INVENTORY MANAGEMENT

INTRODUCING A FRAMEWORK TO ASSESS OPERATIONAL PERFORMANCE.

- Final version
November 27, 2009

Delft University of Technology
Master Thesis – Systems Engineering, Policy Analysis and Management

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INTRODUCTORY

This thesis is submitted in partial fulfilment of the requirement for the degree of *Master of Science* in *Systems Engineering, Policy Analysis and Management* – ICT Infrastructures and Services.

Below you find the details of this research project: the author, the composition of the graduation committee together with the contact details.

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Keywords: Inventory Management, Performance Measurement, Measurement Framework, Enterprise Resource Planning, Key Performance Indicators, Case Study.

Words: 42,605
Pages: 122
Research Period: April – November 2009.

This research has been supported by KPMG IT Advisory, The Hague & Delft University of Technology.

PREFACE

This report is the result of the last challenge of my Master studies at Delft University of Technology, entitled Systems Engineering, Policy Analysis and Management (SEPAM) at the Faculty of Technology, Policy and Management. This report forms the graduation thesis thereof. The research described in this report was conducted from April 2009 until November 2009. Based on my research a scientific paper has also been written. My research was supported by KPMG IT Advisory; I really appreciate it that they offered me the opportunity to write my thesis with them. KPMG offered me a great help with my thesis and also made it fun due to several social events that were organized during my stay: they really kept me motivated!

The topic of this research is inventory management and in particular the performance measurement thereof. This report also made a first attempt to see what influence the use of Enterprise Resource Planning (ERP) software has on inventory activities.

I worked on this project with great pleasure. I am personally very proud of the final result and I sincerely hope that you as a reader will also enjoy reading this thesis!

Delft, December 2009,
Guido van Heck

ACKNOWLEDGEMENTS

First, I would like to acknowledge my deep gratitude to my graduation committee:

Jan van den Berg as chair of the committee: it was again a pleasure working with you! Besides good feedback, some of the meetings also included a free lecture: you talked with great enthusiasm about fuzzy logic, but also explained Popper's view on the world for instance. I enjoyed all our meetings: thanks for all the good advice and additional lectures!

Mohsen Davarynejad being my first supervisor kept me critical. Especially his critical questions forced me to give good explanations on the steps I took during my research. Although my research was totally different and Mohsen had less experience in the field of logistics, I noticed that he was very well able to help me and provide useful input: many thanks for that! I hope you learned something from supervising me too!

Ron van Duin was my second supervisor and I really appreciate that he could find some time in his busy schedule to help me with my thesis. Ron, as an expert in logistics, provided me with good help, towards where I could find relevant information or whom I should talk to. Also we had some very useful meetings about the methodologies to use and the direction of the thesis. Thanks for your (very) precious time!

Björn Roskott as an external supervisor helped me to keep on track and especially kept me motivated to do case studies! I experienced Björn as a professional person and a really good motivator. It has been a pleasure working with him on this project. Our weekly meetings (especially in the beginning) and his feedback during these meetings offered a critical contribution to my work and really helped to increase the quality of my work!

Next I wish to thank the logistics experts I consulted and which provided me with useful input for creating and validating my (frame)work: Jacqueline Rutten (KPMG, IT Advisory), Frederik Kooistra (KPMG, IT Advisory), Ramon Hoogewerf (KPMG, IT Advisory), Arjan Vreeke (KPMG, IT Advisory), Dennis van de Wiel (KPMG, IT Advisory) and last but certainly not least Walther Ploos van Amstel (TNO Mobiliteit en Logistiek).

I also would like to thank the organisations that supported me and provided me with information: first of all KPMG IT Advisory Den Haag which offered me a great place to work and an environment with friendly people and a good atmosphere. Additionally I very much thank the people at Hospital A and Hospital B for their cooperation, openness during the interviews and for providing me with information about their organisation.

Finally I would like to thank all my family and friends who supported me. I would especially like to thank my dad for asking dozens of annoying, but critical and useful questions about my work and the applicability of it. Furthermore I would like to thank my mum for keeping my dad of my back every once in a while. Particular thanks also go to the reviewers who evaluated (parts of) my work: Jessica Sun, Jouke Dessens and Luke Arnts.

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EXECUTIVE SUMMARY

Over the past decade, the Enterprise Systems (ES) industry has proven to be an enormous growth market. The broad adoption and enormous attention from the business world in ES is considered the most important development in the corporate use of information technology during the 1990s. The ES market has become significant. The last couple of years the attention paid to this phenomenon in literature is slowly increasing again as well.

Enterprise Resource Planning (ERP) is an example of a typical ES software application. ERP software packages aim to integrate and support as many information flows in organisations as possible. ERP typically integrates business processes with information technologies. ERP is strongly related to Business Intelligence (BI), because the gathering and centralised storage of data in order to create more business insight is a key characteristic of BI. Furthermore, most of the reporting that is done within ERP concerns BI. Because ERP covers a wide range of domains, it is chosen to focus on one specific domain: inventory management in this case. The expectations of ERP are generally quite high. Organising the internal logistics using ERP software is aimed at the improvement of processes and creates greater performances. However, where the exact benefits are and how it is possible to measure those is still quit unclear: a good BI tool is lacking. Although there is only limited insight into the actual benefits available, many large companies implemented ERP packages. The BI tools available in ERP which should provide insight into the improvements are not always used optimal. With the proper use of BI tools a lot more can be gained from the implemented ERP-systems. Currently the descriptions in literature on how to measure performance are generally too specific (e.g. focussing on single metrics only) or take a perspective that is too broad for inventory management (e.g. focussing on the whole supply chain). An effective BI-tool, applicable for measuring the performance of inventory management and which provides a good insight into the operational coherence of different factors, does not seem to be available in today's literature.

Due to the absence of an inventory management specific performance measurement evaluation tool, this research is conducted to acquire that knowledge. Still some interesting improvements can be made in this field. ERP claims to provide several improvements at this point and a good performance measurement tool would help to evaluate those statements.

GOAL

A good performance measurement tool is needed to provide a structured way to gain insight in inventory management's business processes by monitoring relevant metrics. Such a tool would also complement existing Business Intelligence literature. Here lies the challenge of this research and therefore the corresponding research goal was formulated as follows:

> *The research goal is to design a tool for assessing inventory management's performance.*

Besides the goal stated above, this research also entailed a first attempt to actually find quantitative proof for the possible improvements yielded by ERP.

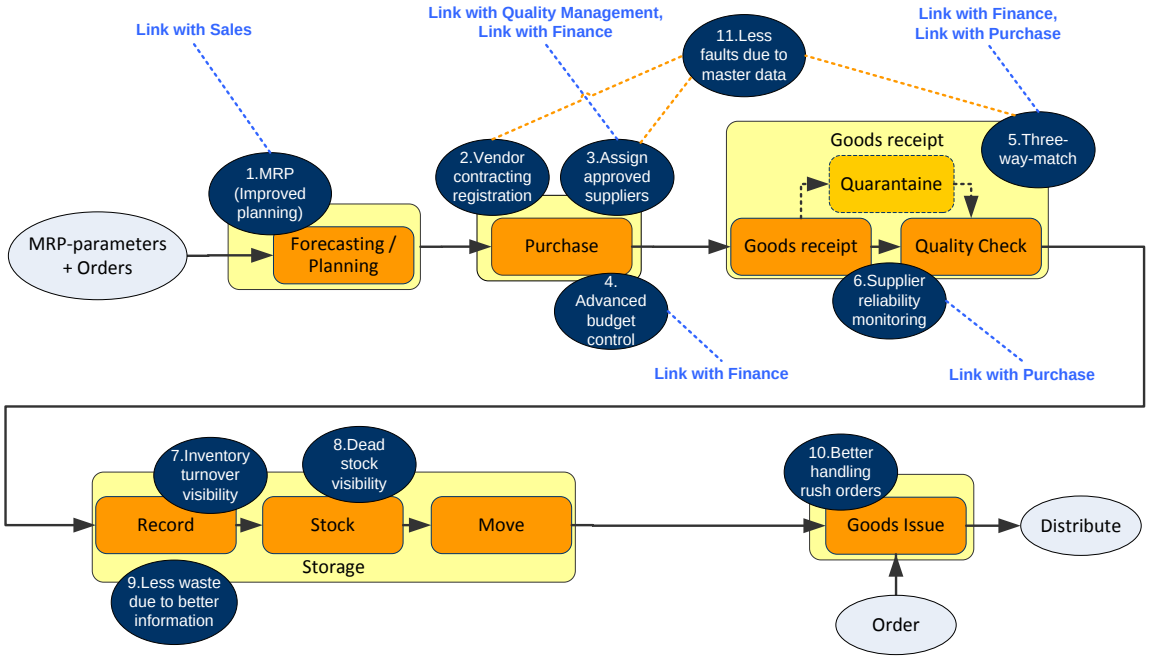
RESEARCH STEPS

To achieve the above goal, several research activities were performed subsequently. First the theoretical background was investigated and described based on literature. Within ERP, information is kept from an entire organisation: using business intelligence tools this information can be used to create advantageous insights in the operations of an organisation. Due to the centralised storage of data from all departments within an organisation, an integrated, real-time and centralised environment is created which makes faster, more accurate and more extensive business (intelligence) monitoring possible. Here lies the potential strength of ERP. ERP might be used to actively monitor inventories in order to make sure that the costs of keeping inventories do not become too high and the offered service levels are not becoming too low either. These two objectives form the two main goals of optimal inventory management. The main reason for keeping inventories is uncertainty: stocks create a buffer to cope with that. An inventory

management performance measurement tool could offer more insight into the source of these uncertainties and helps to improve this process. Furthermore performance measurement makes benchmarking between situations, and before and after changes, possible.

The theoretical background was followed by an analysis. To design a performance measurement tool, first a good analysis of the current situation and the information-need is necessary. The analysis focused on the mapping of the typical business process steps taking place within inventory management. The following five main processes were found:

Each process step was described in detail: within some of these steps, several activities took place again. Next the potential benefits provided by ERP where investigated and allocated to the above process steps. The figure below shows the entire inventory management process; with each identified potential ERP benefit, allocated to a specific process step:



The structured allocation of the potential benefits provided by ERP within the inventory process steps created hypotheses. In total eleven points of optimization offered by ERP were found. These benefits are actually potential benefits, because it still has to be proven that the identified benefits are actually achieved in reality; therefore these eleven potential benefits formed hypotheses. The hypotheses functioned as a test for the final performance measurement framework, because it shows how the model might be used.

