated here. It is important to understand this process because a good production schedule is an essential precondition towards successful production. This is underlined by (McKay & Wiers, 2004).

The production planning process
In the foregoing, IDEF0 models were used to describe the different business processes. The IDEF0 methodology is useful to model these processes from a functional perspective. To describe the production planning process, IDEF0 models were considered not very helpful. To properly model the production planning process, we built a model based on the BWW framework (Bertrand, Wortmann, & Wijngaard, 1998). The BWW framework provides an overview of how different levels of planning influence the production at the lowest level. This serves our purpose; we want to sketch a comprehensible overview of the different planning types at Decor Son and Eurostrip, how they influence each other and which other information flows are relevant.

![Figure 20 – The production planning process based on the BWW framework by (Bertrand, Wortmann, & Wijngaard, 1998)](image-url)
The resulting model can be seen in Figure 20, the planning process starts with creating a demand forecast at the end of each year for the coming year. Based on this demand forecast, an annual sales forecast is created. This sales forecast is then translated into a strategic production planning. The annual sales forecast and the strategic production planning are updated when new customers are contracted that require more volume than what is planned or forecasted.

The strategic production planning then leads to a short term planning. This is where we shift from a tactical to an operational setting; the strategic planning has a one year scope, whereas the short term planning has a focus of one or two months ahead. The short term planning is influenced by several variables; the strategic production planning is a guideline for the short term planning, but the short term planning is revised when new customers are contracted or when order processing experiences more demand volume than initially expected. In a meeting at the beginning of each month, the Eurostrip production manager (TLPB) discusses the production schedule for that month with the manager of the inventory management department (TLV). In this meeting, the planned production quantities for that month are evaluated based on the current quantities in stock and the forecasted sales for that month. The available production capacity is also considered here. After this meeting, the short term production planning is agreed upon by both parties and a copy is sent to the general manager for approval. From now on, this short term (monthly) production planning is ‘leading’ and the production amounts in this planning are translated into the daily production schedule at Eurostrip.

The material flow can be seen at the bottom of Figure 20, entering the Eurostrip plant as raw materials inventory. After production, completed products are transported to the inventory at the Decor Son warehouse, from where it is shipped to the customers.

A proper short term planning and thus a proper production schedule can only be created when the planning process as described above is successfully executed. The quality of the production schedule depends on three information sources (the three control arrows steering activity A71);

- Stock quantities
- Strategic planning
- Updated sales

Both stock quantities and updated sales can be seen as reliable information sources, they are easily measured in the ERP system and therefore they provide a reliable input for the short term planning. The strategic planning however is different; it is based on a forecasted demand and thus not as deterministic as the other two information sources. Therefore we choose to analyse the demand forecasting process at Decor Son. This way we can get some more insight into this important input parameter for the planning.

**The demand forecasting process**

First we will describe the way in which the demand forecasts are currently made within Decor Son. Secondly, we will describe a suggested forecasting framework found in literature. The way in which demand forecasting is currently done will then be compared with this suggested forecasting framework to see if the current way of demand forecasting has shortcomings.
At Decor Son, a yearly demand forecast is created at the end of each year for the coming year. This forecast is generated by the ERP software (ACP). The forecasting method is rather simplistic; demand data from the previous three years is used to calculate a seasonal influence factor for each individual month in the coming year. This is done based on a non-weighted average, meaning that each of the past three years have an equal influence in the calculation of the forecast for the coming year. Apart from the seasonal influence factor each month, a trend factor is also calculated based on the last three years. This model eventually creates a proposed forecast, which is then updated based on human input, and finally results in an approved demand forecast.

A suggested demand forecasting framework found in literature can be found in Figure 21. A demand forecasting should obviously start with historical data. Then, a mathematical model is chosen to generate a statistical forecast. This forecast should always be corrected by human input. This results in a demand forecast. Based on the actual demand observed during the year, the forecast error should be calculated, so that the forecast model or its parameters can be updated when necessary. Feedback about the demand forecast performance should also be given to the people that provide input to the statistical forecast. The actual demand forecasting method used by Decor Son will now be analysed based on the suggested forecasting framework from Figure 21.

The forecasting method used by Decor Son roughly follows the proposed framework presented in Figure 21. Historical data is used and through a mathematical model a proposed forecast is created, which is then corrected by human input. However, from this point on, the actual forecast error is never evaluated, resulting in the situation that the used forecasting model and its parameters is not updated and feedback regarding the forecasting performance is never fed back to the people in control. This is the biggest drawback of the current forecasting method used at Decor; it is not constantly re-evaluated. Note that this issue was mentioned before in the problem analysis (chapter 2). There is certainly room for improvement here. This issue will only be signalled here, but not further researched. The scope of this project is at measurement, not forecasting. Therefore this issue will not be further elaborated here but it will be repeated as a recommendation.

Concluding this paragraph on production scheduling, we can say that the production schedules for Eurostrip are a direct result of Decor Son’s needs. Some of these needs can be derived directly from

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**Figure 21 - A suggested forecasting framework (Silver, Pyke, & Peterson, 1998)**

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deterministic information sources, but the first and most important input in the planning process, demand forecasting, is not as reliable.

4.3.3.3 A72: Execute Production
This paragraph describes the actual production processes as they currently take place within Eurostrip. This activity is controlled by the production schedule which is created in activity A71. The physical input to this process is raw material. The physical outputs here are end products and waste material. Also, a non-physical output of this process is production related data.

In the next sub-paragraphs, we will describe the A72 activity in a top-down fashion. First, a general description of the production process is given. Then, each of the production lines will be discussed in more detail so that specific characteristics of these lines can be outlined.

General production process
In the Eurostrip plant, two different types of stone strips are produced: concrete stone strips and plaster stone strips. The main difference between these types is that the concrete strips are water resistant, which makes them suitable for both outdoor and indoor use. The plaster strips can only be used indoors. The advantage of plaster over concrete is that it can be shaped more easily into various moulds and thus can be used to create more ‘exotic’ shaped strips.

The stone strip production process is in fact quite simple in nature. It is largely the same for all stone strip types and roughly consists of 5 steps (see Figure 22 below). All the products are created batch-wise.

For each product batch, a mixture is prepared. Each product type requires a different mixture. This mixture is then injected in moulds, determining the shape of the stone strip. The moulds are then moved to an area to dry. Concrete strips have to dry for about 24 hrs, whereas the plaster strips dry within 3 hours. When dry, the strips are removed from the moulds and packaged in carton boxes.

The next paragraph will discuss the different production processes in the Eurostrip plant in more detail.

Detailed description of the production lines
Eurostrip has three more or less automated production lines. These lines are named ‘Euroc 1’, ‘Euroc 3’ and ‘Gips’. Apart from these three lines there are two manual production lines, called ‘Hoek Beton’ and ‘Hoek Gips’ where the concrete and the plaster corner stones are produced. Due to fact that these corner stones are ‘L’ shaped, it is not possible to automatically fill the moulds, and after drying, remove the stones from the moulds. On top of this, the required production volume for these strips is substantially lower compared to the normal strips (about 1:10). So in total there are five distinct production lines, of which two are fully manual.

The degree of automation differs quite somewhat among the lines, the most highly automated production line is Euroc3, featuring an almost fully automated process. The Euroc 1 line operates
mostly manual, the filling of the moulds happens in a semi-automated fashion, and the moulds are transported by a conveyor belt. The moving towards the drying area as well as removing the products from the moulds and the packing is done manually. The plaster strip production line called ‘Gips’ is automated to the same extent as Euroc 1.

Below, each of the five production processes is discussed in more detail and where needed they are supported by simple workflow models.

**Euroc 1**

Euroc 1 is a semi automated production line that produces several product types. At this moment the line is operated 24 hours per day, 7 days a week. A flowchart representing the production process on the Euroc 1 line can be found below in Figure 23. The general structure of the stone strip production process (Figure 22) can be distinguished here. The process starts with the creation of a concrete mixture. The machine operator first enters the required amounts of sand, gravel and water, after which these amounts are automatically put in the mixer. He then manually adds the required amount of cement and other additions. Additions here are colour powder and plasticizer, which is added to increase the fluidity of the mixture. A full mixer contains about 286 kg of mixture. After the mixer has been filled, the mixture is injected in the moulds, which are loaded onto a conveyor belt manually. The moulds are filled manually at the conveyor belt by an operator using a hose attached to the concrete mixer. A significant amount of mixture is spilled when filling the moulds because it is done fully manual. This is collected at the conveyor belt in a ‘waste mixture’ container. At the other end of the conveyor belt, one or two employees take the filled moulds from the belt and place them on carts. These carts are simple wheel mounted vehicles containing several shelves to store the filled moulds. Depending on product type, one cart can hold between 80 and 300 filled moulds. When a cart is full, it is moved to a dry area, where it is left to dry for at least 24 hours. This is as far as the ‘filling’ part of the process goes; four employees are required for this part of the process.
When the stone strips are dry, the second part of the process starts. About 6 to 8 employees are required here, depending on the amount of work available. The moulds are taken from the carts and the stones strips are removed from the moulds. At the moment, around 8% of the stone strips are scrapped when removed from the moulds. The stone strips can be already broken in the mould, due to too much air bubbles or they are removed too roughly from the moulds by the employees. The broken products are collected in scrap product containers. These containers are emptied in a big waste container at the outside terrain, together with the spilled mixture from earlier in the process. The good products are packaged in carton boxes and stacked onto pallets. When a pallet is finished, it is moved to the pallet storage, a small storage location in the plant used for temporary storage of finished goods until they are shipped to the warehouse in Son.

**Euroc 3**

As said before, the Euroc 3 line is almost fully automated. The flowchart of Euroc 3 is largely the same as the Euroc 1 flowchart. This is not strange, since the production process in essence consists of the same basic steps. However, there are some essential differences between the Euroc 1 and Euroc 3 production line. At the Euroc 3 line, the filled moulds are stored at big shelves, which are automatically moved from and to a dry room by a big robot. After drying for 24 hours, the robot picks the shelves with dry product from the dry room and the moulds are places back on a conveyor belt, after which the products are automatically removed from the moulds. There are two points here where the products can be rejected. If it is broken right away when it is taken out of the mould, it falls through the openings in the conveyor belt, where it is collected in a container. The products that are not broken are subjected to a computerized quality control, where a machine visually inspects the products and rejects them if they do not qualify according to the set standards.

![Flowchart of production process on line Euroc 3](image)

**Gips**

This production process is very similar to the Euroc1 production process; it is therefore not needed to repeat the flowchart here. The major difference between this plaster line and the (concrete) Euroc1 line are the different required raw materials. The plaster mixture is made from plaster powder and...
water. The time required for drying is also substantially lower, about 3 hours. The rest of the process is the same as the Euroc1 production process, with about the same degree of automation.

**Hoeken (plaster and concrete)**
The production of the concrete and plaster corner stone strips is done manually. This process follows the general stone strip process from Figure 22. A mixer is prepared, after which the corner shaped moulds are filled. After drying, the stones are removed from the moulds and packaged.

This concludes the description of the production processes at Eurostrip. As said before, there are two sorts of physical outputs: finished products and waste material. The finished products are shipped to the Son warehouse for storage, whereas the waste material is collected by a third party contractor. The third output of this activity is production related data; it is not a physical goods flow but a flow of information.

**4.3.3.4 A73 – Collect and Process Production Data**
Within this activity, the production data resulting from activity A72 is collected by the cell coordinators at each production line and then processed by the administrative employee at the front office. We will first describe which data is currently collected and how this is done. Then, we will describe how this data is processed at the front office and which reports are created.

At this moment, all production related data is collected through handwritten paper forms. For each of the lines, the responsible cell coordinator (CCo) writes down production run data after each completed batch, which consists of the following data:

- The type of product that is produced
- The number of mixtures (= the number of batches)
- Start time and end time of the run
- Duration of breaks
- Duration of unplanned downtime
- The amount of moulds filled

Each individual employee also fills out a paper form during or at the end of their shift, containing information on his activities during the day. A typical form contains the following information:

- The time spent at the machine
- The duration of breaks
- The number of carton boxes packaged (optional)
- The time spent packaging the boxes (optional)

The set-up of the paper forms varies somewhat in between the production lines, but the general set-up is the same. All the paper forms are collected in a paper tray at the end of each shift; the administrative employee (APm) collects them the next day for further processing.

The collected production data is checked and approved by the administrative employee. Checking and approving everything is very labour intensive. This process can easily cost five to ten hours weekly. Lots of parameters have to be calculated manually and several cross checks have to be performed. For example, the amount of packaged products for each employee has to be added up to see if it consistent with the total amount of packaged products that were moved towards the
finished goods inventory that day. This way she can make sure that no-one cheated in the amount of boxes that were packaged.

Apart from this, she has to manually check all the sheets on which the employees filled out their hourly logs. This also includes several different cross-checks. She for example has to cross check if the hours that an employee spent at a machine are consistent with the reports that were submitted by the responsible coordinator for that line.

After all the necessary checks have been completed, she enters the aggregated information in a customized MS Excel spreadsheet document. She enters the totaled production amounts and used machine hours for each production line. From this input data, two different reports are created weekly;

- **Production team leader report**
  This report contains an overview of the planned production quantities versus the realized production quantities. It is split out per day and per production line. The aim of this report is to provide the production team leader (TLPB) a quick overview of the performance of each of the production lines in the last week.