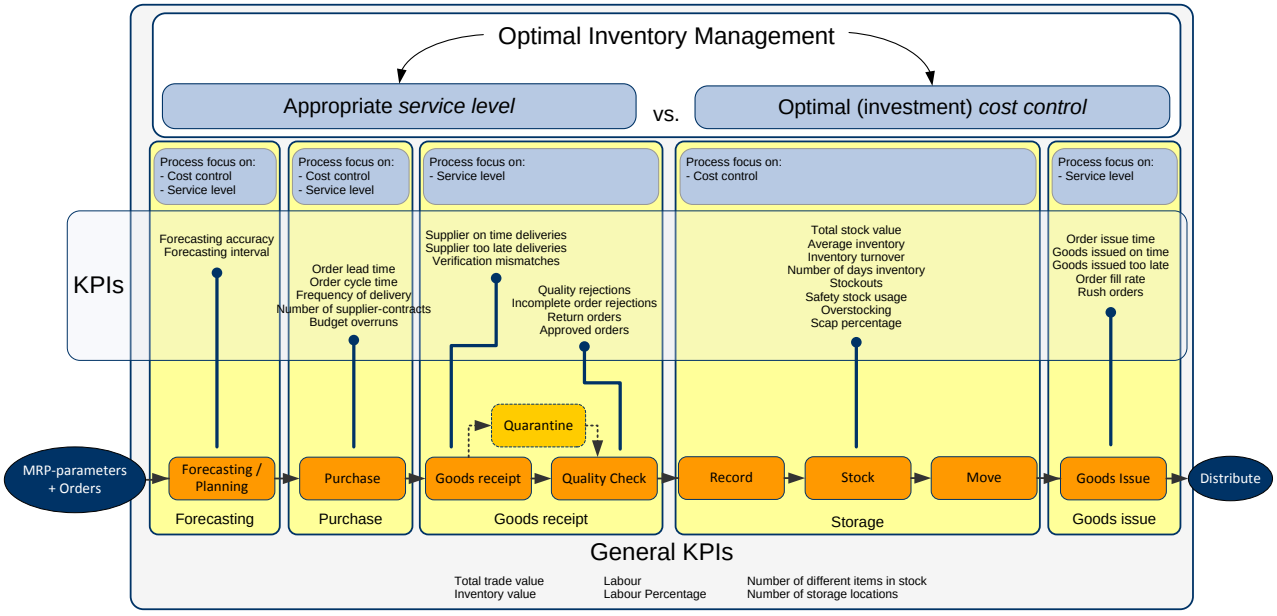
To evaluate the performance in each process step a specific method must be followed. What technique is best suitable for this application was therefore evaluated accordingly. Listing existing performance measurement techniques resulted into the following techniques:

- Key performance indicators
- Balanced scorecard
- Return on investment
- Net present value
- Critical success factors
- SCOR

From the above techniques, Key Performance Indicators (KPIs) are chosen as the most suitable measure to use, because other measurement techniques basically all rely on this method as well and with KPIs the designer can freely chose and categorize relevant metrics which is seen as an advantage. This freedom makes this technique suitable to create an own categorization which suits the process steps identified earlier.

THE FRAMEWORK

To construct a measurement tool (a framework), first a large number of different sources of literature were consulted to acquire a large set of KPIs, relevant for inventory management. This created a long-list of relevant KPIs. Next a selection was made, based on duplication and most popular KPIs, but also based on interviews with experts and the theoretical background described at the beginning. Finally the selected KPIs were mapped on one of the five process steps identified during the analysis. At the top of the framework the two goals of optimal inventory management are displayed. This is basically how the final inventory performance measurement framework is constructed. The final result looks as follows:



INVENTORY PERFORMANCE MEASUREMENT FRAMEWORK

To validate the designed framework, case studies were performed at two hospitals with different environments. An ERP and a non-ERP environment were chosen as cases to put the developed framework to the test with the hypotheses formulated during the analysis. This should create insight in the applicability of the framework and creating more insight in the impacts of ERP indirectly as well. Next to the case studies, three experts reflected on the KPIs used in the model and indicated for each metric how important it is to measure a specific KPI. This evaluation was added because the 33 KPIs present in the framework might be too much to implement all at once. Based on the importance assigned to each KPI by the three experts, a TOP-10 of most interesting KPIs to measure was constructed.

From the case studies it was concluded that it was not possible to validate all hypotheses due to a lack of data. Looking at the metrics, it seemed that the hospital with ERP however performed slightly better. Three (out of the eleven) hypotheses were not rejected:

- The forecasting accuracy seemed to be improved with ERP.
- With ERP there is better support for the registration supplier-contracts.
- ERP simplifies the three-way-match process.

Most differences between both hospitals were seen at the forecasting, purchase and goods receipt processes: at the hospital with ERP these process steps were automated compared to (mostly) manual operations in the non-ERP cases. These advantages are reflected in the number

of personnel, which is far less at the ERP hospital if it is compared to the amount of stock that has to be managed. The hospital with ERP was already in an advanced stage of arranging and automating their processes and therefore only a few recommendations were made to them. The most recommendations were reserved to the hospital without ERP: there was still room for several improvements.

It was also remarkable that both hospitals currently measured hardly anything on a regular basis. A recommendation towards both hospitals is therefore to perform periodic measurements of KPIs. It is strongly advised to at least measure the TOP-10 KPIs in order to gain more insight in their own process: this should be done periodically, ideally on a monthly basis.

Conclusions

The aim of this research was to develop a performance measurement tool for inventory management. As a result a unique framework is developed which enables organisations to measure their inventory management's performance. Contrary to existing literature the designed model provides a business process overview of inventory management and the relevant metrics. The structure provided by the framework gives organisations something to hold on to and prescribes them what to measure and how to measure it. Furthermore the framework is unique in its design, because different process steps are represented due to its span. This is a good aspect, as it makes sure that the accent is not on a single process or output only, but really serves the two goals of good inventory management.

Overall the framework provided a structured way to measure the performances in two cases and made an orderly comparison of the results possible. As a final conclusion it can be put that the strength of the developed model lies within the structured, holistic measurement approach which the framework represents. If the full framework is too much to implement at once, it is strongly recommended to measure at least the TOP-10 KPIs. Off course, if it is possible one should measure all the metrics present in the framework to gain the best insight in inventory management processes.

Generalization of the results

In this research the framework was applied to hospitals, however the framework can be applied to other industries as well, because at other organisations the same main basic processes take place within inventory management. The framework represents inventory management process steps which are quit generic and not very detailed, which creates the possibility to apply the framework to various types of industries or organisations.

A second interesting opportunity for the framework lies with its possibility to test other technologies as well. In this research the framework is used to validate hypotheses concerning the improvements caused by ERP. Yet it is considered possible to use the framework for studying the effects on inventory management caused by other technologies as well. Additionally in this research the framework is used to compare two organisations, but an opportunity for applying the framework would also be to analyse changes over time.

Further Research

The framework offers several opportunities, but unfortunately limitations should be remarked as well. First of all, the framework is developed based on various kinds of literature and expert interviews. The list of KPIs that was comprised is not exhaustive. It is however very hard and probably even an impossible job, to create a framework that is complete towards all situations and scenarios. More research in other industries and with other technologies is therefore advised to validate the completeness and applicability of the framework even further. Further research is also recommended to test the hypotheses towards ERP even more. Finally further research on aggregating the operational KPIs presented in the framework could be conducted. Such a research could create a higher level 'above' the current KPIs, which is interesting for top management for instance and provides an even quicker insight in the performances of the inventory management process.

1 INTRODUCTION

"Enterprise systems appear to be a dream come true" – Thomas H. Davenport

Over the past decades the there were huge developments in the field of information systems. The broad adoption and enormous attention from the business world in Enterprise Systems (ES) is considered the most important development in the corporate use of information technology during the 1990s (Davenport, 1998), (Gable, 1998), (Kumar & Hillegersberg, 2000). The ES market has become significant (Klaus et al., 2000), (Umble et al., 2003) and the last four years the attention paid to this market in literature is again increasing slowly as well (Pairat & Jungthirapanich, 2005).

Enterprise Resource Planning (ERP) is an example of a typical ES software application. ERP software, which is commercially available, aims to integrate and support all information flows in organisations. An ERP application typically integrates business processes with information technologies (Wier et al., 2007). One ERP application is (in theory) able to replace dozens of legacy systems which cost a lot to maintain because of the different expertise required. For managers who have to deal with numerous legacy information systems and duplicate, incompatible information, these standardised ERP software package solutions could provide the perfect solution to their problems if these promises are indeed met (Umble et al., 2003). SAP, Oracle and Microsoft are the three biggest vendors of ERP software. They offer various software-packages that support many different business activities ranging from operations & logistics to sales & marketing, to financials and human resource management for example (Davenport, 1998), (Umble et al., 2003). ERP is strongly related to Business Intelligence (BI), because the gathering and centralised storage of data in order to create more business insight is a key characteristic of BI. Furthermore, most of the reporting that is done within ERP concerns BI.

Due to the wide range of possibilities and the well-presented promises made by vendors, expectations of ERP packages are high. The promise of a standardised (off-the-shelf) solution to business integration problems seems very tempting (Davenport, 1998). Organising production and (internal) logistics using ERP software is supposed to improve processes and create greater performances as previously mentioned. Mainly large enterprises invested heavily in ERP advice, software and implementation processes over the past decade. These investments were done for several reasons; one of them being the optimization of internal logistic processes. More often, small and medium sized enterprises also started to embrace and implement ERP applications (Klaus et al., 2000), (Everdingen et al., 2000). This indicates that the ERP-market is still growing. The reasons for implementing ERP are not always quite obvious. Most companies mainly implemented an ERP package because their competition was doing so. In some industries ERP has even become the standard: for example SAP has set the standard in Oil and Gas and Baan in Aerospace (Akkermans et al., 2003). The BI tools available in ERP are not always used optimal and still a lot of improvements can be made at this point to gain even more from ERP-systems (Gunasekaran et al., 2001).

1.1 PROBLEM STATEMENT

Although the prospects of ERP look promising, implementing an ERP application and setting up a good BI-tool to extract the useful and relevant information, for monitoring and managing operations, is not a simple task. This usually takes several years and requires large funds (Beheshti, 2006). Additionally in most cases the business processes will have to be redesigned and even cultural changes in the enterprise are mostly unavoidable (Umble et al., 2003). The investments required to implement an ES are typically expressed in millions of dollars (Davenport, 1998). The Meta Group analysed costs and implementation times among 62 companies. They concluded that an ERP implementation process on average takes 23 months and costs about 10.6 million dollars. This enormous spending has to be earned back. Strangely enough most enterprises did not make any proper return on investment (ROI) calculations beforehand (Umble et al., 2003). Also often no ERP success evaluation is done afterwards at all, because for instance it is still vague how this can be done and measured (Ifinedo, 2008) For most

companies ERP investments were mostly a strategic choice; no proper business cases were worked out because benefits were presumed to be seen over a much longer period (Klundert, 2003). Much data is stored, but this valuable source of information is often only used to a very limited extend. Most enterprises only started looking into the benefits after implementation (Stein, 1999). Still a lot can be gained by introducing effective BI-tools.