- **Management report**
  This report contains more aggregated information. All the amounts are totaled over one week instead of days and sorted out per line. This report is forwarded to the managing director (AD).

Both these reports have a quite straightforward set-up. Data from the input sheets is simply summarized to calculate totals per week, per machine and per day. This approach has some drawbacks; in the first place it is very prone to input errors. On top of this, the reports are based on a fixed (weekly) interval. When the management wants to have a report covering a full month instead of one week, this is nearly impossible using these spreadsheets. These drawbacks, together with all the problems mentioned earlier, created the need for a redesign of the measurement system for Eurostrip.

### 4.4 Conclusions

This chapter described the Decor Son organisation based on the three hard elements of the McKinsey 7S model. We first described the organizational structure of Decor Son, and explained the position and structure of the Eurostrip production unit. Then, Decor Son’s business-level strategy was described. The third S, Systems, was described using IDEF0 models and flowcharts. Taking the overall business process as a starting point, we zoomed in on the Eurostrip production process and explained it in sufficient detail. By doing this, we have developed a thorough understanding of the current situation at Decor Son and more specific Eurostrip. Within the next chapters, we will continue our problem solving cycle and develop a redesign for the measurement system of Eurostrip. The analysis of the current situation that was described in this chapter helps us, because a problem cannot be properly solved without understanding the background and context.
5. Design of the Performance Measurement System

5.1 Introduction
As described in the previous chapter, a measurement system is already in place. However, as described in the problem definition, this measurement system has several shortcomings. Therefore a redesign of this measurement system is proposed here. This chapter, together with chapter 6, describes a proposed redesign for this measurement system from scratch. In this chapter, we describe the process in which we construct a list of performance metrics based on the Eurostrip strategy.

5.2 Design process
The five step PMS development process as it was described in chapter 3 will be applied here to construct a suitable list of metrics. This process is summarized here:

1. Define a strategic objective in each of the four performance dimensions at the 2nd layer in the performance pyramid (Lynch & Cross, 1995): Quality, Delivery, Cycle time & Waste.
2. Apply the Goal Question Metric (Basili, Caldiera, & Rombach, 1994) methodology to translate each of these goals into measurable metrics.
3. For each of the metrics, define the input parameters and the way in which the metric should be calculated. Describe the metrics using the performance measure record sheet (Neely, Richards, Mills, Platts, & Bourne, 1997).
4. Design a data collection system able to collect the parameter data, to aggregate and calculate the metrics on a periodical interval, and to present the data.
5. Implement this system at Eurostrip.

In this chapter, the first three steps will be followed. This means that by the end of this chapter we have constructed a list of metrics, together with the parameters needed for their calculation.

5.3 Eurostrip strategic objectives
To be able to sketch a complete picture of the performance of Eurostrip, the choice was made to determine strategic objectives in each of the four performance dimension located at the bottom of the performance pyramid. These strategic objectives are documented in the Eurostrip annual reports and have also been discussed in interview sessions with the three employees that have been mentioned in the previous chapters (AD, TLPB and IA). In the next four sub paragraphs, each of the performance dimensions will be discussed and the strategic objectives belonging to that dimension will be explained. In essence, a strategic objective is providing an answer to the question: What

Figure 25 - The performance pyramid with the four Eurostrip performance dimensions highlighted
do we want to achieve with respect to quality, delivery, cycle time and waste? After determining what the strategic objectives are in each of these dimensions, the next step is to translate these objectives into so-called measurement goals, suitable for use in the GQM process. A simple version of a GQM template (Basili, Caldiera, & Rombach, 1994) is used to describe the goals.

5.3.1 Quality
Quality means meeting customer expectations (internal and external) 100 percent of the time through the delivery of defect-free products or services (Lynch & Cross, 1988).

The strategic objective for Eurostrip in the quality dimension is:

![Guarantee product quality](image)

This is a straightforward goal; Eurostrip should guarantee the quality of the products they produce. Delivering products to customers that are not of the required quality has a big negative influence on the external customer satisfaction and can be very costly. The stone strips produced by Eurostrip can for example be broken or the color schemes can be different among stones. Other examples of insufficient product quality are also thinkable here. Either way, the customer will not be satisfied with the end product and this is inevitably a costly scenario due to warranty claims and a possibly damaged brand image.

The objective ‘guarantee product quality’ is rather abstract. The first step to take is translating this objective into a measurement goal. Structuring this goal according to the GQM template requires us to describe this goal in a more structured manner. The purpose, issue, object and viewpoint have to be described here.

The product quality here can be seen as the experienced product quality at the end customer. The purpose of this goal is to measure this experienced product quality. One question has been defined here; what is the experienced product quality? Answering this question fully answers the measurement goal as it is defined here, so there is no need for other questions in this area. Two metrics are chosen that can provide an answer to this question. On the one hand the number of actual warranty returns should be counted relative to the amount of products sold. A second metric here is the number of customer complaints. Customers in this case can be private persons or, more often, retail outlets selling Eurostrip products. There can be various types of product-related complaints where the warranty is not used. By measuring these two metrics, the posed question can be answered. The GQM sheet filled in for this dimension can be seen in Table 2.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td>The experienced product quality of</td>
</tr>
<tr>
<td>Object (product)</td>
<td>Eurostrip products</td>
</tr>
<tr>
<td>Viewpoint</td>
<td>From an external customer viewpoint</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the experienced product quality?</td>
<td>The percentage of warranty returns</td>
</tr>
<tr>
<td>Metric [2]</td>
<td>The number of customer complaints</td>
</tr>
</tbody>
</table>

Table 2 - GQM sheet for the Quality dimension
5.3.2 Delivery

Delivery involves the quantity of product or service being delivered on time to the customer, user, or next department, as defined by the customer. Good delivery results when performance equals expectations. In the performance pyramid theory (Lynch & Cross, 1988), delivery performance is seen in two dimensions: quantity and timeliness. In other words, when Eurostrip delivers the right amount of products at the right moment, their delivery performance is good. The strategic objective formulated by the Decor Son management with respect to delivery performance of Eurostrip is:

Prevent lost sales of stone strips

This seems like a clear objective, Eurostrip should produce enough products to stock so that lost sales can be avoided. A lost sale occurs when a customer orders a product that is not on stock at the warehouse. Since backordering is not done at Decor Son, a lost sale is always fully lost. It is evident that this is costly and therefore lost sales should always be prevented. Two different sorts of causes for lost sales can be distinguished;

- **External**: The demand is more than expected. This is why safety stocks are held. It should be the responsibility of the warehouse and logistics department to maintain enough safety stock of all products so that unexpected demand can be overcome to a certain extent.
- **Internal**: The demand is not significantly more than expected but the products cannot be delivered because they are not on stock.

For the Eurostrip production unit, we are only interested in the second issue. These are the lost sales where Eurostrip is ‘to blame for’. The agreed production schedule should be followed by Eurostrip. When Eurostrip produces exactly the amount they should produce according to the schedule and still too much lost sales occur, either the safety stocks are not high enough or the production schedule is erroneous. This is however the area of expertise of the warehouse and logistics department and as such Eurostrip should not be held responsible for them.

Based on these arguments, the choice is made to measure the delivery performance of Eurostrip from an internal customer viewpoint only. The delivery performance of Eurostrip will thus be measured as the degree of schedule adherence.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Purpose</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td>The delivery performance of</td>
<td>The delivery performance of</td>
</tr>
<tr>
<td>Object (process)</td>
<td>The Eurostrip production unit</td>
<td>From an internal customer viewpoint</td>
</tr>
<tr>
<td>Viewpoint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>What is the current delivery performance?</td>
<td>The percentage of products delivered according to schedule</td>
</tr>
</tbody>
</table>

Table 3 - GQM sheet for the Delivery dimension

5.3.3 Cycle Time

Where the delivery aspect is mainly concerned with external effectiveness, the cycle time dimension is concerned with the internal effectiveness of the production process. Cycle time refers to the time spent producing the product. The Eurostrip strategic objective in this area is:

Guarantee a reliable production process
The management strives for a reliable production process. Reliability here means the ability of the production ‘system’ to perform its required functions for a period of time. This means that the performance of the process should be deterministic; the more reliable a process, the better its performance can be forecasted. This is also reflected by cycle time, the more reliable the production process, the more closely cycle time can be predicted. The measurement goal in the cycle time is chosen as: Measure the reliability of the production processes. The GQM sheet belonging to this measurement goal can be seen in Table 4.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Purpose</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td>From a production manager viewpoint</td>
<td></td>
</tr>
<tr>
<td>Object (process)</td>
<td>The reliability of the production processes</td>
<td></td>
</tr>
<tr>
<td>Viewpoint</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Metric [4]</th>
<th>The percentage of time that the lines are up in their scheduled uptime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric [5]</td>
<td>How effective are the machines running?</td>
<td>The machine speed performance</td>
</tr>
<tr>
<td>Metric [6]</td>
<td>How effective is the labour force working?</td>
<td>The employee speed performance</td>
</tr>
</tbody>
</table>

Table 4 - GQM sheet for the Cycle Time dimension

5.3.4 Waste

Waste is defined as the non-value-added activities and resources incurred in meeting the requirements of the customer and it includes all the effort and costs associated with failures, appraisals and surpluses. In this area, the strategic objective set out by the Decor Son management is:

Realize the lowest possible cost price

Realizing the lowest possible cost price is inevitably linked to waste reduction. Lowering the cost price is in essence the removal of waste from the production process. In this performance dimension, the internal efficiency of the production process is what it’s all about. The efficiency of the process is simply how good inputs are transformed into outputs.

The measurement goal here is defined as minimize the amount of waste generated in the production processes. The GQM sheet for this measurement goal filled out with questions and metrics can be seen in Table 5.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Purpose</th>
<th>Minimize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td>From a production manager viewpoint</td>
<td></td>
</tr>
<tr>
<td>Object (process)</td>
<td>The amount of waste generated in the production processes</td>
<td></td>
</tr>
<tr>
<td>Viewpoint</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Metric [7]</th>
<th>Material input/output ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric [8]</td>
<td>What is the scrap rate?</td>
<td>The scrap rate over a period of time</td>
</tr>
<tr>
<td>Metric [9]</td>
<td>How efficient are direct labour hours spent?</td>
<td>Productivity per man hour</td>
</tr>
</tbody>
</table>

Table 5 - GQM sheet for the Waste dimension
5.4 Calculation of the metrics

5.4.1 Metric parameters
The next step is to determine how each of the identified performance metrics can be calculated. Each of the metrics is calculated from parameters. There are two different sorts of parameters:

- **Variable parameters**: These are the parameters that should be measured somewhere in the production process. The data collection system described in chapter 6 is designed to collect the data for these parameters. For each of these parameters, we will describe where they can be measured.
- **Fixed parameters**: these are the parameters that are known beforehand. Examples here are scheduled production quantities and normative machine- and employee production times. The data for these parameters does not have to be collected, but can be copied from another source.

Below, we will describe for each of the nine metrics:

- Which parameters are needed to calculate the metric
- How the metric should be calculated
- The data sources for the parameters

**Metric 1: The percentage of warranty returns**

This metric is a ratio of the number of products on which the warranty was claimed to the total number of produced items in a given time period. The parameter values needed are:

- Delivered product amount in a given month
- Number of warranty claims that can be contributed to Eurostrip in a time period

Both these parameters are currently measured. However, the second parameter is measured in the after sales department but is not used anywhere in the existing measurement system. The data for this parameter will have to be collected for the newly designed system.

**Metric 2: The number of customer complaints**

This metric requires only one single parameter:

- The number of customer complaints that can be contributed to Eurostrip in a time period

Customer complaints are also handled by the after sales department but they are also not included in the current measurement system.

**Metric 3: The percentage of products delivered according to schedule**

This metric is the ratio of the actual amount of products delivered to the scheduled amount: the schedule adherence. This metric can only be measured once per month, as the strategic planning is also based on months. Two parameters are required here:

- Delivered product amount in a given month
- Scheduled production amount in that month
The delivered product amount is in fact measured in the current measurement system, but only on a weekly basis. Due to the set-up of the existing system, it proves to be very hard to calculate monthly totals. The monthly scheduled production amount is a fixed parameter that should be taken from the strategic planning.

**Metric 4: The percentage of time that the lines are up in their scheduled uptime**

This is the first internal operational metric. It is the ratio of the actual uptime of the production lines to the scheduled time. The actual uptime of the machine is the scheduled uptime minus the unplanned downtime. Therefore we need two parameters:

- Unplanned production line downtime
- Scheduled uptime

The unplanned downtime should be recorded by the production coordinator, it is a variable parameter. The scheduled uptime is known beforehand and thus fixed. Both parameters are currently measured in the existing measurement system. The ratio of the downtime as part of the scheduled uptime is not calculated though. The downtime is just reported as an absolute number, together with the scheduled uptime.

**Metric 5: The machine speed performance**

This metric tells us how well a machine (or production line) performed compared to its maximum production speed. We need two parameters for this metric:

- Actual machine production amount in a given time period
- Maximum machine production amount in a given time period

The actual production amount is a variable parameter that should be recorded by the responsible production coordinator after each production run. The second parameter is fixed. The maximum speed of the production lines is currently unknown. In the current situation, normative times are used for several production activities. These normative times basically tell us the maximum time that each production activity should take. What we need to know here are the optimal cycle times: the fastest cycle time that can possibly be reached at a given line when all circumstances are perfect. These ideal cycle times are not known and they should be determined in the future.