In literature much is written about implementation processes and teaching of ERP as Klaus et al. (2000) indicate after extensively analyzing literature. It is mostly agreed upon that ERP applications do provide significant benefits in organising internal (and external) processes due to its integrated nature. Most benefits gained through ERP are however difficult to measure and only a limited number of researches focused on expressing the benefits gained with ERP in numbers (Klaus et al., 2000), (Hunton et al., 2003). The benefits gained from ERP systems are thus still quite unclear: mostly it is only assumed that costs will be reduced (Ploos van Amstel, 2008), production times shortened, stock levels lowered and the customers' satisfaction improved for example, but no quantified proof is available. Quantifiable proof can be very interesting, because it creates a more tangible view on the assumed benefits and makes it possible to assess the scale of the impact caused by ERP, which is harder to predict using qualitative research. A quantitative method to measure performances therefore has to be developed first in order to see where the advantages of ERP actually are.

A good performance measurement tool on itself would greatly complement existing Business Intelligence literature by providing a structured way to gain insight in business processes. Currently within literature mostly only a limited set of metrics relevant for inventory management are mentioned, see for instance (Hendricks et al., 2007), (Kleijnen & Smits, 2003), (Gunasekaran et al., 2001), (Fawcett et al., 2007), (Lee & Billington, 1992). The Balanced Score Card (BSC) (Kaplan & Norton, 1992) is sometimes used in practice to create a business intelligence tool for monitoring different aspects of inventory management. In literature however no clear prescription or guide to determine which metrics should be included in the BSC are available. Besides the BSC, only limited attempts are made to structure performance measurement of inventories. The Supply Chain Council developed a supply chain, performance measurement reference framework (SCC, 2006) which provides some ideas about what to measure. Their framework typically takes a very high perspective and is not suitable for inventory management. Furthermore some attempts have been made to structure the measurement of performance in terms of different levels, see Gunasekaran et al. (2001) for instance. They made an attempt to structure performance metrics into three levels: strategic, tactical and operational. None of the above literature however provides a good overview of the coherence between different performance metric and it seems that a BI-tool through which this insight can be gained is not available.

There is still room left to develop a performance measurement tool that explains the coherence between activities within inventory management, but again does not take a too broad perspective (i.e. looking at the whole supply chain again). Especially on the operational level this is very useful and there lies the challenge of this research. The aim of this research is also to take the first steps towards a good way of benchmarking the performance of ERP (on an operational level), with the focus on a specific domain: inventory management. The next section elaborates on this scope in more detail.

1.2 Scope and Perspective

The introduction provided a general background and broadly indicated the issues at hand; this section further narrows down the focus of this research, which finally leads to the main research question in the next paragraph.

ERP packages operate in a wide range of different fields. ERP software consists of different modules; especially the modules to support the supply chain have become popular over the past several years. This is due to the fact that the interest and attention paid to Supply Chain Management (SCM) has grown rapidly as well (Akkermans et al., 2003), (Gunasekaran et al., 2001). Most companies have first reduced their manufacturing costs as much as practically

possible, and they are now looking for other means to reduce their costs (Simchi-Levi et al., 2003). One way of doing this is by effectively planning and managing the supply chain (both internal and external). Wal-Mart is a successful example which showed that good SCM can provide huge benefits[1]. Because of the gains that can be made in SCM, especially when using ERP as the ERP-vendors claim, this will form the scope of this research: to provide more insight onto those gains.

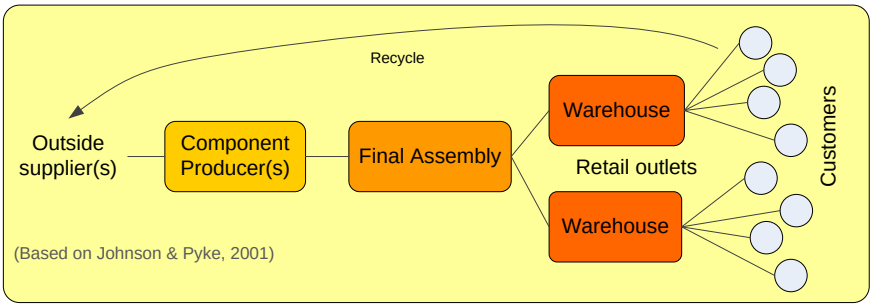


FIGURE 1 A SCHEMATIC OF A SUPPLY CHAIN

Figure 1 provides a schematic overview of an entire supply chain. As can be seen the supply chain reaches very far and therefore SCM incorporates a wide range of activities. Amongst others, inventory management, manufacturing, operations management and logistic processes and planning all fall within range of SCM. ERP packages originated from the automation of manufacturing, planning and controlling processes. Manufacturing can therefore often be seen as a core module of ERP packages, around which other activities are concentrated. Currently, most ERP packages on the market evolved from one core functionality to other business areas as well later on. SAP is a good example hereof, which started off as a materials requirements planning (MRP) solution and later incorporated other activities as well, such as finance and human resource management for example. ERP-vendors claim that their ERP-packages are able to support activities along the whole supply chain. In terms of information management and Business Intelligence, ERP packages aim to support the information management part. By providing intelligent business information additional efficiency and effectiveness should be reached. ERP vendors also claim that their packages are not only able to support activities, but are also capable of achieving additional benefits as mentioned earlier. However where the exact benefits are and how it is possible to measure that is still vague (Ifinedo, 2008): a good BI tool is lacking. This research takes up the challenge to create a tool that can measure performance, which additionally enables the validation of the claimed benefits provided by ERP packages.

As Figure 1 shows, SCM stretches out from suppliers to clients with a lot of operations in between, and is therefore a very large research field. Researching the performance of the whole supply chain will be too comprehensive for this research project. For this reason the focus is on a small part of SCM: inventory management. Further argumentation about this focus is provided in chapter three. Figure 2 provides an enlarged view on a typical process taking place at the final assembly (i.e. a manufacturing firm). This is just one prototypical manufacturing process, others exist as well which will be discussed in chapter three. This picture however provides a quick overview of where inventories are kept during the manufacturing process. Typically several different inventories exist: raw materials, finished products and work in process. As Figure 2 shows, storage of raw materials and finished goods take place at the beginning and the end of manufacturing. During the production semi-finished products have to be stored occasionally as well, those are called work in process inventories. This research focuses only on inventory management of raw materials, which are located at the beginning of the production process.

[1] Wal-Mart for example applies vendor managed inventory and an innovative logistics strategy called 'crossdocking'.

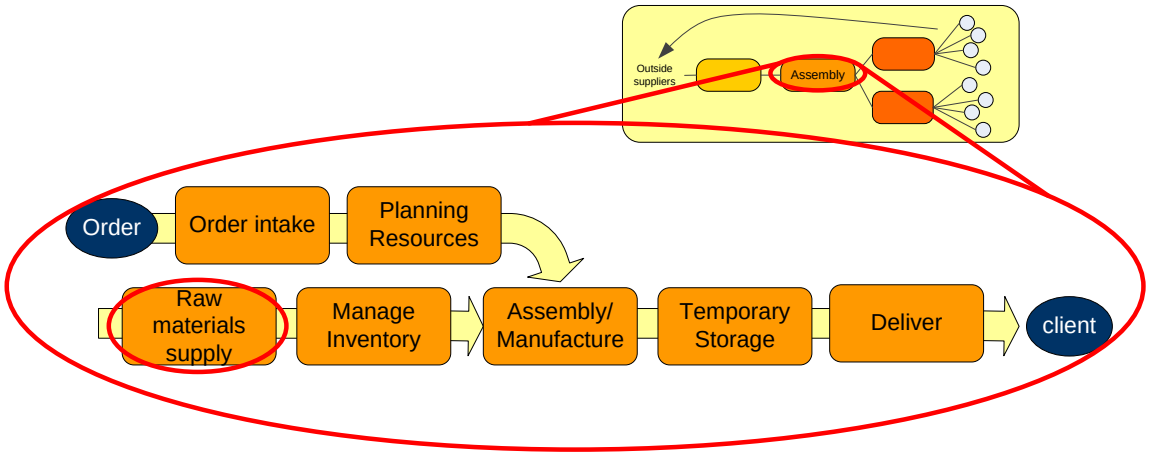


FIGURE 2 DETAILED VIEW ON FINAL ASSEMBLY

More often the focus in SCM is shifting from the competitive advantage of one single firm (e.g. an assembly firm) to the competitive advantage of an entire supply chain (including component producers, assemblers and warehouses for example) (Kumar, 2001), (Kelle & Akbulut, 2005). Because logistics processes are being viewed as a whole supply chain, system integration and information sharing become more and more important. Following this trend, ERP also aims to support these developments and is currently evolving towards 'extended ERP' (e-ERP) and supply chain systems integration. e-ERP is a trend in literature that has attracted increased attention lately. e-ERP is not the topic of this research for explicit reasons described in chapter two. As the introduction mentioned, it is mostly agreed that ERP software to support SCM provides benefits. Nevertheless, measuring the impact of ERP software on logistics is still difficult and limited research is performed in this area (Ifinedo, 2008). As Krauth et al. (2005) mention the supply chain performance can be measured using internal or inter-organisational performance measures. The focus of this research will take an internal perspective, looking at the benefits realised in inventory management due to an ERP implementation. This 'internal perspective' refers to benefits gained in one company, internally, only. As mentioned several times before, the focus of this research is aimed at the benefits only. Listing the cost-structure and determining what costs are associated to inventory management of raw materials is a whole different research that is not included in this research.

There are many different ERP packages on the market. Assumed benefits of ERP might therefore vary for different packages. Due to time constraints it will not be possible to look into all ERP packages. Only SAP software is considered in this research, for two reasons. The first reason is that SAP claims to be market leader, which makes it more interesting to investigate specifically this software because there are many users to which the results of this research will eventually apply (Das, 2006). Secondly SAP will be considered due to the comprehensive experience and knowledge at hand about this software. Measuring the performance of inventory management however should not be software dependent. The choice made for SAP therefore should have no effects on hypotheses and examples used.

1.3 RESEARCH QUESTIONS

Based on the introduction, problem statement and scope described above, the central research question is derived. This section deals with the formulation of the central research question and sub-questions.

1.3.1 RESEARCH GOAL

The goal of this research project is formulated as follows:

> *The research goal is to design a tool for assessing inventory management's performance.*

The main target is thus to develop a performance measurement tool, aimed at providing insight in the coherence of activities on an operational level. Because performance measurement is strongly related to the business intelligence activities performed by ERP, ERP is described throughout the report as well. ERP is used for business process analysis and to test the final design on the applicability of hypothesis-testing towards a certain technology.

In order to reach this goal, several smaller activities which finally should lead to achieving this goal are identified. In the next section, questions are formulated to support these smaller activities. All the subsequent small activities finally lead to a *Framework to assess Inventory Management's Performance*.

1.3.2 Sub-questions

This research contains six research steps. Figure 3 provides a simplified overview of the phases this research contains. The different phases are thereupon described shortly, together with the corresponding sub questions.

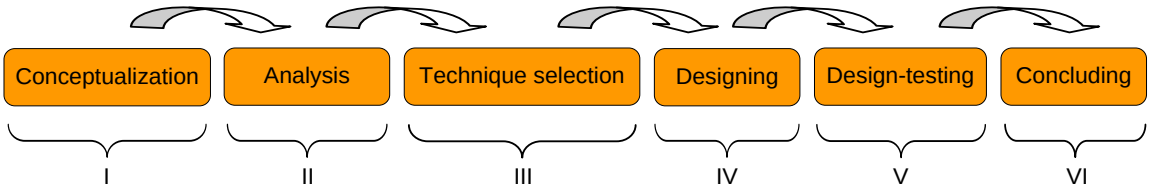


Figure 3 Research Activities

Part I. Conceptualization

The conceptualization phase will describe the background, which sets the context and focus of this research in more detail. The two main aspects of this research, ERP and Inventory management, are described first; therefore the following questions need to be answered:

- How can Enterprise Resource Planning be defined?
- What is inventory management?
- What does inventory management all comprise?

Part II. Analysis

An analysis is conducted in Part II. In order to be able to measure the performance of ERP it is necessary to analyse the situation first. As a consequence the activities taking place at inventory management need to be analysed to create an overview of the business processes. This information and the knowledge gathered during the conceptualization phase can be combined to identify where ERP offers possible improvements to the inventory management process: these assumptions form hypotheses, which are tested later (see part V). The questions to be answered in this part are as follows:

- What typical business processes take place within inventory management?
- How can ERP provide benefit to inventory management processes?

Part III. Technique selection

Having the background, focus and potential benefits defined, a literature study is conducted regarding available performance measurement techniques. This is done, because in order to test the hypotheses a method has to be found first to make performance measurement possible. One technique should be selected that is used to evaluate the effects of ERP on inventory management. The questions to be answered in this part are:

- Which performance measurement techniques are available?
- What technique is most suitable to measure performance in this case?
- How can this technique be applied in this case?

PART IV. DESIGNING

With the most suitable measurement technique defined, a tool is developed accordingly. This tool forms a descriptive guide to measure performances between situations and to make sure that information is gathered and compared in the same way in different cases.

- How should the performance of inventory management be measured and evaluated using the selected technique?

PART V. DESIGN-TESTING

In Part V the designed tool is applied and tested in two individual cases, to see whether we can say something about the hypotheses and about the applicability of the model. The way to measure and gather data is dictated by the tool, which will therefore be strictly followed. Expert judgments are a second means to see if the tool is complete and correct. The questions corresponding to this section are:

- What is measured when applying the model to test cases?
- To what extend is the model applicable in practise?
- How do experts judge the model?

Finally there is reflected on the hypothesis (formulated earlier in part II). The corresponding question to be answered is as follows:

- What can we say about the performances between an ERP- and a non-ERP-environment?

PART VI. CONCLUDING

In the final part of this research, reflection is done on the found results and the research process. The results are put in context and it is discussed what the found results implicate and how the results can be applied to other cases or situations as well. The corresponding sub-questions discussed in this final section are:

- How suitable is the developed model for measuring performances and comparing results?
- How did the ERP-case perform compared to the non-ERP case?
- What can be recommended about the use of the designed model?
- Under what conditions do the findings apply?
- Can the model be applied to other areas as well?

1.4 RELEVANCE

The introduction indicated that although most researchers and users agree that ERP packages provide several benefits, there is still limited (numerical) proof that indicates the scale of these benefits. ERP performance measurement literature is just starting to appear (Ifinedo, 2008). The ES success evaluations area is very diverse and often hard to apply in practise. Furthermore organisations often do not exactly know what to measure in order to evaluate the performance of their ERP implementation (Ifinedo, 2008). Much more is written on implementation and teaching of ERP (Klaus et al., 2000). Akkermans et al. (2003) also state that “in fact, one can argue that very little academic research has been done on ERP, except for research on reasons for implementation and on the challenges of the implementation project itself”. Accordingly they proceed with “Yet, in spite of the explosive growth of the ERP ecosystem, very little academic research has been done on the business impacts of ERP systems once they are implemented”.

This research complements current academic research in the field of Inventory Management and Performance Measurement, which forms the first step towards evaluation of ERP’s benefits for instance, but maybe other technologies as well. Furthermore, considering the high costs generally involved with the implementation of ERP, it is very relevant to known what the (financial) benefits or improvements gained through an ERP implementation exactly are. Especially for organisations considering an ERP implementation, this research could be of great relevance. Knowing how to measure performance creates more insight and makes benchmarking possible. A good performance measurement tool can finally prove to what extend ERP provides benefits, which helps to create a viable business case for other organisations that have yet to

decide, as well. The possible optimization and cost-savings from implementing ERP software can accordingly better be predicted, which also provides organisations with more certainty.

1.5 Research Approach

Section 1.3 described in detail how the research is performed. During the various steps, different techniques are used which are described in this section shortly.

A combination of research techniques is used. Study of literature, interviews with experts and case studies are the main research methodologies used. Part I is performed using literature and interviews. Part II is mainly based on interviews and for a small part on literature as well. Part III is performed using literature only; various sources of literature are consulted to come to a unified selection of metrics (data triangulation is used in this case (Denzin, 1978)). Accordingly, Part IV is a combination of previous sections; part of the construction of the performance measurement tool is done using literature as well.

Part V contains case studies to test the design in practise. During the case studies experts in the field are interviewed. Interviews were performed with purchasers and logistics managers (for a complete overview of all interviews conducted, see Appendix A). Interview-reports were sent back for validation and feedback (data triangulation (Denzin, 1978)). Based on the interviews, business processes are mapped and metrics are measured. Pattern matching is applied to the business process mappings to illustrate the differences between the two cases. Pattern matching is a core methodology applicable to theory-testing with cases (Yin, 1994). The first step in pattern matching is to develop a framework around which the case studies are accordingly organised (Tellis, 1997). This corresponds with the design that will be made in chapter six. Pattern matching consists of matching an *observed pattern* (the case study in this case) with an *expected pattern* (the framework in this case), and deciding whether the patterns match with each other or not (Yin, 1994), (Hak & Dul, 2009). In this case the process steps will be compared to the model and to each other. The cases will be used to see whether the design matches with practice.

Additionally logistics experts are consulted to assess the importance (i.e. applicability) of the different elements in the model. Logically Part VI, being the final part, does not use any methodology because the research is concluded in this section and no new information is required at this point.

1.6 Structure

The structure of this research is as follows. As part of the theoretical background, ERP-business intelligence technology is first described in chapter two. This is followed by Inventory Logistics in chapter three: chapter three mainly elaborates on inventory management and for a small part on SCM. Accordingly in chapter four an in-depth analysis is performed of inventory management and the linkage with ERP is described. Based on this linkage, several hypotheses are formulated about the potential benefits offered by ERP. Chapter five thereupon describes various performance-measurement techniques. In this chapter also one specific method is selected and described in more detail. The selected method is subsequently used to design a conceptual framework in chapter six. The framework is tested in practise, using case studies: this is comprehensively described in chapter seven. Chapter seven is followed by a reflection in chapter eight. Finally conclusions are drawn in chapter nine. Thereafter, the Appendices follow. The coherence between different chapters, their relation to each research activity and the research methods used in the research are shown in Figure 4 on the next page.

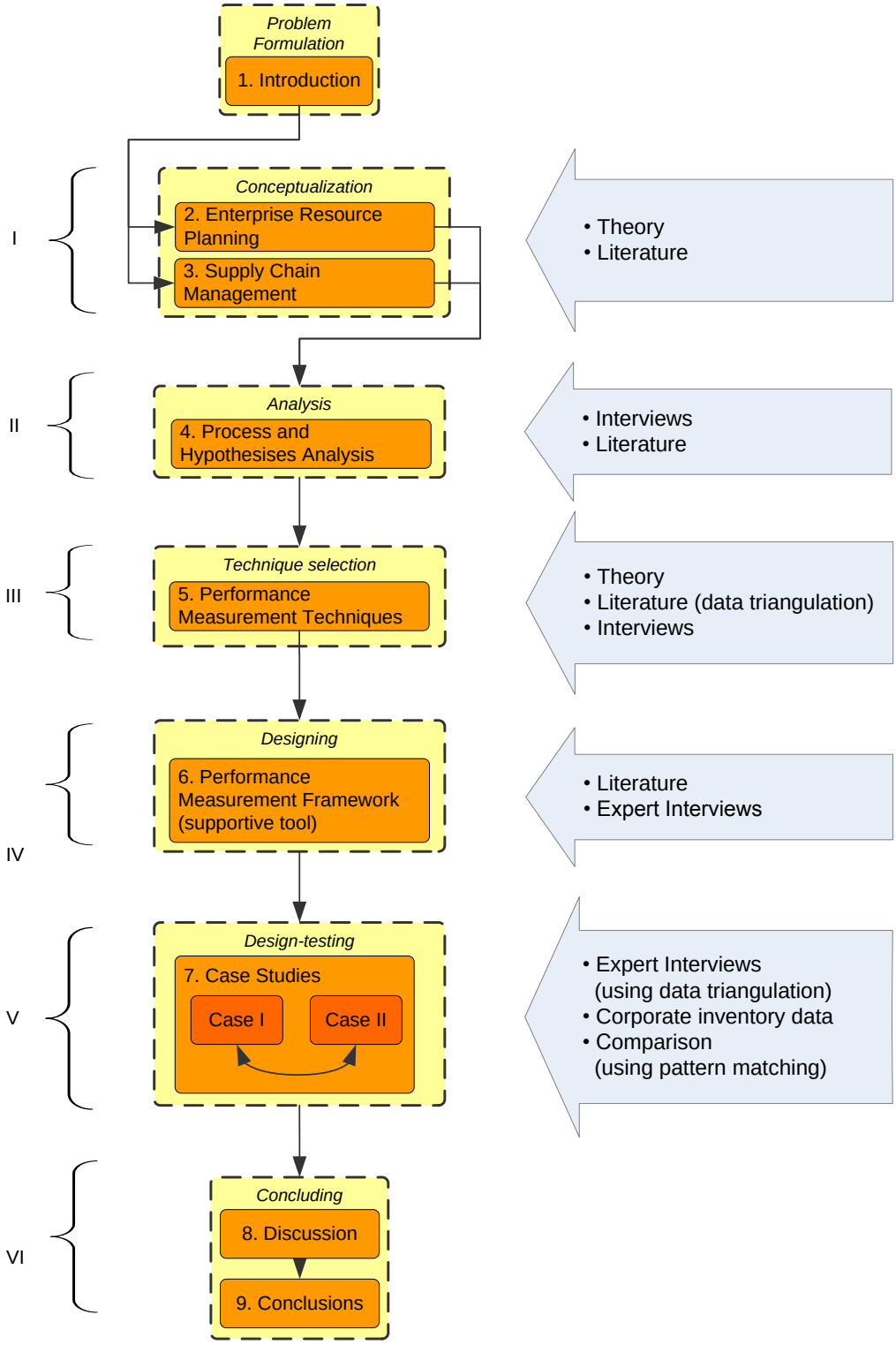


FIGURE 4 REPORT STRUCTURE

PART I. CONCEPTUALIZATION

2 BUSINESS INFORMATION

"For many users, an ERP is a 'do it all' system that performs everything from entry of sales orders to customer service" – A. Gupta

Business information is of great importance to make the right decisions within an organisation (Watson & Wixom, 2007). Data collection is therefore important as well, because more data might help to make a better decision if it is put to the right use. Performance evaluation is usually based on collected data as well: performance metrics represent a visual summary of large amounts of data (Watson & Wixom, 2007). In order to monitor the performance correctly, a tool needs to be in place which collects business information first. This is exactly where Enterprise Systems can be very helpful. Applications, such as Enterprise Resource Planning (ERP) software for instance, collect data from all sources within an organisation and store that information at a central location. From this central location data can be retrieved and using Business Intelligence methods the right information can be extracted to monitor the performance for instance.