**Metric 6: The employee speed performance**

This metric is comparable to the previous one. Whereas the previous metric gives an indication of the speed performance of machines, this metric gives us the speed performance of individual employees. Two parameters are needed here:

- Actual employee production amount in a given time period
- Maximum employee production amount in a given time period

The data sources of the actual employee production amounts are the employees themselves. Employees manually fill the corner stone moulds and all the products except those of Euroc 3 are manually packaged. Both the filling and packaging activities have a certain output, which is the actual employee production amount. Just like the ideal cycle times for the machine activities, the ideal cycle
times for the employee activities are not known. In the future, these should also be established such that the maximum production amounts can be calculated.

**Metric 7: Material input/output ratio**

This metric provides a bottom line figure of the actual efficiency in which the raw materials are transformed into end products. The fraction of raw materials that is not shipped as end products is waste. This waste consists of both spilled mixture as well as scrapped products. The scrapped products rate deserves special attention; therefore this rate is included as a separate metric (see metric 8 below). The material input/output metric should be calculated for each production line. Two parameters are needed for calculating this metric:

- Amount of raw materials used in a given period
- Amount of materials shipped as end product in a given period

The data for the first parameter should be recorded by the responsible production coordinators during their work. They should record the amount of mixtures they have used. From this we can calculate the amount of raw materials consumed at each of the production lines. The amount of materials shipped as end product can be calculated by multiplying the amount of products shipped with the weight of these products.

**Metric 8: The scrap rate over a period of time**

This metric is comparable to the previous one, although more specific. The scrap rate is the ratio of broken stone strips to the amount of dried stone strips. As explained in the previous chapter, a fraction of the stone strips break when they are removed from the moulds after drying. Since these products have already gone through the majority of the production process, it is very costly when they break just before they can be packed. Knowing the exact scrap rate is therefore important, because it has a major influence on the cost price and the capacity utilisation. For calculating this metric, we need two parameters:

- Number of scrapped stone strips in a given period
- Number of moulds filled in a given period

The number of scrapped products is currently measured at each line, but this measurement is not precise enough. We propose a slightly different method for measuring this parameter in chapter 6. The number of moulds filled can be recorded by the responsible coordinators while producing.

**Metric 9: Productivity per man hour**

Whereas metric 7 gives us insight in the bottom line efficiency of the material transformation process, this metric gives us insight in the bottom line efficiency in which direct labor hours are spent. This metric is a high level indicator of the employee productivity, and should be split out per production line. Two parameters are needed here:

- Actual production amount in a given period
- Amount of direct labor hours spent in a given period
The actual production amounts, as well as the amount of direct labor hours spent, should be recorded by the responsible coordinators during and at the end of their shifts.

5.4.2 Structured description of the metrics

By now, we have a good understanding of the set of metrics and their parameters. To accurately describe the metrics, we need some more information on them than just the short description given above. A useful way to describe the metrics is proposed by (Neely, Richards, Mills, Platts, & Bourne, 1997). These authors state that performance metrics should be structurally described using a so-called performance measure record sheet. On this sheet, a performance metric is described based on several aspects. One record sheet filled out for the first metric (the percentage of warranty returns) can be seen in Table 6 below. The rest of the record sheets are placed in Appendix C because including these tables for all these metrics would be too elaborate here.

<table>
<thead>
<tr>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
</tr>
<tr>
<td><strong>Relates to</strong></td>
</tr>
<tr>
<td><strong>Target</strong></td>
</tr>
</tbody>
</table>
| **Formula** | \[
\frac{\text{Total number of produced items in a time period}}{\text{Number of warranty claims that can be contributed to Eurostrip}}
\] |
| **Frequency** | Monthly |
| **Who measures?** | Employee of the After Sales department |
| **Source of data** | Incoming claims, by phone or e-mail |
| **Who acts on the data?** | Management of Eurostrip (PM/TLPB) |
| **What do they do?** | Identify problem causes, improve production process where needed |
| **Notes and comments** | Warranty claims should be categorized: only the claims that can be traced back to errors in Eurostrip production should be counted here |

Table 6 - Example of the performance measure record sheet filled out for metric 1

5.4.3 Frequency of measurement

Based on the frequency in which the metrics should be measured, they can roughly be divided in two categories:

- **Non-frequent metrics.** Reporting of these metrics will be done at most once a month. The first three metrics are of this category. These are the metrics in the external performance dimensions: quality and delivery.

- **Frequent metrics.** These metrics require more frequent calculation, daily or weekly reporting is needed. This is the case for the metrics four till nine; these are all internal operational metrics.

The frequency of measurement has its implications on the reports on which the metrics will be presented. At least two reports will be needed containing the metrics: a monthly report with the non-frequent metrics and a weekly or daily report with the frequent metrics. The way in which the metrics will be reported will be described in chapter 6, as the reporting of the metrics is part of the data collection system.
5.5 The Overall Equipment Effectiveness (OEE)

5.5.1 Usage of the OEE metric

The Overall Equipment Effectiveness concept was already discussed in chapter three. We found that it was not suitable to be included into our five step PMS design method. Since we have now built the list of performance metrics, we will discuss this concept again and see if it can be useful to us here.

In chapter three, we described that the OEE metric is a composed metric that can be used to describe the effectiveness of a manufacturing operation. It rates the actual output of a line or a machine against the output under optimal circumstances. Looking at our set of nine metrics, we see that some of our metrics closely resemble the metrics of which the OEE is composed. We will shortly repeat the three components of the OEE metric here and for each component, we will describe the metric in our system that resembles that component.

The OEE metric was built from three components (Ljungberg, 1998):

- **Availability**
  
  In our system, the availability of the production line is also measured. In metric 4, we measure the percentage of time that the lines are up in their scheduled uptime. This is the same uptime fraction as the availability ratio in the OEE metric.

- **Performance rate**
  
  The performance rate of a machine is measured in our system in metric 5: the machine speed performance. This ratio gives us the percentage of produced items compared to the maximum amount that could have been produced in optimal cycle times.

- **Quality rate**
  
  The quality rate is the ratio of good products to the total amount of products produced. Looking at the Eurostrip production processes, the amount of products produced equals the number of moulds filled. The ratio of ‘good’ products can then be calculated as: the amount of moulds filled minus the amount of broken stone strips. Metric 8 is the scrap ratio: the fraction of stone strips that break after they have been dried. The quality rate directly follows from this scrap rate, because all the stone strips that are not scrapped at this point, are ‘good’.

We see that all three of the OEE metric’s components are also present in our list of metrics. Because of this, we choose to use the OEE metric in our PMS also. Our list of metrics will not change, the OEE metric will be used together with the other metrics. It is a composed metric that can give us a quick insight in the metrics 4, 5 and 8.

5.5.2 Relevance of the OEE metric

As noted by (Johnson & Lesshammar, 1999): “...the most important objective of OEE is not to get an optimum measure, but to get a simpler measure that indicates the areas for improvement.” This is also the reason for including it into our measurement system. Our measurement system might seem simple at first sight, but rating the performance of the Eurostrip production processes against 9 distinct measures might prove to be difficult after all. Using the OEE can simplify this task somewhat. By looking at the OEE every day or every week, the managing director has one metric that tells him just about everything he wants to know about the operational performance of his production lines. If the OEE metric is at an acceptable level, he might not even have to look further. If the OEE is lower
than expected, the managing director can see right away which of the three metrics 4, 5 or 8 caused the lower value, indicating where the performance was insufficient.

The OEE metric value should always be presented together with the three metrics of which it is composed. This is underlined by (Kaydos, 1998), who states that “...if a component measure is used, it should be accompanied by its component parts. If everyone is not reminded of what makes up the composite measure, it will soon become a meaningless abstraction.” On top of that, the value for the OEE metric can be the same for two consecutive weeks, but this is no guarantee that the underlying metrics have not changed.

Some critical notes have to be made here as well. It should be stressed that the OEE metric is not a ‘holy grail’. It is a nice and easy way of looking at three of our metrics, but nothing more. On top of these three OEE metrics, the other 6 metrics should receive just as much attention. Just taking a quick peek at the weekly OEE values is not sufficient. A second issue is that the OEE metric has a geometric mean. As such it punishes variability among each of the metrics from which it is composed. For example 20 % * 80 % = 16 %, whereas 50 % * 50 % = 25 %. When any of the three metrics are seen as more important compared to the other two, the OEE metric may become less appropriate. Workarounds here are thinkable, for example weighting factors can be assigned to each of the components.

5.7 Discussion
The measurement system described in this chapter might seem rather straightforward. After all, one could say that it is just a list of nine simple metrics. Keeping these metrics simple and understandable is done on purpose. Many authors in the field of performance measurement argue that it is very important that performance metrics should be kept simple and understandable (see for example: (Fortuin, 1988), (Maskell, 1991) & (Lynch & Cross, 1995)). This improves the acceptance of the employees towards the metrics.

Apart from the fact that it is easy to understand, the real power of this measurement system lies in the fact that it is aligned with strategy. This strategic alignment can be ensured because the design process proposed in chapter 3 was followed. A set of goals was formulated in each of the four performance dimensions, after which each of these goals were translated into measurable metrics. This way we can assure that by using this set of metrics, Decor Son can track whether the proposed strategy is followed.

5.8 Conclusions
In this chapter, we have answered the question: What do we have to measure at Eurostrip? By taking strategic objectives in each of the four performance dimensions as a starting point, we have applied the Goal Question Metric methodology of (Basili, Caldiera, & Rombach, 1994) to derive an appropriate set of metrics. We ended up with a list of 9 metrics that, when measured properly, provide us with an integrated view on the operational performance of Eurostrip. We found out that three of our metrics resembled the components of the OEE metric and chose to use this metric to describe these three metrics. Our resulting measurement system consists of the OEE metric (metrics 4, 5 & 8) together with the other 6 metrics. Each of the metrics is calculated from parameters. We
discussed the parameters for each metric, the way of calculation and the required data sources in paragraph 5.4. The parameters are important, as they define the actual information need now. Taking these parameters as a starting point, the next chapter describes a data collection system that was built to collect this parameter data within Eurostrip.
6. The Data Collection System

6.1 Introduction
Whereas the previous chapter discussed the design of the PMS from a conceptual viewpoint, this chapter is of a more practical nature. In chapter 5, we answered the question: *which parameters should be measured?* This chapter answers the question: *how can the data for these parameters be collected?* This question was answered by designing a data collection application that can be used to collect the needed data at Eurostrip. The design of this application is described in paragraph 6.2, after which this chapter is concluded in paragraph 6.3.

6.2 Design of the Data Collection System
In this paragraph we will describe the design of the data collection on several aspects. We will start by describing the goal for building this system in paragraph 6.2.1, after which the scope of the system is defined in 6.2.2. Then we will describe the chosen method of data collection in 6.2.3. Following on the functionalities that were needed (6.2.4) we chose a type of software package that best suited our needs to develop our application in 6.2.5. In 6.2.6, the overall structure of the application is depicted, after which the back-end and front-end of the application is described in paragraphs 6.2.7 and 6.2.8.

6.2.1 Goal
A Data Collection System was designed with the following goal in mind: *to facilitate the collection and processing of the parameter data for the metrics that populate the performance measurement system described in chapter 5.*

As such, the data collection system is an integral part of the performance measurement system that is developed throughout this thesis. It also contributes towards solving the business problem that was defined in chapter 2.

6.2.2 Scope
This data collection system is designed to collect data throughout the Eurostrip factory. The scope of the system has been limited for use only in Eurostrip. Data for the parameters of the metrics 1 to 3 (the external metrics) cannot be collected through this application right now. In a later stage, the application can be extended such that this data can also be included.

6.2.3 Method of data collection
A data collection can collect data in two ways: automatic or manual. An automatic data collection system is capable of collecting data without user intervention. However, such a system is expensive, complex and the data are collected at an aggregate level (Ljungberg, 1998). Currently at Eurostrip most of the work is done manually in a low tech production environment. Implementing an automatic data collection system here would be very hard, if not impossible. Therefore a manual data collection system was designed, meaning that the employee input is the only data source for this system.
6.2.4 Functionalities of the system
The data collection system should possess two primary functionalities:

- **Data collection**
  The obvious first functionality is to facilitate the collection of the data throughout the factory. After the collection, the data has to be stored safely.

- **Data processing**
  The system should be able to turn the raw data into useful information in the form of reports and graphs.

For a system that can carry out these two functionalities, (Kaydos, 1998) notes that “…the best approach is to use a relational database system. These software systems make it easy to conduct analyses, construct special reports, and make changes to the measurement system. Any of the current popular relational database systems is capable of handling the job.” The next paragraph will discuss the software package that was chosen to develop the system.

6.2.5 Relational Database Management System
The data collection system was developed using Microsoft Access 2007, a widely used relational database management system (RDBMS). This software is licensed by Decor Son and is already being used for various tasks within the company. Sufficient expertise is in house for maintenance and future updates to the data collection system. Microsoft Access features an easy to use graphical user interface and software development tools including Visual Basic for Applications (VBA).

In the following paragraphs we will describe the design of the data collection application in more detail, starting with the structure of the application.

6.2.6 Client-Server Structure
Currently at Eurostrip, a lot of information is passed around on paper sheets. The front office communicates the production schedule to the work floor on a paper print-out and data is collected on handwritten paper forms. As mentioned earlier, this practice has several disadvantages. The data collection application should be designed so that this information can be easily shared over the internal network, thereby reducing the paper trail.