Because ERP is strongly related to the field of Business Intelligence and performance measurement, this technology is described in detail first. Due to its holistic approach towards business processes within an organisation the description of this technology supports the identification of typical inventory management business process, required later on, as well. In the end hypotheses concerning ERP are formulated as a way to see how the performance measurement tool functions, and therefore the background of ERP needs to be described first as well. Hypotheses concerning other technologies might have been chosen also, however due to the significance of the ERP market it is interesting to take this technology as an example. The introduction already mentioned the significance of this ERP-market; in 1997 for example, $10 billion was spent on the purchase of Enterprise Resource Planning systems (Umble et al., 2003). In 2002 the ES market grew about twice as big, to about $20 billion (Klaus et al., 2000). Annual growth rates around thirty percent were seen (Umble et al., 2003). These numbers clearly illustrate the rapid growth and significant size of the ES market and are important reasons to focus on this market. The following sections will further elaborate on ERP to create a better understanding of this technology.

2.1 ENTERPRISE RESOURCE PLANNING

ERP is an Enterprise System. Several other applications are often considered to fall within the range of ES as well, including Supply Chain Management (SCM), Customer Relationship Management (CRM) systems and financial systems across different departments as well (Hendricks et al., 2007). ES applications aim to streamline processes, the information that comes with those processes and finally the monitoring (performance evaluation) of business processes.

Typical several different terms have come up for ERP during the years of its existence. Basically Enterprise Resource Planning, Enterprise Wide Systems, Integrated Vendor Solutions, Integrated Software and Enterprise Application Systems are all synonyms referring to the same (Sedera et al., 2001); however Enterprise Resource Planning (ERP) is most widely used. Some authors even advise against the use of the term ERP, while other see it as term referring to a range of similar products (Klaus et al., 2000). A broadly agreed upon definition has not been defined (Klaus et al., 2000). In this research the following definition will be adopted:

"ENTERPRISE RESOURCE PLANNING SYSTEMS ARE CONFIGURABLE INFORMATION SYSTEMS PACKAGES THAT INTEGRATE INFORMATION AND INFORMATION-BASED PROCESSES WITHIN AND ACROSS FUNCTIONAL AREAS IN AN ORGANISATION. THE CURRENT GENERATION OF ERP SYSTEMS ALSO PROVIDES REFERENCE MODELS OR PROCESS TEMPLATES THAT CLAIM TO EMBODY THE CURRENT BEST BUSINESS PRACTICES" (KUMAR & HILLEGERSBERG, 2000)

This definition is still very broad, therefore the following sections will clarify the different aspects in more detail, providing a richer picture of ERP.

2.1.1 APPLICATION

ERP packages are complex and comprehensive software solutions, incorporating a wide range of business activities. The concept that distinguishes ERP from other software packages is its aim to totally integrate all different business activities taking place within (public and private) organisations (Beheshti, 2006). ERP software is standard software, which means that it is generic and can be used by various different types of businesses across different industries. ERP uses the concept of a totally integrated enterprise solution, across all parts of the enterprise. An integrated solution means that all business activities are integrated in one software solution: information does not have to be inserted and exchanged manually between different departments. From a sales order, almost automatically an invoice can be created for example. The information is also visible in real-time in ERP; if for example the invoice is paid by the client, the audit reports are immediately updated as well.

The biggest ERP vendors are SAP, Oracle and Microsoft. Most ERP packages evolved from one speciality to various other business activities. ERP software offered by SAP for example, originated from manufacturing i.e. from the need to efficiently plan the materials required for production (Klaus et al., 2000). This software evolved and started to incorporate new functionality like sales planning, capacity management and scheduling. Finally the functions of these systems were further extended beyond manufacturing, and encompassed finance, sales, distribution, and human resources as well.

Originally, ERP was most often used for the operational management of manufacturing companies only (Murray, 2006). Currently however, municipalities, health care providers and financial institutions (e.g. banks and insurance companies) use ERP packages as well. Whereas mostly only large organisations and enterprises used to implement ERP, small and medium sized enterprises (SME) are starting to catch up (Klaus et al., 2000), (Everdingen et al., 2000). More and more SME see the potential benefits of implementing ERP. ERP vendors follow this trend by taking up the challenge to offer their packages to these smaller companies as well.

As mentioned before ERP is able to support all most every business activity. SAP R/3, offered by SAP, for example has Financial, Logistic, Supply Chain and Human Resource modules very tightly integrated. SAP offers the following (major) modules within their current SAP R/3 software package (Davenport, 1998), (Murray, 2006), (Umble et al., 2003):

TABLE 1 SAP MODULES

Module Name	Abbreviation
Sales and Distribution	SD
Materials Management	MM
Production Planning	PP
Quality Management	QM
Plant Maintenance	PM
Human Resources	HR
Workflow	WF
Project Systems	PS
Asset Management	AM
Controlling	CO
Financial Accounting	FI
Industry Solutions	IS (tailored package)

FIGURE 5 SAP MODULES
BASED ON A FIGURE BY (THINK IT SOLUTIONS, 2009)

Additional modules to this list also exist, like a warehouse management (WMT) module for example. The IS module (Industry Solution) presented at the bottom of this list is not a 'standard' module like the others. The IS-module is actually more than just a module. IS are tailored solutions for different industries: a modification of the standard SAP software to fit a specific industry. An IS contains a preformatted template that will cover all modules and offers additional functionalities that are specifically required for a certain industry due to its unique

characteristics. SAP for example also offers software to medical organisations, i.e. hospitals, were they use an electronic medical record for their patients. Medical records are out of the ordinary and thus offered in an industry solution, including a template that makes it possible to handle this type of environment.

SAP R/3 was released by SAP AG, a German company, in 1979. SAP R/3 is the successor of SAP R/2. SAP R/3 is used to run the business processes of medium to large corporations. MM, SD, PP, QM, WM, PM are key logistics modules which are widely used by industries. These modules are so vast and so deep that they have been further divided into sub modules (Garlapati, 2009). SAP is considered market and technology leader in client/server ERP software (Murray, 2006). Following this SAP-example, the following illustrative story describing a manufacturing company will show the use of different modules and their coherence: the used modules are stated between brackets.

Suppose an order is being sold in the sales department (SD), the next thing to do is calculate and plan the needed materials (PP and MM are used). Because the sales department already entered the information from the client, this data can directly be used to schedule and plan the required material and resources. Some materials that are (nearly) out of stock will have to be ordered. When the supplier delivers the goods a quality inspection takes place by quality management (QM). When the quality and quantity are in order the goods will be added to the stock. Additionally the received goods have to be paid for to the supplier by the finance department (FI). Subsequently the delivered goods will lie in a warehouse for a certain period of time, waiting to be used during the production process. All parts lying in the warehouse will of course have to be managed (WM). Finally the goods are required for a production order in production planning (PP) or be part of a larger project defined in project system (PS). When manufacturing is complete the finished goods have to be distributed to the customer (SD is again used). Finally a bill has to be sent and the product has to be paid for: again finance (FI) is used to support this task. Finance uses the information entered by the sales department to create invoices.

ERP packages store and manage the information that is needed to coordinate, among other things, the activities described above. As shortly mentioned in the example, ERP especially stimulates information sharing between departments and during different business activities. The strong integration of different departments is a unique aspect of ERP packages. In theory, ERP is thus applicable to various organisations and able to support a wide range of different activities as we have seen.

2.1.2 History

As mentioned in the previous section, the history of ERP lies with the planning of required materials. In the early 1960's when mass production of goods consisting of many parts (e.g. cars, televisions, etc.) emerged very quickly, the need to calculate the required materials also increased (Klundert, 2003). This need was also initiated because due to the increased number of parts also large quantities of inventory had to be maintained. So called Material Requirements Planning (MRP) systems helped to reduce the amount of inventory. MRP represented a huge step forward in the materials planning process (Umble et al., 2003). For the first time, MRP systems made it possible to let a computer calculate gross material requirements. Using the accurate inventory record files, the available quantity of on-hand or scheduled-to-arrive materials could in MRP simply be used to determine net material requirements. MRP were the first 'standard' business applications available (Klaus et al., 2000).

In manufacturing, controlling materials and inventory is just one problem; scheduling capacity forms the same challenge. In response these capabilities were also added to MRP. Tools were developed to support planning of aggregate sales and production levels, forecasting and (among other things) customer-order promising (Umble et al., 2003). During the 1970s MRP systems were extended with further capabilities in order to offer complete support for the whole process of production planning and control cycle (Klaus et al., 2000). Material Requirements Planning finally evolved into Manufacturing Resource Planning, also called MRP II. MRP II encompassed new functionality like sales planning, capacity management and scheduling. Unlike MRP which

mainly only planned material, MRP II could also plan other resources (machine capacity and personnel for example). In the 1980's MRP II systems started to incorporate financial management systems as well (Umble et al., 2003). Finally human resource management capabilities where added. The shortcomings of MRP II and the need to integrate even more (new) techniques led to development of a totally integrated solution called enterprise(-wide) resource planning (ERP) (Gupta, 2000). Enterprise Resource Planning is the final combination of MRP and MRP II.

2.1.3 Recent Developments

A recent development seen more often in literature the past decade is the rise of extended ERP, also referred to as ERP II or e-ERP. ERP traditionally looks into internal processes, whereas ERP II also looks further and uses the Internet. ERP II enables organisations to connect their internal business processes with the (external) systems of their customers and suppliers (Beheshti, 2006). ERP II aims to integrate internet-technology within ERP software in order to enable the exchange of information more easily, for example to coordinate the supply chain between different actors. The future of ERP II clearly includes a perspective in which companies, customers and vendors are all linked electronically (Weston Jr., 2003). Actually ERP II is often seen as a combination of ERP + SCM + e-Business (Pairat & Jungthirapanich, 2005). Although literature presents this phenomenon as something totally new, EDI (Electronic Data Interchange)[2] already exists for a while and is a means to exchange electronic information and can thus be seen as a first version of extended ERP as well.

The next step for organisations, who initially improved internal processes using ERP, is to examine the possibilities the Internet might offer (Búrca et al., 2005). In the supply chain (discussed in the next chapter) information sharing plays an important role and therefore ERP II might offer a good tool to support operations across the supply chain. Information sharing could successfully solve the problem of the bullwhip effect[3]; however there are still several problems which currently stand in the way of ERP II to become a success. The focus of this research is on ERP used in a single organisation only, for several reasons explained below. Inventory management within one firm on itself is already a complicated process; looking further and combining all inventories across the whole supply chain would make research much more complicated. There are several more reasons to focus on ERP only (and not look any further into ERP II) which the next paragraphs will elaborate upon.

Firstly most organisations are still struggling with their internal operations. For organisations to take full advantage of electronic exchange of information across the supply chain, they must ensure that their own ERP systems are implemented efficiently beforehand. If this is not achieved and their ERP systems are not functioning properly, information sharing will only create up- and downstream problems at 'internet speed' (Búrca et al., 2005). Furthermore a huge challenge organisations face when implementing ERP II is the partnership challenge. Because there is no control over a partner's systems, relationships with business partners are of paramount importance to the success of an ERP II implementation (Búrca et al., 2005). Most organisations are currently not ready to take their software to the next level and share their information with other parties. This leads to the second argument why ERP II is not examined. ERP II adoption is still very limited, because organisations are afraid to share their information. Strategic behaviour plays an important role at this point. Many organisations believe their own information is what gives them a competitive advantage and therefore organisations are not willing to share this information freely (Agrawal & Pak, 2001). Sharing knowledge among all business actors, including competitors, requires a paradigm shift and change of mentality in the economy, which has to take place first before ERP II is able to reach its presumed success on a large scale (Mohamed & Adam, 2005). The limited number of ERP II examples currently available, is also a reason supporting the decision not to focus on ERP II in this research.

[2] EDI stands for Electronic Data Interchange and is an electronic form of communication between different applications and firms.

[3] See section 3.2.3 for more information on this effect.

Currently ERP II is only a theoretical best solution to optimize supply chains; in practise however a lot has to be done before information sharing and e-Business can finally be used to its full potential and can be adopted on a large scale. Even if parties are willing to share information and ERP II is about to be implemented this is not without risk. Challenges like: resistance to change, local culture issues, training, testing and good project management are all key factors which play an important role to a successful ERP II implementation (Weston Jr., 2003). These are the same issues that may also be faced when implementing ERP within one organisation, thus one can imagine that with the implementation of ERP II across different actors along the supply chain, these issues become more and more complex.

Finally ERP II may in the end only have a small effect on the performance of the whole supply chain as Agrawal & Pak (2001) argue. The biggest benefits are still to be gained within one organisation and for these reasons the focus of this research is limited to ERP only, seeing the early stage that ERP II is still in.

2.1.4 ADVANTAGES

ERP is currently in a more mature stage of development and has been adopted for various reasons. There were several reasons why ERP software has become so successful and such a fast growing market. Some companies implemented ERP, because they were forced by the year-2000-issue to undertake action and replace their legacy systems (Davenport, 1998). Subsequently ERP promised additional benefits that seemed appealing. As already mentioned, ERP integrates all business activities (Beheshti, 2006). This provides several benefits, which will be illustrated by the following example, based on (Gupta, 2000). If a purchase is entered in ERP by the sales department the order can be automatically passed to the manufacturing application. This application, in turn, is able to automatically calculate the required materials and create a production planning. The list with required materials is again passed to the purchase department where materials can either be ordered automatically (via EDI) or via a purchaser. Because the order was entered before, the logistics can easily be coordinated as well and it is immediately clear where the materials are required and have to be delivered. Additionally all (financial) transactions are tracked in ERP. This provides the possibility to monitor in real-time, the planning status and predicted delivery times. Because transactions are tracked across all business activities, management can also track the financial performance of the organisation in real-time (Kelle & Akbulut, 2005). Interconnections in ERP make sure that information in one part of the business can be obtained by another (Beheshti, 2006). As the example shows, ERP is thus able to react faster to orders, purchases etc. due to the automated interconnections between different business activities. Stein (1999) for example refers to Toro Co.[4], which is a seeing a return due to the integrated nature of SAP and higher data-quality which helped to be more responsive to their customers' demand (according to officials).

With ERP, planning can automatically be adjusted and has become more flexible (Gupta, 2000). Also due to automated processes, delivery times and order-to-cash cycle times can be shortened drastically (Hendricks et al., 2007), (Stein, 1999). Moreover the information is often available to supply chain partners; due to the speed at which the information is available, ERP has the potential to radically reduce inventories and increase customer service (Johnson & Pyke, 2001). The many interconnections also prevent people from reentering information into different systems which was often the case with legacy systems (Fawcett et al., 2007). Reentering information is a waste of time and may cause unwanted errors. With ERP (in theory) less people are required which is of course a costs saving.

Furthermore, it is costly to maintain dozens of different platforms. Maintaining just one application (i.e. ERP) is easier and cheaper. Thus from a maintenance perspective ERP applications are considered to provide significant cost savings as well (Murray, 2006). Cost can of course only be saved if all legacy systems are being replaced by ERP, otherwise ERP will only cause additional costs.

[4] Toro Co. is a $1 billion commercial outdoor environmental-machinery manufacturer located in Minneapolis (US). Toro Co. produces machinery such as lawn mowers and snow throwers.

2.1.5 DISADVANTAGES

All the advantages seem promising and also suggest that all companies should implement ERP. One might also wonder why companies did not implement ERP a long time ago already, seeing all the advantages it provides. There are however also downsides to ERP which prevent or have prevented companies from implementing an ERP package.

A major reason usually is the costs of implementation (Stein, 1999). Changeover to ERP is often experienced as taking more time than scheduled and therefore causing (enormous) cost overruns (Gupta, 2000), (Poston & Grabski, 2000). Implementation of an ERP package proves to be very expensive: to install an ERP software package, costing € 100.0000, often more than one million Euros is needed to implement the software (Visser & Goor, 2004). Implementation costs typically range from one million Euros up to even hundred million Euros. The Meta Group did a research among 62 companies and based on these cases concluded that the average implementation costs $10.6 million and took 23 months to complete (Umble et al., 2003). There are dozens of examples where budgets are overrun dramatically: according to research, 90% of ERP implementations end up late or over budget (Umble et al., 2003). The software itself represents only a fraction of the total costs of implementation. After installing an ERP package, the software needs to be customised and fit to the organisational processes. Attention will also have to be paid to the employees who have to accept the application, otherwise the implementation is useless. ERP software is worth nothing without proper education to its users, working procedures and preservation of functionalities (Cliffe, 1999), (Bingi et al., 1999). Because of the huge impact ERP has across all different layers and locations of a firm, it can disrupt a company's culture or even lead to productivity dips and mishandled orders (especially in the start-up phase) which may cause additional damage(s) on the long run (Stein, 1999).

Another disadvantage of ERP is the complexity of the software (Visser & Goor, 2004); many departments will be interlinked which makes changes also more complex. This complexity is being reduced by using separate modules that each offer different functionality. Still because of the many interconnections the complexity will exists for a large part. Adding more functionality to ERP also requires its users to learn more about the system to do their daily work with it and know the consequences of their input: ERP can create excessive training requirements (Stein, 1999). Due to the interlinked structure an error or wrongly entered input may even cause a series of faults throughout the system (Gupta, 2000).

2.2 ERP CHARACTERIZATION

Originally MRP applications already tried to link as much information as possible. Integration of information across different departments is a core element of ERP. This is where ERP (theoretically) should provide the most benefit. Actions that require information from different departments can typically be very well supported by ERP.

2.2.1 PROCESSES SUPPORTED BY ERP

As shown in the previous section, many modules to support different activities exist. The main aim of ERP Vendors in the end is to support all processes, which could possibly take place at an organisation, in one integrated application. Figure 6 (based on a figure provided by Gardiner et al. (2002)) provides a schematic overview of typical processes taking place at a manufacturing company. SAP is used in this example; the colours illustrate different SAP-modules and show what processes or departments are supported by each SAP-module. The figure provides a nice overview of the different modules that could be used throughout the enterprise.

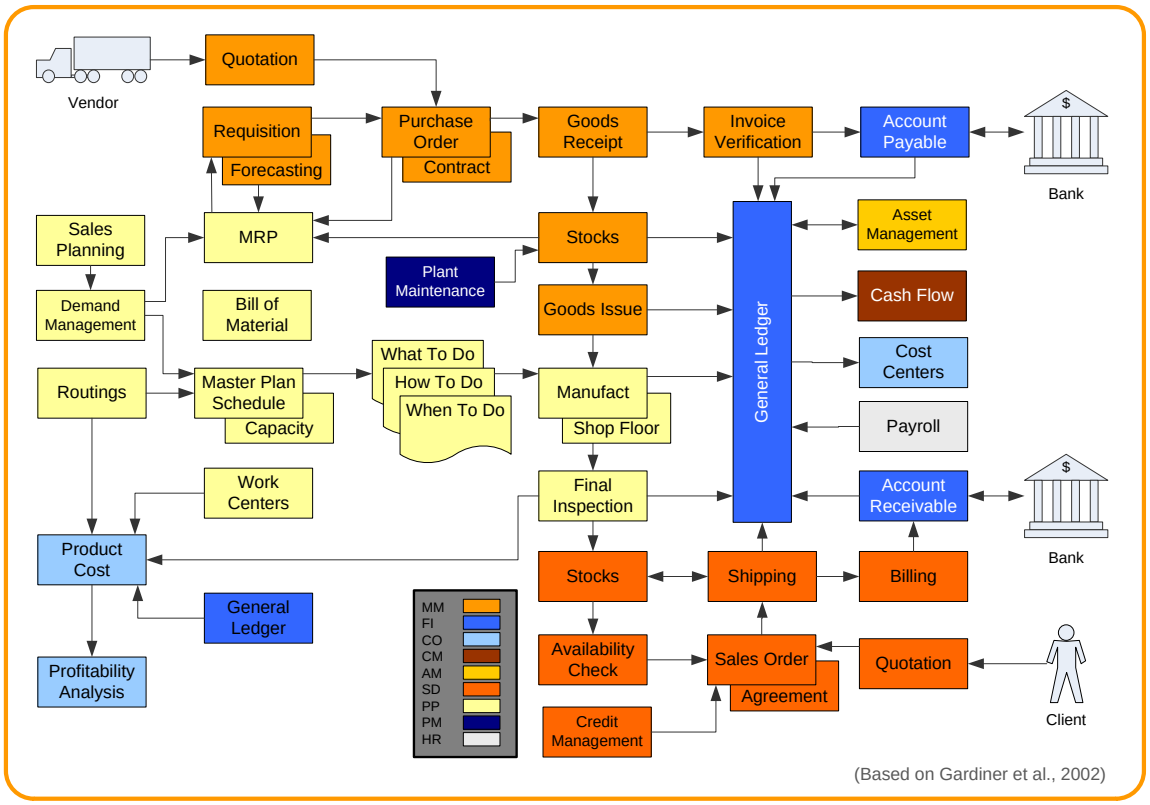


FIGURE 6 SAP R/3 TYPICAL BUSINESS BLUEPRINT

Remarkably all processes are being supported by modules from SAP. Experiences from users do however sometimes indicate otherwise. Willem Wijnia (Centric, (Logistiek.nl, 2007)) for example argues that ERP is only able to handle predictable, continues inventory streams; if the demand is not continuous anymore but becomes more and more complex, ERP packages become incomplete and additional tools are needed (Logistiek.nl, 2007). Additionally it is argued that investing in ERP only becomes interesting when the total value of inventory is above one million euro (Froukje de Vries, E-Optimaal, part of Infolog), and that ERP only operates well in a manufacturing company with simple forecast (Frank Bongers, Galvano Retail) (Logistiek.nl, 2007).