The question now is how to design the data collection application so that it can perform the best in a network setting. In Microsoft Access 2007, there are roughly three approaches that can be taken regarding the architectural layout of the database application. These approaches are also described in (Silberschatz, Korth, & Sudarshan, 1997):

- The application can be built as a centralized database system. The database back- and front-end remain both in one application on one physical system. This makes interaction with other computer systems nearly impossible. This is not desirable for our application.

- A client-server approach, using a Microsoft SQL server as a back-end transaction server, hosting the relational database together with an SQL engine on the back-end. Front-end applications can send queries to the SQL interface of the back-end.
• A second client-server approach, where the back-end server acts only as a data server. In this approach, the only job of the back-end data server is to host the tables of the relational database. The tables are shared over the network and should be loaded in the front-end MS Access application as so-called linked tables. In this set-up, all the functionality except for the physical storage of the database is located at the front-end.

In designing our data collection application, we took the third approach. Obviously we need to be able to share data over a network, so we need some kind of client-server setting. When we would take the second approach, we would have to install and maintain a complete MS SQL server for just a relatively small database; it would cause a lot of work and complexity. The third approach on the other hand is fairly simple, in a few clicks a centralized database application can be split into several front-end applications and a single back-end containing just the tables. The drawback to splitting the MS Access database this way is that complete database tables have to be shipped back and forth between the server and the clients to perform queries. This could lead to bad performance of the application in terms of response speed. In Eurostrip this will not pose to be a problem though, because a fast internal network is installed and the database will not get too big in the first place.

In Figure 26, the chosen structure of the database application can be seen. We will now shortly discuss the components of the application and explain how they interrelate. The arrows in the figure all represent information flows.

As mentioned before, the back end acts only as a data server and hosts the database tables. MS Access does not have to be installed at the back end server. The folder containing the database file is shared over the internal network for a limited set of users.

The front end application contains the Microsoft Jet Database Engine: the MS Access internal query engine. This engine interprets the requests of both queries and macros for the retrieval or modification of data stored in the database.

Since the future users of the application don’t have knowledge of MS Access queries nor macros, these will not be visible to them. All the interaction with the user will happen through forms and reports. As can be seen in the figure, reports are used for presenting information to the user. Forms are also used for presenting information to the users, but more importantly: to receive input from the users.

In the paragraph, we will describe the structure of the relational database located in the back end. Then, the functionality of the various front end applications will be described.

6.2.7 Back-end Database
The relational database containing the tables is the heart of the application, it is the repository in which all the collected data is stored. To clarify the database structure and the relational properties,
an Entity Relationship Diagram (ERD) has been constructed (Silberschatz, Korth, & Sudarshan, 1997). This diagram can be found in Appendix C.

6.2.8 Front-end Applications
Five different front-end applications were designed. These are named after the place where they should be installed:

- Euroc 1
- Euroc 3
- Gips
- Expeditie
- Kantoor

For these front-end applications, graphical user interfaces (GUI’s) have been created. MS Access 2007 forms were used for this purpose. This was done to make the process of entering data as easy and intuitively as possible for the user.

Below, we will first describe the applications for the production lines, as these are comparable to each other (Euroc 1, Euroc 3 & Gips). Then, the application for the expedition warehouse (Expeditie) is described. Finally, the front office application (Kantoor) is described. In the next few paragraphs, we will briefly describe the functionalities of these applications. In Appendix E, a more detailed description of the applications can be found, supported by screenshots.

6.2.8.1 The production lines
These applications should be installed at the personal computers located near each of the three biggest production lines (Euroc 1, Euroc 3 & Gips). This is the easiest way to collect data from the responsible operators. The data collected here is needed for the following parameters:

- Unplanned production line downtime
- Actual machine production amount in a given time period
- Actual employee production amount in a given time period
- Amount of raw materials used in a given period
- Number of scrapped stone strips in a given period
- Amount of direct labour hours spent in a given period

The required set of data differs somewhat between Euroc 3 and the other production lines. This is because at Euroc 3 the packaging is automated, whereas the packaging at all the other lines is done manual. At the lines with manual packaging we need to collect information on the packaging performance of the individual employees. In Table 7 below, the data that will be collected is categorized per production line.

<table>
<thead>
<tr>
<th>Euroc 1, Gips, Hoeken Beton &amp; Hoeken Gips</th>
<th>Euroc 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For each production run:</strong></td>
<td><strong>For each production run:</strong></td>
</tr>
<tr>
<td>- Type of mould filled during the run</td>
<td>- Type of mould filled during the run</td>
</tr>
<tr>
<td>- Start and End time of the run</td>
<td>- Start and End time of the run</td>
</tr>
<tr>
<td>- Duration of an unexpected breakdown</td>
<td>- Duration of an unexpected breakdown</td>
</tr>
<tr>
<td>- Duration of a break during the run</td>
<td>- Duration of a break during the run</td>
</tr>
<tr>
<td>- The number of concrete mixtures prepared during the run</td>
<td>- The number of concrete mixtures prepared during the run</td>
</tr>
</tbody>
</table>
The data needed from the manual production line ‘Hoeken Beton’ can be collected at the Euroc 1 application. For the plaster corner stone line ‘Hoeken Gips’, the data can be collected at the Gips application.

By the end of each working day when all the data is collected, the responsible coordinators (CCo) can print out reports of that day. These reports contain detailed information on the production runs and the hours spent per employee of that day. This way, the system can provide fast feedback of that day’s performance to the responsible coordinators. Short feedback cycles will lead to increased user acceptance and involvement in any measurement project (Pritchard, 1990). Enabling the production coordinators to review these reports daily will make them feel more involved here too. They will feel that the data they have entered during the day was not useless, and they can use these reports as a basis for discussion with their team members at the end of a shift. Apart from this, these reports will not be used, as they are too detailed for higher management levels. The management reports can be generated in the ‘Kantoor’ application, which is discussed later.

### 6.2.8.2 The expedition warehouse

At the expedition warehouse, the finished products are loaded on trucks and shipped to the warehouse in Son. This is the best place to measure the amount of products that leave Eurostrip: the real output. Data is collected here for one parameter:

- Amount of products shipped in a given period

From this amount, we can also calculate the amount of materials that left Eurostrip as finished goods, since we know the exact contents of each article.
The expedition employee who loads a truck has to create a delivery note, containing the exact contents of the delivery. In the current situation, this is filled out on a handwritten paper form. Using the Expeditie application, the employees can now create digital delivery notes. When completely filled out, the delivery note is printed in twofold. Both have to be signed by the expedition employee and the truck driver, thereby approving the contents of the truck load. One is handed to the truck driver and the other one is archived at Eurostrip. This delivery note can then be emailed directly to the incoming goods desk at the Decor Son warehouse, so that they can start making the necessary preparations.

Using the application for the creation of delivery notes reduces the potential source of error that comes with handwritten forms. The biggest advantage here however is that the deliveries contents are stored in the database after they have been approved. Using the power of the relational database, we can create detailed overviews of the exact amount of products that were shipped each day. Up until now

6.2.8.3 The front office
The fifth front end application is named ‘Kantoor’; it is designed for the front office. Whereas the four applications above are mainly aimed at collecting data, the ‘Kantoor’ application is mainly aimed at the processing of data: creating reports and graphs from the collected data. This is where data is transformed into information.

This paragraph is split up in three sub-paragraphs. We will first describe which data is collected in the Kantoor application. Then, the reporting functionalities are discussed, after which the additional functionality is described.

Data Collection
There are two parameters for which data needs to be collected in the ‘Kantoor’ application. These can be seen in Table 9 below.

<table>
<thead>
<tr>
<th>Kantoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>The amount of raw materials purchased</td>
</tr>
<tr>
<td>The amount of waste material shipped away</td>
</tr>
</tbody>
</table>

Table 9 - Data collected at the front office

The first parameter can be calculated from the purchases of raw materials at the supplier. For each delivery, the administrative employee has to enter delivery details, such as the name of the supplier, the sort of material that was delivered and the amount in kilograms. For the amount of waste that is shipped, the administrative employee enters the weights of the waste containers that are shipped away. The company that removes these containers weights them every time and this weight is mentioned on each invoice.

Both these parameters provide insight in the incoming and outgoing material flows on a factory level. These variables can serve as a cross check for the measurements at the lower levels. For example, the amount of raw materials purchased over a month should add up to the total amount of raw materials used at the production lines.
**Reporting**

Reporting is concerned with the presentation and visualization of the collected data so that it can be easily understood. This is where the power of the relational database system comes in. Using complex queries, aggregation of data becomes fairly easy.

MS Access reports are used to present the aggregated data to the user. These reports contain information on the metrics that were defined in our PMS.

Two reports can be generated here:

- **An OEE report.** This report provides an overview of the performance of the production lines based on the OEE metric explained in chapter 3 and 5. This report describes the actual effectiveness of the production lines. It should contain information on the metrics 4, 5 & 8 of our PMS. This report should give a good indication of the performance in the third dimension of the performance pyramid: process time.

- **An efficiency report.** A report that provides an overview of the efficiency of the production lines. This report should give us insight in the metrics 6 till 9. This report should give us a good indication of the performance in the fourth dimension of the performance pyramid: waste.

By studying these reports, the management can get insight in the performance of Eurostrip in the two internal performance dimensions: process time and waste. We suggest that these two management reports are created in a weekly interval.

The two reports mentioned above do not contain any information on the two external dimensions of performance: quality and delivery. The performance in these areas is presented by the metrics 1 to 3. Not all the required data for these parameters can currently be collected by this system. This functionality should be added in a later stage. Until then, a third report containing the metrics 1, 2 and 3 can be fairly easy generated manually. A suitable name for this report could be: external performance report. For the metrics 1 and 3, the shipped product amount in a given time period is needed. This amount can be retrieved from the database; it is measured at the expedition warehouse. In the Kantoor application, it is possible to retrieve the amount of shipped products for any given time period. A suggested interval to create this external performance report would be monthly, because the strategic planning contains monthly production amounts.

**Additional functionality: Assist in production scheduling**

As said before, collecting and processing data are the two core functionalities of the database application. Some additional functionality has been added though.

The application can assist in scheduling production quantities and man hours. In the current situation (as-is), scheduling production quantities happens at three different levels:

- **Product families;** the highest level, total daily production capacity is first divided over the product sorts.
- **Mould types;** the capacity allocated to each product family is divided over the mould types in the family. This results in a daily planning for filling the moulds.
• **Articles**: This is the planning for packing the products. Each of the mould types can be packed into different articles. In some cases, one mould type can be packaged as four different articles.

Right now, the planning on these three levels is created manually by the administrative employee at Eurostrip. Needless to say, this is a very time consuming job. When changes are made in any of these three levels of scheduling, everything has to be re-calculated. Therefore it is not a surprise that the current production schedule is in fact nothing more than the monthly required production amount divided by the number of production days in that month.

When the production is scheduled using the Kantoor application, only one quantity has to be scheduled: Articles. Since this is the most specific, the application can automatically calculate how much moulds per type should be filled. Also, the application alarms the user when a schedule is not feasible. After the schedules have been created, they are stored in the database. These schedules are then presented to the responsible coordinators in their applications at the production lines.

**6.3 Discussion**
The data collection system described here is not completely finished yet. The vast majority of the data collection and processing functionality is completed, but fine-tuning the application to the user’s wishes proved to be very time consuming in the end. The actual implementation will therefore be done in a later stage. Designing this application has led to valuable insights into ways in which measurement can be made much easier.

**6.4 Conclusions**
The set of performance metrics defined in chapter five was supplemented with a data collection system in this chapter. This way, a usable performance measurement system could be developed. Without a data collection system, the performance measurement system would merely consist of a set of metrics. From these metrics, we know which parameters we need to measure the performance of Eurostrip. By implementing the data collection system discussed in this chapter, we have elaborated how these parameters can be measured practically at Eurostrip. We advised the use of in total three different reports. Altogether, they present the 9 metrics of which our PMS consists, and as such these reports can provide a complete picture of the performance of Eurostrip.

Together with this data collection system, our performance measurement system has now shifted from being a rather abstract list of metrics into a practical and usable software application.
7. Validation

7.1 Introduction
Validation is the last stage of the regulative cycle (Aken, Berends, & van der Bij, 2004) that was executed in this research. According to the regulative cycle, the validation should be done after the actual implementation. The users should work with the implemented solution, after which they should be questioned about their experiences. Validation should be done to ensure that the designed application can indeed be used for the intended purpose.

7.2 Validation Procedure
Because the actual implementation of the data collection application is not part of this project, we did not have the possibility to validate the application based on real user experiences. Therefore we had to take a different approach here. We chose to do a so-called minimal validation here. Validating the data collection application was done in two sessions; one with the Eurostrip management and one with the Decor Son management.

At Eurostrip, we held a discussion session with three future users of the application: the administrative employee at Eurostrip (APm), the production team leader (TLPB) and the information analyst (IA). During this session we explained our solution, starting at the beginning. We described our performance measurement system first and explained that the data collection system was designed to collect data for the metrics. Then, we described the functionality and the design of the data collection application using screenshots of the MS Access forms (see Appendix E for an elaborate description). We described for each of these screens, where it should be used and what data should be entered. The session with the Decor Son management was a presentation in which we described the results of this complete project. We explained why performance measurement was important and which aspects of performance should be measured at Eurostrip. Finally we described the data collection application.

During both these sessions, we tried to get answers to the following questions:

- Will this application be really useful for Eurostrip when it is implemented?
- Is this data collection application an improvement compared to the current measurement system?
- Are you satisfied with the output that can be generated with the data collection application?

When these questions are answered, we know if the data collection system can serve the purpose for which it was designed. When this is indeed the case, we can say that the validation was successful.

7.3 Validation Results
In this paragraph, we will describe the results of the validation. Below, we will shortly describe the input of the stakeholders during the sessions based on the three validation questions that were stated above.
Will this application be really useful for Eurostrip when it is implemented?

The employees at Eurostrip confirmed that the application will indeed be useful for Eurostrip when it is implemented. It was noted that the current system is a mess and every improvement to this system will be embraced. This application, when fully implemented, will certainly be useful. This was also underlined by the Decor Son management.

Is this data collection application an improvement compared to the current measurement system?

The added value of the data collection application compared to the current situation was recognized by all the stakeholders. They agreed that the administrative workload will be decreased significantly and the system will be less sensitive to typing and reading errors than the previous system. The fact that a relational database is now used to store the data instead of separate (weekly) MS Excel files was also seen as a big improvement. For example, cumulating data over a time interval other than one week will now be possible. Also, it will be much easier to find older detailed information whenever this is needed. An example mentioned here was that it will now be possible to see in a blink which activities an employee did at a certain day several months ago. The current measurement system is not able to give us these kinds of insights. We would have to search a big amount of archived paper to find this kind of information, assuming that this paper is not already destroyed.

The advantages mentioned above were recognized by the both the management of Eurostrip and Decor Son. During the session, we also noted that the added value of this application comes not only from the functionalities it possesses right now, but also from the possibilities it creates for the future.

Are you satisfied with the output that can be generated with the data collection application?

The Eurostrip production team leader (TLPB) and the administrative employee (APm) of Eurostrip expressed that they were satisfied with the example output that was shown in the screenshots. They asked for modifications in some places but the overall tendency was positive.

Some example output in the form of management reports was also shown to the Decor Son management during the presentation. They were generally satisfied with this outcome, although they had some questions about the source of the data. This was clarified in a short discussion session after the presentation.

7.4 Towards Implementation

After the solution was presented to the Decor Son management, they decided that the data collection application should be implemented at Eurostrip. An implementation project plan was created which will be initiated after the completion of this thesis. First, the parts that are not fully finished yet will be completed, and the existing parts will be modified where needed. Then, the data collection application will be implemented at the expedition warehouse, the Euroc 1 production line and the front office. After this, it will be rolled out to the other production lines. During the implementation phase, this system will be used in parallel to the measurement system which is already in place. Several steps have to be taken before the old system can be discarded. For example, employees have to be instructed and possible errors have to be removed that were not found while testing.
7.5 Conclusion

We tried to validate our designed data collection application to the best extent possible here. Discussing the application based on screenshots is not the best way to validate an application like this. In this case it was the only possible way, because the application was not yet implemented and not all the parts were completely finished as well. We can say that both the Eurostrip and the Decor Son management were positive about this solution and see the added value. For us, this is a welcome confirmation that we did indeed build a useful application. Apart from the minimal validation described in this chapter, the fact that the management chose to start the implementation of this solution can also be seen as a sort of validation. The fact that the data collection application was received positively should be seen as a good motivation to start the implementation project.
8. Conclusions & Recommendations

In this chapter, we will first evaluate the solutions proposed in this thesis against the project goal. Then, we will discuss how it contributed to solving the existing problems. After this, some conclusions are drawn and a reflection of the used literature is given. This chapter is concluded with several recommendations.

8.1 Project Goal

The original goal for this project as stated in chapter 2 was:

*Design and implement a performance measurement system (PMS) for the Eurostrip production unit*

This goal was partly achieved. A performance measurement system was designed together with a data collection application. The actual implementation of the data collection application was postponed, but the application in itself is nearly ready to be implemented.

8.2 Problem mess

The next step is to evaluate to what extent this thesis contributed to solving the business problem defined in chapter 2: “Measurement system not performing as desired”. Therefore the original problem mess surrounding the key problem is repeated below. We will shortly describe for each of the sub-problems, whether they have been solved or not.

- **Information need not clear**: The motivation behind the measurements was missing in the current system. By building a performance measurement system in a structured way, we have created a better picture of the information that is really needed. We have documented not only which elements should be measured, but also why and how they should be measured.

- **Insufficient systems integration**: This issue is resolved after implementing the data collection application. The paper trail that currently exists can then be reduced to a minimum. The data collection application is designed as a complete and integrated approach to data collection and storage. Different systems for data collection, storage and presentation will not be needed anymore, because it is all included in one application.

- **Existing systems not updated**: The existing system in which the measurement data is currently stored will be fully replaced by the new data collection application. The fact that the old system...
was not updated will then not be an issue anymore. After implementation, the new system should also frequently be updated and revised, otherwise this issue will reoccur.

- **Collected data not accurate**: The data collection application is built to collect a specified set of data. The accuracy of the collected data will be increased. On the one hand, more data is collected for several parts of the process where there was a lack of information. On the other hand, the accuracy of the data is improved because it is centrally stored right away after it is entered at the production lines. Therefore there is less ground for reading errors. The risk of typing errors still exists of course but the administrative employee should check the data coming from the work floor for errors.

- **Wrong assumptions**: During the redesign of the measurement system, some wrong assumptions were found and removed. The new system still relies on several assumptions. We were not able to test the validity of all these assumptions and therefore we cannot guarantee that all assumptions are still correct. Examples here are the weights of the stone strips. Average weights were stored in the old system but as we have not weighed the stone strips ourselves, we just have to assume that they are correct. It is always important to keep a critical attitude towards assumptions in general, and they should be periodically re-evaluated.

### 8.3 General Conclusions

We will draw several general conclusions here; they reflect the most important insights that were gained during this project.

**The PMS designed during this thesis gives the management a better insight in the performance of Eurostrip**

The main reason for redesigning the measurement system was to improve the current system, because this was not performing as desired. Our system was designed to give a complete and comprehensible overview of the performance of Eurostrip. Apart from presenting the correct numbers and figures, this system is also designed to assist the management in understanding these figures. The redesigned PMS is built on the fact that performance is multi-dimensional. Good performance in one area does not necessary mean an improvement in overall performance. This PMS gives the management this insight because it can quantify the real performance in each of these dimensions. The management can now periodically review the performance in each of these dimensions and by doing so they can get a reliable and complete picture of the performance of Eurostrip.

**The data collection application that was developed, is an improvement compared to the current situation**

The data collection application developed during this thesis should be seen as an example elaboration of how performance data can be easily collected at Eurostrip. The data that was needed was defined during the design of the PMS. When the data collection application will eventually be put to use, this will be an improvement compared to the current situation.
This improvement is twofold; First of all, the collection and storage of data will be much easier, since a much bigger part of this process is automated. The administrative workload will be significantly decreased here. Secondly, the possibilities for processing this data have been improved, because all the data is stored in a relational database now.

**A structured approach towards designing a performance measurement system is essential**

Designing a performance measurement system is not done overnight. Although performance measurement systems in general appear to be straightforward, designing such a system is more than just defining some ratios and measuring data. In depth knowledge of both strategy and business processes are necessary preconditions for success.

Strategy should always be taken as a starting point in designing a measurement system. It defines what a measurement plan should be aimed at. Although mentioned by all authors in this field, our own experience underlined this. Strategy should be translated into a set of measures that should be periodically communicated to the management. Without taking a structured approach in finding out what needs to be measured, one can easily get lost in details. After all, everything can be measured. Explicitly defining what needs to be measured and what not, is an incremental process in which management involvement is very important.

**Proper measurement of performance is an essential basis for improvement**

The future performance of the Eurostrip production processes will not depend solely on the availability of proper measurement information. The path of action taken by the management is what will ultimately influence the performance of Eurostrip. How the performance of these processes can be improved is not the subject of this thesis, it belongs to the field of performance management. However, performance management relies heavily on proper measurement information. After all, any improvement initiative will have to be supported by some kind of measurement. Otherwise no management can know whether its actions were successful or not.

Therefore we say here that implementing a performance measurement system is not an end goal at itself: it is a necessary foundation that should be in place before real improvement of processes can start. Following this reasoning, this thesis is not a final solution; it should enable the management of Decor Son to get better insights into the performance of their processes. They will be able to recognize good and bad performance faster, and the impact of their course of actions on performance will be better visible. This performance measurement system is a toolbox that the management should have before they can really start improving their business.

**8.4 Literature Reflection**

Throughout this thesis, we used several theories and concepts from scientific literature. This paragraph contains a reflection on this literature; we will describe how it was useful and which insights it gave us.

This project followed the regulative cycle (Aken, Berends, & van der Bij, 2004). This method enabled us to structure the project and report in different phases and chapters. It also helped us in maintaining a logical order in terms of project steps.
The initial project description did not contain any guidance about the theoretical background of this project. The problem that was defined stated that the measurement system in place at Eurostrip was not performing as desired. It was not clear what should be measured, why it should be measured and how it should be measured. In the next phase of the regulative cycle, we studied the background of the problem in the analysis and diagnosis phase. The problem had a background in the field of performance measurement. We studied literature on performance measurement, found out what it is and why it is important for a company such as Decor Son.

The project goal for this thesis was to design and implement a performance measurement system for Eurostrip. Being new to this field, literature proved to be very helpful. We did not have to reinvent the wheel here. This research field received a lot of attention mainly in the last two decades. A range of theories and methodologies exist that offer guidance on how to develop performance measurement systems. As in any research field, there is no universal theory that could be applied here. Each business situation is very different and has specific characteristics. Based on these characteristics, available theory should be studied and an approach should be chosen that fits the situation. In some situations, a method can simply be followed. In other situations, a combination of methodologies can best be applied. This was also the case in this project. Based on the characteristics of the situation at hand, we selected a set of methodologies that could be applied here. This resulted in a step-wise development plan that we followed in the remainder of this project. Although there were many differences between the methodologies that were studied, there was one issue that was common for all theories: strategy should be used as a starting point when defining what needs to be measured. Each measurement plan should be strategically aligned.

The performance pyramid (Lynch & Cross, 1995) helped us in defining the dimensions of performance for a business unit such as Eurostrip. It provided an answer to the question: which aspects of performance should we measure?

After tracking down the strategic objectives in each of these four performance dimensions, the next step was to translate these rather abstract objectives into concrete metrics. For this purpose, we used the Goal Question Metric approach (Basili, Caldiera, & Rombach, 1994). Although originally designed for use in software engineering environments, we showed that this approach can be used in other fields as well. It is a very understandable and intuitive approach to translate goals into metrics.

In the analysis of the current situation, we used IDEF0 process models to describe the relevant business processes. The IDEF0 modeling method with its functional decomposition possibilities, gave us the possibility to model the overall business process and zoom in on sub-processes, without getting lost in details. It was a helpful tool to visually support our analysis of the current situation.

Concluding this paragraph, we can say that literature was certainly helpful during this project. Although measurement systems in general appear to be simple and straightforward, it is hard to design a performance measurement system without guidance. Existing methods should be followed to ensure that the right things are measured and that the system gives good information on all relevant aspects of performance.
8.5 Recommendations

Below, several recommendations are given that are related to this project. Some non-project related recommendations are given as well, since they fall outside the scope for this project, they are given in appendix F.

**Optimal cycle times should be used instead of normative times**

In the current situation, normative times are used for several manufacturing activities. These normative times are used as a sort of maximum cycle time for these activities. This expresses a ‘good enough’ attitude: when someone works faster than the normative time, he takes a longer lunch break so that he will end up exactly within the normative time. Our measurement system should invoke a process of continuous improvement in which ‘good enough’ is not sufficient anymore. Therefore normative times should be replaced with optimal cycle times. This way there is always room for improvement and ‘good enough’ behavior will be diminished. This line of thought is also expressed in our measurement system: in chapter 5, we noted that optimal cycle times are needed for several metrics.

**Launch improvement initiatives aimed at improving the overall performance**

Every initiative to improve the performance will somehow influence the performance that is measured by our system. It is commonly seen that a better performance in one area goes hand in hand with a decreased performance in another area. For example, the management should not get blinded by an increase of the output, when this is accompanied by a substantial increase in cost price. The measurement system that was developed here should give a good indication of the performance in all of these areas. Good improvement initiatives should lead to improvement in all performance dimensions.

**Keep the performance measurement system and the data collection application up to date**

When this system is implemented, it will not remain up to date forever. Therefore it should be reviewed from time to time. When changes are made in the strategy, this will somehow influence what has to be measured. This also has its implications on the data collection application. In the future, more detailed data might be needed in some places, whereas other parts might become superfluous. The application should be modified accordingly based on the measurement system for which it is designed.
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Appendix A – Organizational Chart
Appendix B - The IDEF0 Modelling Method

IDEF is an abbreviation of Integrated Computer Aided Manufacturing Definition Language. The IDEF methods are derived from a graphical language, the Structured Analysis and Design Technique (SADT). This technique was developed by the United States Air Force in order to be able to analyze and communicate the functional perspective of a system.

The IDEF0 method can be used to model complex systems in a graphical way. An effective IDEF0 model helps to organize the analysis of a system and to promote good communication between the analyst and the customer. The IDEF0 method is often used as the first tool in system development.