Typically ERP is also a very functional tool when information needs to be shared in real-time. Because of the integration of different business departments the information can easily be shared. Information that is updated by the sales department for example can directly be consulted by the inventory manager, which provides him with the necessary information to match the upcoming demand.

2.2.2 ERP VS. NON-ERP

The foregoing sections described what an ERP is and what processes are supported. The alternative to using ERP software is separate modules for different business units or operations. For example a financial system may be used which is not linked to the sales or purchase department. In that case orders will have to be retyped to exchange the information between systems. With more than one database, the data is often stored twice and the information between databases is not updated in real-time and can easily get out of sync or outdated. ERP integrates all these separate databases into one. Additionally reports are generated from the information available in the ERP database using BI-tools already available within ERP or specially build within/around the standard ERP package. Also software packages are available that form an extension to existing ERP software: Business Intelligence Software. Slim4, developed by Slimstock B.V. is an example hereof: they developed a software application that makes use of information stored in ERP to optimize inventory forecasts. Because standard ERP did not seem to provide enough (or not specific enough) reports and data for steering, they developed an additional tool which does.

Figure 7 shows the different stages, from separate software solutions to ERP and business intelligence that supplement standard ERP packages. The orange cylinders represent databases and the yellow shapes are separate software packages: in the left figure four separate pieces of software can be seen, whilst on the right only ERP is displayed. The blue shape represents the business intelligence tools that extract the data from the ERP-database and translate it to reports with interesting information for steering and monitoring processes.

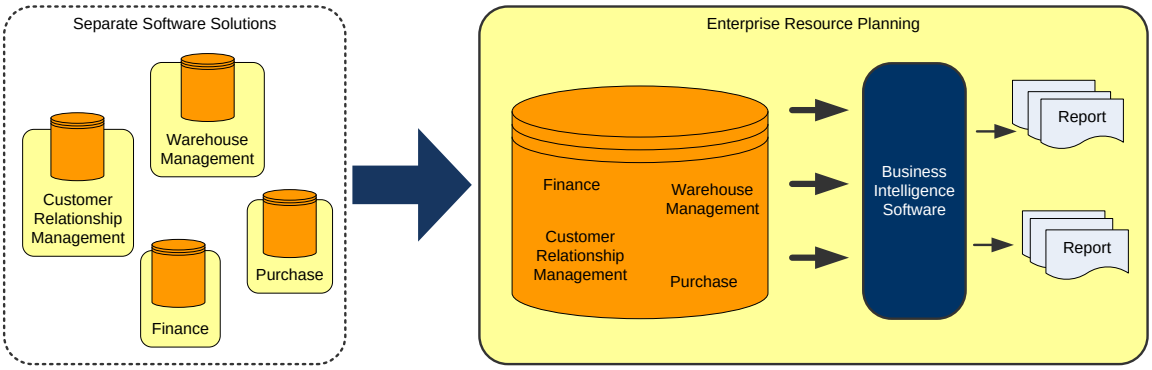


FIGURE 7 SOFTWARE STAGES

To summarize, an ERP package is defined by the following key characteristics:

Enterprise Resource Planning (Integrated solution):

1. INTEGRATION of all[5] business processes.
2. One integrated software solution for the above processes.
3. One CENTRAL DATABASE: data is stored at one location (/database) only.
4. Data is exchanged and updated REAL-TIME between business units, departments, operations etc.

2.3 WINDING UP

This chapter described the use of ERP to support the information management within an organisation. Within ERP, information is kept from an entire organisation. Using business intelligence tools this information can be used to create advantageous insights in the operations of an organisation. This chapter showed the difference between a non-ERP and an ERP environment and the positioning of possible business intelligence (or performance measurement/evaluation) tools in relation to software.

Furthermore within most ERP packages the typical business processes are described in a structured way. This chapter showed the business blueprint of an entire organisation as an example: this provided an overall overview of the activities taking place. The next chapter takes a detailed view at a specific part, namely logistics. The information from this chapter, combined with the logistics part in the next chapter, is used during the analysis further on.

[5] As much business processes as possible; with the ultimate goal to integrate all relevant processes.

3 INVENTORY LOGISTICS

"The amateurs discuss tactics: the professionals discuss logistics" – Napoleon

The introduction already mentioned that the focus of this research will be on inventory management. Inventory management is part of supply chain management (SCM). Therefore first SCM will be described shortly. This is done to show how inventory management relates to this much broader field of research. Accordingly the different aspects of inventory management are described. As the previous chapter pointed out, ERP packages support a wide range of business activities: supply chain management and inventory management are two of them. ERP and logistics are related to each other in a way that ERP supports these processes with information; in many cases IT systems even form the core of the logistic processes (Ploos van Amstel & van Goor, 2006). The relation between ERP and logistics is also addressed in the proceeding sections.

3.1 SUPPLY CHAIN MANAGEMENT

Supply Chain Management is a very broad term, because it incorporates a wide range of activities: transportation & logistics, inventory & forecasting, supplier management, after sales support and reverse logistics are some examples. Inventory management is just one aspect of SCM. Johnson & Pyke (2001) even distinguished up to twelve different categories within SCM. About SCM, there are various (slightly) different definitions available, for instance:

"SUPPLY CHAIN MANAGEMENT (SCM) IS THE TERM USED TO DESCRIBE THE MANAGEMENT OF THE FLOW OF MATERIALS, INFORMATION, AND FUNDS ACROSS THE ENTIRE SUPPLY CHAIN, FROM SUPPLIERS TO COMPONENTS PRODUCERS TO FINAL ASSEMBLERS TO DISTRIBUTION (WAREHOUSES AND RETAILERS), AND ULTIMATELY TO THE CONSUMER" (JOHNSON & PYKE, 2001)

"SUPPLY CHAIN MANAGEMENT (SCM) IS THE MANAGEMENT OF A NETWORK OF INTERCONNECTED BUSINESSES INVOLVED IN THE ULTIMATE PROVISION OF PRODUCT AND SERVICE PACKAGES REQUIRED BY END CUSTOMERS" (HARLAND, 1996).

"THE SUPPLY CHAIN CAN BE DEFINED AS A NETWORK OF RETAILERS, DISTRIBUTORS, TRANSPORTERS, STORAGE FACILITIES, AND SUPPLIERS THAT PARTICIPATE IN THE SALE, DELIVERY, AND PRODUCTION OF A PARTICULAR PRODUCT." (MURRAY, 2006).

Although these definitions differ, they do contain several similar elements. For example all definitions include consumers, products and businesses. SCM can therefore be seen as *the joint operation of several businesses to manufacture and deliver a product to the consumer*. All activities that have to be performed to achieve this operation are part of SCM. Logistics is often also used to refer to SCM. A small difference can however be seen. Logistics can be seen as all activities that concern the transportation of goods in the supply chain. Logistics can be defined as "the management of business operations, including the acquisition, storage, transportation, and delivery of goods along the supply chain" (Murray, 2006). The most important distinction that can be made between logistics and SCM is the scope: SCM has a broader scope (as mentioned before SCM looks across different enterprises). Whether logistics and SCM are the same, is still heavily being discussed in literature as well (Larson et al., 2007). Due to the focus of this research, which is restricted to single organisations, logistics will be used mostly throughout this report.

Figure 1 (in the introduction) depicted a simplified supply chain; this figure showed suppliers, manufactures, assemblers, retailers and customers. All these actors exchange goods, funds and information with each other. The exchange of these three items among the actors involved is considered the three key flows within logistics (Akkermans et al., 2003). ERP typically supports the exchange of information and financial data (which can be seen as information as well at a certain point) between companies and within a single company. In a supply chain the actors involved often strongly depend on each other. These dependencies also create uncertainties for

internal processes. If for example an outside supplier fails to deliver a specific order on time, this can cause delays during the production or service-delivery as well.

3.2 Inventory Management

Uncertainties are one example why most parties within the supply chain keep inventories. Inventories function as a buffer to cope with uncertainties as described above (Waters, 2003). Inventories are kept at all most each party within a chain of supply. This section will elaborate on inventory management in more detail.

3.2.1 Inventory (management) definition

'Inventory' and 'stock' are often used to relate to the same thing (Wild, 2002); yet when inventory management is mentioned, there is however a slight difference with stock. Stock is usually an amount of goods that is being kept at a specific place (in a warehouse for example), sometimes referred to as inventory. Conversely, inventory *management* is primarily about specifying the size and placement of stocked goods. Inventory management is necessary at different locations within an organisation or within multiple locations of a supply chain, to protect (the production) from running out of materials or goods.

The scope of inventory management is broader than stock. Basically inventory management can be defined as the "management of materials in motion *and* at rest" (Coyle et al., 2003). The following activities all fall within the range of inventory management (Wikipedia, 2009): control of lead times, carrying costs of inventory, asset management, inventory forecasting, inventory valuation, inventory visibility, future inventory price forecasting, physical inventory, available physical space for inventory, quality management, replenishment, returns and defective goods and demand forecasting.

Inventory management basically serves two main goals (Reid & Sanders, 2007). First of all good inventory management is responsible for the availability of goods. It is important for running operations that the required materials are present in the right quantities, quality and at the right time in order to deliver a specific level of service. The second goal is to achieve this service level against optimal costs. Not all items can be held in stock against every cost for example and therefore choices have to be made.

3.2.2 Why focus on inventory management?

Inventory is often where the biggest costs are hidden in businesses (Harrington, 1996). This is also the first reason for choosing inventory management as the subject of this research as discussed during the introduction. Figure 2 showed various processes taking place at the manufacturer; for three reasons only inventory will be picked out.