An IDEF0 diagram consists of boxes and arrows (see the figure below). A box represents a function and an arrow represents a flow of information/interface. The arrows are also called ICOM arrows, which stands for:

I = Input: the ‘raw material’ that gets transformed during the activity.
C = Control: influences or directs how the process works, e.g. plans, specifications, standards.
O = Output: the result of the activity.
M = Mechanism: causes the process to operate, e.g. people, tools, machines.

[Diagram of IDEF0 model]

IDEF0 is a hierarchical method. The basic diagram is the diagram on the A-0 (A minus 0) level. This diagram represents the core process of the organization in only one box. After the A-0 diagram there can be zoomed in on the process. The guideline for the decomposition level is that each level should have between three and six boxes. The first level after the A-0 level is the A0 level. If the A0 level has six boxes, these are the A1 till A6 boxes. There can be zoomed in on each of these boxes and therefore the next levels are the A1 till A6 levels. If there is being zoomed in on one of these level, the next levels are for example A11, A12, A13, etcetera. Arrows which do not connect to a box at one end are those that come from or go to the parent box, from which this diagram is decomposed. These arrows are numbered to indicate which ICOM arrow they represent.
There are several decomposition strategies that can be used:

Functional decomposition: the activities are broken down according to what is done, rather than how it is done.

- Role decomposition: the activities are broken down according to who does what.
- Subsystems decomposition: divides systems first by major subsystem.
- Lifecycle decomposition: the system is broken down first by the phases of activity.

Besides the several diagrams the IDEF0 method also consists of a description of the processes and a list of all terms and components that are being used in the diagrams.

The primary strength of IDEF0 is that the method has proven effective in detailing the systems activities for function modeling. The description of a system can be easily refined into greater and greater detail until the model is as descriptive as necessary. The hierarchical nature of IDEF0 facilitates the ability to construct AS-IS models that have a top-down representation and interpretation, but which are based on a bottom-up analysis process.

One of the observed problems with IDEF0 models is that they often are so concise that they are understandable only if the reader is a domain expert or has participated in the model development.

Another problem with IDEF0 is the tendency of IDEF0 models to be interpreted as representing a sequence of activities. While IDEF0 is not intended to be used for modeling activity sequences, it is easy to do so. Without intent, activity sequencing can be imbedded in the IDEF0 model. In cases where activity sequences are not included in the model, readers of the model may be tempted to add such an interpretation.
Appendix C – Performance Measures Record Sheets
Below we will describe the 9 metrics of our performance measurement system as defined in chapter 5 according to the performance measures record sheet developed by (Neely, Richards, Mills, Platts, & Bourne, 1997).

<table>
<thead>
<tr>
<th>Metric 1 - Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
</tr>
<tr>
<td><strong>Relates to</strong></td>
</tr>
<tr>
<td><strong>Target</strong></td>
</tr>
</tbody>
</table>
| **Formula**        | Total number of produced items in a time period \(
|                    | \frac{\text{Number of warranty claims that can be contributed to Eurostrip}}{\text{Total number of produced items in a time period}} \times 100\% \) |
| **Frequency**      | Monthly |
| **Who measures?**  | Employee of the After Sales department |
| **Source of data** | Incoming claims, by phone or e-mail |
| **Who acts on the data?** | Management of Eurostrip (PM/TLPB) |
| **What do they do?** | Identify problem causes, improve production process where needed |
| **Notes and comments** | Warranty claims should be categorized: only the claims that can be traced back to errors in Eurostrip production should be counted here |

<table>
<thead>
<tr>
<th>Metric 2 - Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
</tr>
<tr>
<td><strong>Relates to</strong></td>
</tr>
<tr>
<td><strong>Target</strong></td>
</tr>
<tr>
<td><strong>Formula</strong></td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
</tr>
<tr>
<td><strong>Who measures?</strong></td>
</tr>
<tr>
<td><strong>Source of data</strong></td>
</tr>
<tr>
<td><strong>Who acts on the data?</strong></td>
</tr>
<tr>
<td><strong>What do they do?</strong></td>
</tr>
<tr>
<td><strong>Notes and comments</strong></td>
</tr>
</tbody>
</table>
### Metric 3 - Details

<table>
<thead>
<tr>
<th>Title</th>
<th>The percentage of products delivered according to schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Measure the delivery performance of Eurostrip</td>
</tr>
<tr>
<td>Relates to</td>
<td>Strategic objective: Prevent lost sales of stone strips</td>
</tr>
<tr>
<td>Target</td>
<td>No target formulated yet</td>
</tr>
</tbody>
</table>
| Formula | \[
\text{Delivered product amount in a given month} \div \text{Scheduled production amount in that month} \times 100\% 
\] |
| Frequency | Monthly |
| Who measures? | Administrative employee (APm) at Eurostrip, and Logistics employee at Decor Son |
| Source of data | Data collection system, Strategic planning, Incoming shipments Son warehouse |
| Who acts on the data? | Management of Eurostrip (PM/TLPB) & Management of Decor Son |
| What do they do? | Find and discuss the causes of not meeting the strategic planning. Based on this discussion, modify schedule for next month accordingly, or improve the process such that next month’s planning can be met |
| Notes and comments | This metric can best be discussed in a monthly meeting, where the performance of the past month is first rated, after which the strategic planning for next few months is discussed. |

### Metric 4 - Details

<table>
<thead>
<tr>
<th>Title</th>
<th>The percentage of time that the lines are up in their scheduled uptime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Measure the reliability of the production processes</td>
</tr>
<tr>
<td>Relates to</td>
<td>Strategic objective: Guarantee a reliable production process</td>
</tr>
<tr>
<td>Target</td>
<td>No target formulated yet</td>
</tr>
<tr>
<td>Formula</td>
<td>[(1 - \left( \frac{\text{Unplanned production line downtime}}{\text{Scheduled uptime}} \right)) \times 100% ]</td>
</tr>
<tr>
<td>Frequency</td>
<td>Daily, Weekly</td>
</tr>
<tr>
<td>Who measures?</td>
<td>Production Cell coordinators (CCo)</td>
</tr>
<tr>
<td>Source of data</td>
<td>Data collection system</td>
</tr>
<tr>
<td>Who acts on the data?</td>
<td>Management of Eurostrip (PM/TLPB)</td>
</tr>
<tr>
<td>What do they do?</td>
<td>Continuously guard the uptime of the production lines and locate sources of downtime</td>
</tr>
<tr>
<td>Notes and comments</td>
<td>This metric represents the availability component of the OEE metric</td>
</tr>
</tbody>
</table>

### Metric 5 - Details

<table>
<thead>
<tr>
<th>Title</th>
<th>The machine speed performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Measure the reliability of the production processes</td>
</tr>
<tr>
<td>Relates to</td>
<td>Strategic objective: Guarantee a reliable production process</td>
</tr>
<tr>
<td>Target</td>
<td>No target formulated yet</td>
</tr>
</tbody>
</table>
| Formula | \[
\text{Actual machine production amount in a given time period} \div \text{Maximum machine production amount in a given time period} \times 100\% 
\] |
| Frequency | Daily, Weekly |
| Who measures? | Production Cell coordinators (CCo) |
| Source of data | Data collection system |
| Who acts on the data? | Management of Eurostrip (PM/TLPB) |
| What do they do? | Keep track of the machine speed on the different production lines. Find causes for insufficient machine speed performance by talking to coordinators responsible during the slower runs. |
| Notes and comments | This metric represents the performance rate component of the OEE metric |
## Metric 6 - Details

<table>
<thead>
<tr>
<th>Title</th>
<th>The employee speed performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Measure the reliability of the production processes</td>
</tr>
<tr>
<td>Relates to</td>
<td>Strategic objective: Guarantee a reliable production process</td>
</tr>
<tr>
<td>Target</td>
<td>No target formulated yet</td>
</tr>
</tbody>
</table>
| Formula | \[
\text{Actual employee production amount in a given time period} / \text{Maximum employee production amount in a given time period} \times 100\%\] |
| Frequency | Daily, Weekly |
| Who measures? | Production Cell Coordinators (CCo) |
| Source of data | Data collection system |
| Who acts on the data? | Production Cell Coordinators (CCo) and the management of Eurostrip (PM/TLPB) |
| What do they do? | Cell coordinators can discuss below average packaging performance with their team members and try to improve the employees packaging speed. The Eurostrip management on its turn can call the coordinators and discuss insufficient performance of packaging employees with them. |
| Notes and comments | The cell coordinators can grade the performance of packaging employees when they enter their packaging amounts in their applications. The performance of each packaging employee is calculated automatically. On a more aggregated level, the management of Eurostrip can see the overall employee speed performance for any given time span. |

## Metric 7 - Details

<table>
<thead>
<tr>
<th>Title</th>
<th>Material input/output ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Minimize the amount of waste generated in the production processes</td>
</tr>
<tr>
<td>Relates to</td>
<td>Strategic objective: Realize the lowest possible cost price</td>
</tr>
<tr>
<td>Target</td>
<td>No target formulated yet</td>
</tr>
</tbody>
</table>
| Formula | \[
\frac{\text{Amount of materials shipped as end product in a given period}}{\text{Amount of raw materials used in a given period}} \times 100\%\] |
| Frequency | Daily, Weekly |
| Who measures? | Administrative employee (APm) at Eurostrip |
| Source of data | Data collection system |
| Who acts on the data? | Management of Eurostrip (PM/TLPB) |
| What do they do? | Constantly guard this ratio, find and eliminate causes for inefficient material usage |
| Notes and comments | This metric provides insight in the bottom line efficiency in which materials are transformed into end products. It can be calculated for any production line, but also for combinations of lines such as all the concrete lines together and for Eurostrip as a whole. This metric, together with metric 9 gives us a complete picture of the efficiency of the overall process. |
### Metric 8 - Details

<table>
<thead>
<tr>
<th>Title</th>
<th>The scrap rate over a period of time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Minimize the amount of waste generated in the production processes</td>
</tr>
<tr>
<td>Relates to</td>
<td>Strategic objective: Realize the lowest possible cost price</td>
</tr>
<tr>
<td>Target</td>
<td>No target formulated yet</td>
</tr>
</tbody>
</table>
| Formula | \[
\frac{\text{Number of scrapped stone strips in a given period}}{\text{Number of moulds filled in a given period}} + 100\%
\] |
| Frequency | Daily, Weekly |
| Who measures? | Production Cell Coordinators (CCo) |
| Source of data | Data collection system |
| Who acts on the data? | Production Cell Coordinators (CCo) and the management of Eurostrip (PM/TLPB) |
| What do they do? | Constantly guard this ratio, try to reduce this rate to a minimum |
| Notes and comments | This metric represents the quality rate component of the OEE metric |

### Metric 9 - Details

<table>
<thead>
<tr>
<th>Title</th>
<th>Productivity per man hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Minimize the amount of waste generated in the production processes</td>
</tr>
<tr>
<td>Relates to</td>
<td>Strategic objective: Realize the lowest possible cost price</td>
</tr>
<tr>
<td>Target</td>
<td>No target formulated yet</td>
</tr>
</tbody>
</table>
| Formula | \[
\frac{\text{Actual production amount in a given period}}{\text{Amount of direct labor hours spent in a given period}} + 100\%
\] |
| Frequency | Daily, Weekly |
| Who measures? | Production Cell Coordinators (CCo) |
| Source of data | Data collection system |
| Who acts on the data? | The management of Eurostrip (PM/TLPB) |
| What do they do? | Constantly guard this ratio, try to reduce this rate to a minimum |
| Notes and comments | This metric provides insight in the bottom line efficiency in which man hours are used. Together with metric 7 it gives us a good insight in the efficiency of the overall production processes |
The ER-Diagram representing the MS Access 2007 relational database can be seen in Figure 27 below. For each table, the primary keys (PK) and foreign keys (FK) are given. The Crow’s foot notation\(^1\) is used to clarify the cardinality of the relationships between the entities. The complete ERD can be seen in Figure 1 on the next page. This relational database only has one (\( \leq 1 \)) to many (\( \geq 1 \)) relations.

---

\(^1\) http://www2.cs.uregina.ca/~bernatja/crowsfoot.html
Appendix E – Data Collection Application

In this appendix, the data collection application will be described in more detail. Screenshots of the user interfaces (MS Access forms) have been taken to illustrate the functionalities of this application. As before mentioned, the application was designed in Dutch.

As described in chapter 6, there are three different sorts of front-end applications:

- The production lines
- The expedition warehouse
- The front office

They will be described in this order below.

The production lines

The front-end application that was developed for use at the production lines is described first. We will show only screenshots of the front-end application for the Euroc 1 production line here. The applications for the other lines will be copies of the Euroc 1 application with some small modifications. The application for the Euroc 3 line will for example not include forms for packaging (‘Inpakken’).

Euroc 1 - Start

![Screenshot of Euroc 1 - Start form]

This is the first form that appears upon opening the application. The responsible coordinator can see today’s scheduled production amounts, together with the employees that were scheduled. Finally, a note from the front office is displayed here as well. The schedules and the note were created in the
Kantoor-application, which will be described later. At the bottom, four buttons can be seen, of which three can be used to generate reports when the day is finished. The fourth button (Afsluiten Dag) closes the current day; this should be done by the coordinator when all data for that day is entered. After closing the day, the production schedule and employee planning is loaded for that day.

**Euroc 1 - Vullen**

When the schedule is understood, the production coordinator assembles his team and they start a production run. One mould type is filled per production run. After completing each run, the coordinator should enter information about that run. He can add the information of a run by clicking *Nieuwe Run Invoeren*. He can also modify or review previous runs of that day by clicking *Bewerken Runs*.

**Euroc 1 - Run toevoegen**

This screen pops up when the coordinator chooses to enter a new run. In this screen, the production coordinator should enter several details about the run. These were all described in chapter six before. The coordinator can also enter some additional notes for that run.
In this screen, the production coordinator has to select all the employees that were active in packaging under his supervision. For each packaging employee, the coordinator has to fill out some information. A pop-up screen is opened, after clicking *Invoeren Inpaklijst*.

In this pop-up screen, detailed information about the packaging of the selected employee has to be filled out. Just like the filling of moulds, packaging is done in so called runs. During a run, one employee packs one type of mould. The mould type that was packaged during a run has to be chosen first, using the drop-down box at the top. Then, the amount of dried moulds that the employee has taken out of the dry room has to be entered. In the example run above, the employee ‘Kranjik’ has taken 10 carts containing dried moulds out of the dry room. These 10 carts were loaded with a total...
of 800 Odyssee 1 moulds. These moulds were packed into 90 carton boxes labeled as ‘Decor Odyssee 1 Wit’ and 62 carton boxes labeled as ‘Phoenix No. 1 Crème’. From these amounts, we can calculate the exact amount of stone strips that were broken during this packaging run. This amount, on a more aggregated level, is an important parameter in our performance measurement system (see metric 8: Number of scrapped stone strips in a given period).

Finally, the start and end time of the packaging run has to be entered. In this example, ‘Kranjik’ packaged the Odyssee 1 stones from 6:00 till 15:00, for a total of 9 hours. Packaging these 152 boxes should take a maximum of 9 hours and 40 minutes, according to the normative time for this activity. At the bottom left of the screen, the coordinator can quickly see whether the employee stayed within the normative time (indicated by: ‘Norm Gehaald’). The used time, together with the amount of products packaged is also parameter data for our PMS (see metric 6: The employee speed performance). We also stated in the recommendations that these normative times should eventually be replaced by optimal cycle times. In this situation, an employee’s performance is rated against a normative time and it is calculated whether he passed or not. When optimal cycle times are established, the employee will be rated against this cycle time and his performance can for example be expressed as ‘60% of optimal performance’. This will be possible with a slight modification in this screen.

Euroc 1 - Urenstaat
This is the input screen in which the worked hours per activity can be entered for each individual employee. The production coordinator should fill this out for each of the employees working under his supervision. At the end of each shift, the production coordinator collects the papers of his team members. On these papers, the employees (Pm) have written down what they have done during their shift and how much time they spent per activity.

The time that an employee used for packaging products is already known, as this was already entered in ‘Invoeren Inpaklijst’. When the name of an employee is selected who was active in packaging that day, the total amount of packaging hours (‘Inpakken’) is automatically calculated and filled out.

For all the other employees, the coordinator has to fill out how much time they spent per activity. Activities here include participating in filling production runs, cleaning (‘Poetsen’) or miscellaneous (‘Diversen’). It is also possible that an employee helps out at another production line during the day. This time is noted under the activity ‘Uitleen’.

The lay-out of this screen is also designed to give the coordinator some assistance while filling out the hours per employee. For each filling production run, the used machine time together with the type of mould is given for that day. At the bottom, the total normative employee time for each production run is also displayed. This is the maximum time in man-hours that should be used for that production run, according to the normative time. It is calculated from the production amounts.

When filling out the hours spent per production run, the coordinator should check whether the amount of hours spent by an individual employee in a production run is not larger than the used machine time for that run, as this is not possible. On the other hand, he should check if he stayed within the total normative employee time for that run. This can easily be seen at the bottom.
**Euroc 1 – Dagstaat Vullen**

**Dagoverzicht Productie Vullen EUROC 1**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Opmerkingen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ARMOR21</td>
<td>Netto Productietijd: 1:30</td>
</tr>
<tr>
<td></td>
<td>Pauze: 0:00</td>
<td>Storing: 0:09</td>
</tr>
<tr>
<td></td>
<td>Mergers: 6</td>
<td>Mollen Gevuld: 1872 (6 / 0)</td>
</tr>
<tr>
<td></td>
<td>Grondstoffen: 1716 Kg</td>
<td>Gewicht Gevuld: 1654 Kg</td>
</tr>
<tr>
<td></td>
<td>Verties: 162 Kg</td>
<td>9%</td>
</tr>
<tr>
<td>2</td>
<td>TRADIROC</td>
<td>Netto Productietijd: 1:15</td>
</tr>
<tr>
<td></td>
<td>Pauze: 0:00</td>
<td>Storing: 0:09</td>
</tr>
<tr>
<td></td>
<td>Mergers: 10</td>
<td>Mollen Gevuld: 1152 (8 / 0)</td>
</tr>
<tr>
<td></td>
<td>Grondstoffen: 2860 Kg</td>
<td>Gewicht Gevuld: 2692 Kg</td>
</tr>
<tr>
<td></td>
<td>Verties: 268 Kg</td>
<td>9%</td>
</tr>
<tr>
<td>3</td>
<td>MEGA 1,10</td>
<td>Netto Productietijd: 1:00</td>
</tr>
<tr>
<td></td>
<td>Pauze: 0:15</td>
<td>Storing: 0:09</td>
</tr>
<tr>
<td></td>
<td>Mergers: 6</td>
<td>Mollen Gevuld: 320 (4 / 0)</td>
</tr>
<tr>
<td></td>
<td>Grondstoffen: 1716 Kg</td>
<td>Gewicht Gevuld: 1098 Kg</td>
</tr>
<tr>
<td></td>
<td>Verties: 520 Kg</td>
<td>36%</td>
</tr>
<tr>
<td>4</td>
<td>CHINON 1,10</td>
<td>Netto Productietijd: 4:00</td>
</tr>
<tr>
<td></td>
<td>Pauze: 0:30</td>
<td>Storing: 0:09</td>
</tr>
<tr>
<td></td>
<td>Mergers: 30</td>
<td>Mollen Gevuld: 2700 (27 / 10)</td>
</tr>
<tr>
<td></td>
<td>Grondstoffen: 8580 Kg</td>
<td>Gewicht Gevuld: 7580 Kg</td>
</tr>
<tr>
<td></td>
<td>Verties: 1020 Kg</td>
<td>12%</td>
</tr>
</tbody>
</table>

**Totaaloverzicht maandag 17 mei 2010**

**Effectiviteitsbepaling**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

96,6% 69,8%

**Snelheid**

<table>
<thead>
<tr>
<th>Netto Productietijd: 21.25</th>
<th>Optimaal Productietijd: 14.82</th>
<th>69,8%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

90,1%

**Grondstoffen**

<table>
<thead>
<tr>
<th>Gebruikte grondstoffen: 42614 kg</th>
<th>Geweide grondstof: 38326 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verties grondstof: 4228 kg</td>
<td></td>
</tr>
</tbody>
</table>

beschikbaarheid: De netto beschikbare tijd (t.a.v. de ingepane productietijd voor Euroc 1 is 0.22 uur).

Snelheid: De snelheid waarmee is geproduceerd, vergelijking is een productie met optimale optrekken.

Grondstoffen: Het percentage van gebruikte grondstoffen dat daadwerkelijk in de mollen is aangewend.

**Gantt diagram**

Legenda

- NetToTijd
- Storing
- Pauze
The report on the previous page is an example of the report that a production coordinator can print at the end of his shift. The first part of the report is a simple overview of the filling runs that were completed that day. The details of each run can be seen here. This is the direct result of the information that was filled out in the ‘Run Toevoegen’ screen. The amount of raw materials that was used in the mixers (‘Grondstoffen’), the amount that was filled in moulds (‘Gewicht Gevuld’) and the amount that was spilled here (‘Verlies’) is calculated. The production coordinator should overlook this list at the end of each shift to see if it contains errors. If he finds errors, he is still able to modify the run information accordingly (Run Bewerken).

The second part of this report is shown at the right side of the page and contains two sections. The part at the top contains performance feedback for that day for the filling activities. It shows the net production time and shows how much it deviated from the scheduled production time (Beschikbaarheid). It also shows the operator how well they performed compared to the optimal cycle times. Since optimal cycle times are not yet known, we defined the optimal cycle times as 2/3rd of the normative times here. The operator can see here that 21,25 hours were spent that day. When all the moulds that were filled that day in an optimal cycle time, it would have taken 14,82 hours. This leads to a performance of nearly seventy percent on this factor. The third box contains information about the raw materials used. It shows the coordinator how much raw material he used, and how much was actually filled in moulds. In this example, about 10% was lost here.

The second part of the right page contains a dynamically generated Gantt chart, showing the different production runs in a graphical way. At the y-axis, all the mould types are shown, and the x-axis contains the daily hours. The chart should be read top-down, starting with Armor21 as the first production run at 6am. This chart provides a quick overview of the production runs that day, how long they took, when the breaks were taken and when there were breakdowns.

**Expeditie**

The expedition application should be installed at a computer located in or near the finished goods inventory. All the finished products are loaded in trucks here. A personal computer is not yet installed here, but one should be placed here in the near future. This application should then be installed there. The Expeditie application consists of three different forms, which will be described below.

**Expeditie - Start**

This is the opening screen of the Expeditie front-end application. Employees can search for delivery notes of previous deliveries, based on delivery number or date. The delivery notes that are found, are shown as print previews, they can be printed when needed.
**Expeditie – Zending Invoeren**

In 'Zending Invoeren', the expedition employees have to enter the contents of new shipments. For every shipment, a new record is created in table ZendingenSon.

For administrative purposes, some additional information for this shipment has to be entered first. For example the names of the truck loader and truck driver are recorded, together with the truck’s license plate and name of the truck company.

The most important input for our system is of course the contents of the delivery (see ‘2. Inhoud’). The complete contents of the truckload should be entered here. The user can enter an article ID or select an article from the drop down list. For that article, he can enter the number of full pallets that are loaded. After entering a number there, the application calculates the amount of carton boxes that are on these pallets. There is no standard number of carton boxes that is contained on a pallet, this can vary per article. If some un-palletized boxes are loaded, the number of carton boxes can be changed. At the bottom, the total number of pallets and carton boxes is calculated. Based on that number, the full weight of the shipload is also calculated. This is then also noted on the delivery note, because the load of a truck should always be known for legal reasons.

When everything is filled out, a delivery note should be printed. An example delivery note for this specific delivery can be found on the next page. After signing, the delivery note should be e-mailed to the incoming goods desk (AEM) in Son as a PDF attachment. This is done automatically in the background. By now the delivery is final, and all the data is stored in the database.

<table>
<thead>
<tr>
<th>ArtikelID</th>
<th>ArtikelNaam</th>
<th>Volle Pallets</th>
<th>Aantal Dozen</th>
<th>Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1550107</td>
<td>BE CONF. TRIONON 1</td>
<td>4</td>
<td>104</td>
<td>30</td>
</tr>
<tr>
<td>1550108</td>
<td>DECOR MEGA EURO NO 1 CREME</td>
<td>1</td>
<td>65</td>
<td>2361</td>
</tr>
<tr>
<td>1550109</td>
<td>DECOR EUROC 1 CREME</td>
<td>8</td>
<td>768</td>
<td>34658,12</td>
</tr>
<tr>
<td>1550110</td>
<td>DECOR EUROC 3 ZALM</td>
<td>1</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>1550111</td>
<td>DECOR ODYSSE 1 WIT</td>
<td>5</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>1550112</td>
<td>STONE DESIGN ODYSSE 30 G BR</td>
<td>3</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>1550113</td>
<td>AVIGNON</td>
<td>4</td>
<td>384</td>
<td></td>
</tr>
<tr>
<td>1550114</td>
<td>DECOR EUROC 5 GEEL</td>
<td>&gt; 2</td>
<td>384</td>
<td></td>
</tr>
</tbody>
</table>
This is an example of the digitally generated delivery note that is created when the expedition employee clicks *Afdrukken* on the ‘Zending Invoeren’ screen. All the information that was entered there can be seen in this report. This delivery note is printed in twofold; both should be signed by the expedition employee and the truck driver. By doing this, they both share the responsibility that what is on this delivery note is really in the truck.
**Expeditie - Urenstaat**

In this screen, all the expedition employees should fill out their worked ours per activity. This is comparable to the ‘Urenstaat’ screen at the production lines, but less specific. Usually expedition employees will spend their full shift doing ‘Expeditie’ activities.
**Kantoor**

This is the front office application. In each of the sub paragraphs below, we will describe the different user forms included in this application.

**Kantoor – Planning**

The administrative employee (APm) can use this form to create employee and production schedules. This screenshot shows an example schedule for May 17th. Each production line has its own schedule, consisting of an employee schedule at the top of the screen and a schedule of the production amounts at the bottom.

An employee is scheduled by selecting his name from the drop-down box, filling out the start and end time of his shift and the duration of his break. From these variables, the real working time for that shift is calculated ('Uren').

Below the employee schedule is some room to post a note. This note will be displayed to the production coordinator at the start of the production day in the starting screen of his application.

In the bottom part of the screen, the production amounts can be scheduled. As was discussed in chapter 6, this only has to be done in terms of number of carton boxes. For example, when we schedule 104 carton boxes of ‘Decor Armor nr. 21’ for that day, the application calculates that we will
need to fill 1248 moulds of the type ‘Armor 21’, which equals four full production carts. When this planning would be not feasible, because for example we would just have 1100 moulds of type ‘Armor 21’ in stock, then the planned production amount will color red. This example planning is feasible, as can be seen in the screenshot.

**Kantoor - Rapportages**

**Management**

This screen can be used to generate management reports. At the bottom of the screen, the time period should be selected over which the report is created. After entering a week number, the from and to date for that week number is automatically updated. The same goes for month. Of course, the user can enter any given from and to date.

Two management reports can be generated here. These were described in chapter 6; a report based on the OEE metric describing the **effectiveness** and an **efficiency** report.

These reports are dynamically generated. They are based on complex queries and require data from several tables. Up until now, the database has only been filled with some example data, only for Euroc 1. Filling this database right now is very labor intensive. When the application is implemented, the data will come from various users in various locations. For now, we have chosen not to build a large sample dataset yet. The focus was to build working queries and reports first. These queries and reports will be working no matter how large the dataset will be. In the end, these management reports can be easily generated over weeks, months and years.

Below, we will describe the OEE report first, after which the efficiency report will be described.
This is an example of an OEE report. It contains the three components of the OEE metric that was discussed in chapter three and five.

The availability component is shown in the upper left box (Beschikbaarheid). This is also the fourth metric of our performance measurement system. The speed performance rate is shown in the upper right box (Snelheid). In our PMS, this is metric 5. Finally, the third component, Quality (Kwaliteit), is shown in the bottom left box. This is metric 8 of our PMS. The OEE score that is calculated from these three ratios is shown in the bottom right box. By looking at this report, the general manager can get a quick insight in the performance of the Eurostrip production lines based on three of the metrics.

This is an example of an Efficiency report. This example shows only numbers for one day, and only for the Euroc 1 line. Eventually all the lines should be included on this report. This design is created for Euroc 1 only, but modifying these queries for all the other lines will only cost a fraction of the effort.
put in creating these queries and this report for Euroc 1. The complete report will show this overview for all the lines.

At the top, a visual representation can be seen of the material flows. A simple Sankey diagram was used to visually support the numbers. The green left side of the Sankey diagram contains information about the material usage in the ‘filling’ part of the production process. This is where the moulds are filled with concrete and plaster mixture. We see the total amount of raw materials that was used in the mixers (‘Verbruik’). From this amount, 9.9% is spilled in this example (‘Mengsel Spił’). The rest was filled in 12.604 moulds.

The right hand side of the Sankey diagram shows the information for the packaging activity. In total, 11.768 moulds were taken out of the dry room. There can be some discrepancy between the amount of moulds that are filled and the moulds that are taken out of the dry room. This is due to the nature of the production process; some moulds might still be in the dry room and the next day it is possible that some more moulds are taken out than were filled that day. From the 11.768 moulds that were taken out of the dry room, 937 broke resulting in a scrap rate of 8.0%.

We can see a detailed overview of the material flows here. Also, the summarized amounts of purchased raw materials will be shown, together with the summarized amounts of shipped waste material. These values should be in line with the all the total amounts of the individual lines added up.

**Aflever**

![Kantoor - Rapportages](image)

This screen is used to create delivery reports. The deliveries and their contents are stored in the tables *ZendingenSon* and *ZendingenSon Details*. Using the button ‘Overzicht’, the user can get an overview of the amount of products that were shipped in the selected time period. Clicking ‘Rittenlijst’ shows an overview of all the different truck rides in that period.
This is screen is opened after clicking ‘Overzicht’. It shows the total amount of shipped products for any given period. This is a query opened in a datasheet view. Showing this query’s results in a report layout would have looked better, but then we would lose the possibility to further use this data in other programs. This is a typical table that will be exported to MS Excel. Showing this query in the datasheet layout makes it very easy for the user to export this table to excel. The user can copy the contents of the table or use the MS Access built in ‘Export to Excel sheet’ function. This table in its current form is important in the calculation of the third metric of our PMS: The percentage of products delivered according to schedule. This table contains the values for the first parameter of this metric: Delivered product amount in a given month. By filling out the number of a month in the bottom of the ‘Aflever’ screen, the query returns the amount of products shipped in that month, sorted out per article. This amount should be taken and compared to the amount that was planned in the strategic planning for that month. We can then calculate the delivery performance for that month easily, thereby grading the delivery performance of Eurostrip based on metric 3.

The figure above shows an example overview of the different deliveries in the chosen timespan. The ‘Rittenlijst’ is a list containing details of the deliveries, not their contents. The delivery notes of the truckloads also be retrieved using the ‘Ritnummers’, this can be done in another screen that will be described later.
Medewerkers

This screen can be used to generate detailed reports of the worked hours per employee. An employee should be selected first, after which the user can choose whether he wants to build a cumulative overview or a detailed overview. The cumulative overview is a pivoted table containing the total worked hours summarized per day. Monthly totals are automatically calculated here. An example of the cumulative overview of this employee can be seen below.

This is the cumulative overview for employee ‘Baran’ for the selected period. As can be seen, this employee has only worked one day in our sample dataset. On this day he has worked for 11,25 hours.

This is the more detailed overview for the same employee. We can see here the list of dates on which this employee has worked, together with the detailed overview of the hours he has spent per activity. This data can also be edited where needed.

Apart from viewing these two overviews in Access, the user can also choose to export either of these two query results. The pivot table or the datasheet will then be written to an MS Excel file. This can be done by clicking ‘Exporteer Rapport’.
**Kantoor – Overigen**

All the other functionalities of the ‘Kantoor’ application that don’t belong to either production planning or reporting are located here. The layout of this screen is comparable to the ‘Rapportage’ screen discussed before. A tabbed layout is also used here to make the content easy accessible for the user.

**Dagstaten Productie**

The user can retrieve the daily reports per production line for any given date here. These are the same reports that can also be printed by the coordinators at the end of their shift.

This screen is the same as the opening screen of the expedition application. The employee can search for delivery notes here; these can be found based on the number of the delivery or the date. When searching on a date, it is possible that multiple delivery notes are opened, because multiple shipments can take place on one day. When one or more delivery notes are found, they can be
printed. A message box is displayed when no deliveries are found on a certain date or with a certain number.

Each time a delivery of raw materials takes place, the administrative employee has to enter the details for that delivery in this screen. She chooses the date of the delivery, the name of the supplier and which sort of raw material this supplier delivered. Each supplier hands in a ticket when supplying. This ticket has a unique number (BonNr) and also the amount of raw material is listed there. These two details also have to be entered here. Obviously the amount of raw materials that is purchased is an important variable as this is the place where we can measure the total amount of raw materials that enter Eurostrip.

Each time a garbage container is collected by the garbage removal company (Van Happen), they hand in a note. The weight of the container’s contents is shown on this note. This amount should be
entered in this screen every time a container is collected. This amount is important to get an insight in the overall material flow that exits Eurostrip. In the end, the amount of material that leaves the factory as end products together with the amount of material that is shipped away in the containers should add up to the total amount of purchased raw materials.

This is the final screen of the Kantoor application. This form provides the user quick access to the underlying tables. After clicking these buttons, the corresponding tables are opened in a datasheet view such that they can be edited easily. Entering the information for new employees is one task that can be performed here.
Appendix F – Non Project Related Recommendations

During the course of this project, we became acquainted with Decor Son and its operations. The focus was on the subject of this project, but during several discussions we noticed some issues that are worth mentioning, although they don’t really belong to this project. We will therefore mention these issues here as non-project related recommendations.

The recommendations below reflect insights that we got during the execution of this project. Each of these recommendations offer a lot of possibilities for new research and we are convinced that there is a lot of room for improvement in each of the fields described below.

Each of the recommendations below start with “Critically review and improve...”. This is done on purpose. A critical attitude should be taken in reviewing the current way in which things are done right now. This should eventually result in improvement in these fields.

**Critically review and improve the planning and scheduling at Eurostrip**

This issue was also noted in the problem analysis in chapter 2. The planning and scheduling at Eurostrip is non-optimal. This was stated by the Eurostrip management. The problem is that not enough know-how exists about planning and scheduling. Terminology like “Master Production Schedule”, “Bill Of Materials”, “line balancing” and “Gantt charts” was new to the Eurostrip management. These are rather basic concepts for production planners and schedulers. Therefore we suggest that the Eurostrip management starts learning these concepts, and learns how they can be useful to them. Right now, the production schedule is created in a very simplistic way. The amount that is monthly needed is divided by the number of net operating days. This results in a very ‘static’ and non-optimal planning with lots of switching.

As a start to review and improve the planning and scheduling at Eurostrip, we highly recommend the book by (McKay & Wiers, 2004) here. The book presents the reader with a very practical and hands-on approach to improve the production planning and scheduling. Lots of example situations are sketched that will undoubtedly be recognizable for the Eurostrip management. Suggested improvements can prove to be very helpful. After all, lots of managers around the globe experience largely comparable problems with regard to production planning and scheduling. There is no harm in seeking help in a book like this.

**Critically review and improve the forecasting mechanism that is in use**

This issue was also signalled in paragraph 4.3.3.4. To generate forecasts, the ERP system uses demand data from the previous three years. The expected demand for the complete year is then calculated through a simple, linear extrapolation of the previous three years. This is done with a trend factor. For each month in the coming year, a seasonal index factor is calculated. The system thus forecasts demand using trend and seasonal factors, which is good. It is however too simplistic to just weigh the demand of the last three years equally in these calculations. Only when the demand growth is fully linear, this approach will be effective. When the demand for a certain product grows exponentially, which is an extreme but not unthinkable situation, this method will result in inaccurate forecasts.
On top of this comes the fact that the performance of the forecast models is not revaluated from time to time. Each year, forecasts are proposed by the system, which are modified by human input. The next year, the same forecast models are used again, which are modified by human input again. What actually should be done here, is evaluate the forecasts of the previous year and signal where they were wrong. The models should then be modified so that a better forecast will be created next year. This is an issue that should get some more attention in a later research.

**Critically review and improve the inventory management policies that are in place**

Properly managing inventory is a science. A good inventory policy minimizes the costs incurred by finding the optimum amount of stock to keep. A balance should be found between the number of products that cannot be delivered from stock and the amount of inventory that is kept. A delivery performance of 100% is almost never seen in practice, which is not strange because huge amounts of stock should be kept to be able to deliver everything from stock. This is due to the stochastic nature of demand. Keeping huge amounts of stock to deliver everything from stock will generally be very costly.

The current inventory policy that is in use at the Decor Son warehouse is based on a so-called ‘rotation’. For example, when on average 100 products are sold per week, and a ‘rotation’ of two weeks is used, this means that 200 products should always be kept in stock. For the stone strip products, an ‘rotation’ of two months is used. This means that two months of average demand is kept in stock.

This inventory policy, based on ‘rotations’, is way too simplistic. In (Silver, Pyke, & Peterson, 1998), this inventory policy is named the ‘simple method’. These authors note that this inventory policy is still widely used despite of its shortcomings. The major drawback of this method is that it does not take into account the variability of demand at all. As we know, each stochastic demand pattern should always be described with an average (µ) and a standard deviation (σ). Using ‘rotations’, only the µ is taken into account and the σ is not considered at all. This is alarming to say the least.

We will illustrate the shortcoming of this method by a simple example. We assume for this example that the demand is normally distributed. Let’s take two different products with an equal average demand (µ) of 2.000 items per month. The standard deviation (σ) of the demand for one product is 50, whereas the standard deviation of the second product is 2.800. Thus, the demand for the second product is much more variable than the demand for the first product.

The ‘rotation’ method will advise us to keep 4.000 products of both types on stock. This will lead to very good delivery performance of product one (> 99,99 %) and an insufficient delivery performance of product two (< 93%). Warehouse management will be puzzled here, because they cannot explain how it is possible that the delivery performance of these two products is so different, while the average demand is the same, and the same ‘rotation’ factor is used for both products. For us, it is apparent that in the sketched situation, the amount of stock for product one is way too high, whereas the stock for product two is way too low.

A proper inventory policy will take into account both the average demand and the standard deviation. A good policy can tell us how much of product one and two we should keep on stock if we want to achieve a delivery performance of for example 98% on both products. In our example
situation, the suggested amount to keep on stock for product one will be around 200. For product two, we will need to keep much more inventory, say around 9,000 products on average. This way we will reach a steady delivery performance of 98% on both products.

This example is of course exaggerated. It is meant as an example of the shortcomings of the ‘rotation’ method that is currently used by Decor Son. However, it does illustrate the core of the issue. Not taking into account variability when forecasting demand is a major miss.

The fact that a steady delivery performance of 97% is reached for multiple years now, should be seen as a major achievement in the light of our findings here. This is probably achieved by structurally keeping ‘too much’ inventory on one hand and good manual overrides of the stock levels where needed on the other hand. After all, experience can prove to be a very useful help in determining stock levels.

We will not further elaborate on this issue, a whole new thesis could be dedicated to improving the inventory management policies for Decor Son. Our expectation is that a thorough analysis of the demand patterns and an improvement of the inventory policies in parallel has a lot potential. A significant decrease of warehouse costs, together with an increase in delivery performance is certainly not unthinkable here.

A suggested reading here is the work of (Silver, Pyke, & Peterson, 1998), which offers a lot of insights into the matter of inventory management and related disciplines.