First of all stocks are responsible for a large part of the total working capital costs: up to about one third (Goor & Weijers, 1998). Inventory costs also represent a significant component of total logistics costs (Coyle et al., 2003). Consequently the biggest benefits can thus be gained by reducing these costs (using ERP according to expectations). Working capital invested in stocks could also have been a very useful resource when it could have been used otherwise (Wild, 2002), (Fawcett et al., 2007). Capital invested in stocks is thus, from a company-perspective, a 'useless' waste of money. Cost reductions are required by the market in order to keep offering competitive products and services; reducing the working capital costs using more efficient inventory management is one way to achieve this goal.

Secondly stocks are a source for risks (Visser & Goor, 2004), (Fawcett et al., 2007). For example stock may catch fire, can be stolen, damaged or may decay over time. Consequently these events might influence the production process and could even cause it to stop and orders are delivered too late accordingly. If stock levels are lower the related risks will also be reduced. Risks caused by maintaining stocks are again related to costs, because stocks have to be stored secure and have to be protected against these risks, which costs money.

A third reason to focus on inventory (management) is because inventory costs are some of the easiest to identify and reduce when attacking supply chain problems (Johnson & Pyke, 2001). Budgets are often under pressure and costs have to be reduced to keep up with the competition. In accordance working capital costs will have to be reduced; optimizing internal logistics is a way to do this in a relatively easy manner (Ploos van Amstel, 2008). ERP is presumed to enable stock reductions and thus as a consequence able to reduce related costs and risks. Inventory management aims to control materials and related costs and finance.

3.2.3 FUNCTIONS OF INVENTORIES

Having (an amount of) stock is costly and can cause various additional risks. Waters (2003) states the following: "stocks are expensive, because of the costs of tied-up capital, warehousing, protection, deterioration, loss, insurance, packaging, administration and so on". He therefore also wonders why inventories are being maintained by organisations at all. According to the Just-in-Time principle (JIT) when all materials arrive just in time, no stock will be needed and thus inventory management will not have to deal with the temporary storage of all these goods (Coyle et al., 2003). This is how managers often explain the JIT-principle. Unfortunately the JIT-principle cannot always be applied and JIT is just a way of control in a situation where production takes place based on an order (no mass production). JIT does not mean there are no inventories at all, but aims at elimination of unnecessary stocks during production (Dijk et al., 2007).

Inventories will probably always exist due to several reasons. There are three main reasons why stocks are necessary or sometimes even inevitable:

- Uncertainties are the most important reason to keep inventories (DHL, 2009). If for example a specific order is delivered exactly according to plan and on the agreed date and time, but the wrong goods are delivered or the delivery is damaged and can therefore not be used. This example illustrates two possible causes of uncertainty. Although a delivery might be perfectly on time (as being identified as the first reason for maintaining stock), there might still be something wrong with the stock as well. Uncertainties in delivery times may also form a reason to maintain a safety stock, in case a delivery arrives late. If all processes subsequent to a specific delivery are interrupted as well, it may cause major losses in the end. For this reason a stock is usually kept, to cope with unforeseen events that could otherwise prevent the production from moving on. Another important source of uncertainties is caused on the demand side; the expected orders placed by the clients are hard to predict (Wild, 2002). In order to guarantee deliveries and a certain level of service to the clients also a stock is often maintained to cope with uncertainties on the demand side. To summarize, stocks thus allow for variation and uncertainty in both supply and demand, which lets operations continue smoothly when problems arise (Waters, 2003).
- In relation to uncertainties, time also plays a role. Time lags which are present in the supply chain can be intercepted by maintaining stock. A certain amount needs to be kept in stock, to use during this 'lead time'. When something is ordered, it usually takes a while before the goods are actually delivered; during this period the production cannot stand still and therefore the stock will function as a buffer to overcome this period. Time lags in deliveries can lead to very large fluctuations and are exaggerated down the supply chain: this effect is called the Bullwhip effect (Lee et al., 1997), (Fawcett et al., 2007), (Johnson & Pyke, 2001). Inventories are thus a means to protect oneself against this effect (Klundert, 2003).
- Finally it may sometimes be cheaper to keep some stock. Economies of scale for example are a reason why inventories are kept. Buying bigger quantities is often more beneficial than ordering small amounts, due to the related discounts (Waters, 2003), (Coyle et al., 2003). Additionally ordering one unit at a time that has to be delivered to a specific place every time the user needs it, requires more logistic movements and accordingly raises high costs as well. Also fluctuating prices may form a reason to keep a stock: buying a product at a low price can provide a benefit (Waters, 2003). That is off course when the total costs of keeping additional goods in stock is cost-efficient compared to buying at a higher price, otherwise high stocking costs will immediately diminish the intended profit.

In addition to this list seasonal goods can be added (DHL, 2009): crops for example can mostly only be harvest once a year, which makes it impossible to produce according to the just-in-time principle.

3.3 INVENTORY STRATEGIES

Previous sections showed that stocks take up valuable working capital, cost money to maintain and form a source of risks. On the other hand we have seen that it is often inevitable to do without stocks. Stocks can even bring in additional money due to economies of scale, as the previous section just showed. Thus in the end stocks will most probably never cease to exist. The important question that still remains is; what is the optimal amount of stock to maintain? Unfortunately there is no unambiguous answer to this question and it has to be considered for each separate situation individually. The amount of inventory that should be kept depends on various factors and upon the activity that is defining the stock (Wild, 2002).

3.3.1 CORPORATE STRATEGY

The most determining factor is the corporate strategy (Dijk et al., 2007). First the corporate strategy is set by the management. Accordingly the choices made in inventory management have to fit within the corporate strategy to reach those goals. The pursued service level is an example of the choices that are made by the management. In some cases this is also partly determined by what the market demands (for instance concerning medical supplies people are more likely to expect that those are in stock).

Inventory management is used as a means to achieve those goals. Treacy et al. (1993) and Dijk et al. (2007) define three different key strategies:

- Operational excellence; companies following this strategy aim to offer good quality products against the lowest possible prices. Dell computers, for example is following this strategy.
- Customer intimacy; firms operating according to this principle, constantly adjust their products to meet the requirements of their clients. These types of firms try to build up a good relation with their clients and aim to have more than just one transaction with a client. High service levels are often an important (sub) goal within this strategy.
- Product leadership; is a strategy aimed at innovation. Enterprises following this tactic try to stand out due to their new and innovative products; Apple is a good example of this principle.

Customer intimacy is a term that is used by Treacy et al. (1993) and should not be confused with customer service. Customer service can be seen as one specific aspect of customer intimacy. Offering a good service is one aspect whereby one should make sure that the products are of good quality and always available for example. Customer intimacy stretches out beyond this scope and also incorporates bonding with clients for instance. For example, making personalized offers or tracking the customers' desires to adjust the service providing on their behaviour are activities that do not directly concern a good service level but do concern customer intimacy. There is thus a difference, which the following example also illustrates.

A good example of the corporate strategy having effect on inventory management can be seen if one would compare Aldi (and Lidl) to Albert Heijn, which both are grocery stores. Aldi and Lidl for example compete on operational excellence (Dijk et al., 2007), whereas Albert Heijn focus on customer intimacy. The Aldi looks like a warehouse: not much attention is paid to the presentation of products. The ratio between price and quality at the Aldi is however very competitive. The Aldi is following the operational excellence strategy, whereas Albert Heijn is focusing much more on customer intimacy. At Albert Heijn all registered clients for instance get additional discounts and in the shops the products are neatly presented. Additionally leading brands are sold and the assortment is kept up-to-date with new product. At the Aldi more often products are out-of-stock than the products at the Albert Heijn; this is part of the followed strategy. Accordingly one can imagine that the logistics and inventory management at Albert Heijn and the Aldi is therefore also very different. Stock levels are very different when a higher service level has to be offered for example (Wild, 2002).

3.3.2 BUSINESS MODEL

In addition to the corporate strategy, an organisation chooses a business model that is aligned with their strategy. By a business model the way of operation is meant in this case, also referred to as basic structures. The four most important defined *basic structures* are (Hoekstra & Romme, 1991), (Dijk et al., 2007, p.38):

- Make-to-stock.
  In this structure, products are manufactured, regardless of any order placed by a client. It is even possible that products are produced, but there is (hopefully temporarily) no demand at all. In this structure the pressure is on the sales department when the demand drops. Paperclip manufacturers are an example of a make to stock environment.
- Deliver-from-stock.
  The deliver from stock variant looks similar to the make-to-stock structure. However in this case the assortment is much bigger and products are not being manufactured first. This structure is usually found at a wholesaler or retailer: a builder's merchant for example has this structure.
- Assemble-to-order.
  Some manufacturing companies only assemble. They combine different components based on the desired configuration of the client. Using a limited number of components, they are able to produce various different end-products. Dell computers for example offer various components where the clients are able to pick from; accordingly their combination of components will be assembled.
- Make-to-order.
  A make to order structure is most common for products that have to be tailored to the consumers' desires. In this case products are only produced on (customers') demand. Building a luxuries yacht is a make-to-order example.

Variations to this list exist: Hoekstra & Romme (1991) for instance also mention a fifth structure called 'purchase and make to order'. This is an even more specific case of the make-to-order structure. The order in which the above four structures are presented also represent their rank in relation to the amount of influence a customer has. In case of the make-to-stock structure, the interaction with the client takes place at the end of the production process (Hoekstra & Romme, 1993), (Coyle et al., 2003). The client also has no influence during the production process, whereas in the make-to-order structure the client is already being involved at the beginning of the production process. The point in the process at which the client gets influence is called the decoupling point[6] or Push/Pull-boundary (Simchi-Levi et al., 2003).

The basic structure is very defining for the amount of stock that is kept. In case of make-to-order for example materials cannot be held in stock very easily, because the materials required depend heavily on the order that is placed by the client. If in the ideal situation the required materials are delivered precisely at the moment when they are required, no stocks will exist. This principle is called Just-In-Time (JIT) delivery. Using JIT, the make-to-order structure could in theory thus do without any inventories, if all materials and (sub) components are delivered perfectly in time.

The JIT principle aims to eliminate all unnecessary materials from the production process (Klundert, 2003). This can only be achieved when all materials are handled at a specific station and it is possible to pass them on immediately after they are finished at that station. The principle of JIT is to have items when they are needed and not have those when they are not needed (Wild, 2002), (Goor & Weijers, 1998). When this theory is carried through consequently there will be no stocks at all. The basic structure may however sometimes dictate otherwise. For example the make-to-stock structure by definition always contains a stock in the end, although during and before production there does not need to be any stock. Keeping stock as small as possible is often desired, because this reduces costs and risks.

[6] In Dutch referred to as KOOP: klantorderontkoppelpunt.

3.3.3 Different views on inventory

Different perspectives on inventory management also cause the ideal stock levels to be ambiguous. From a sales perspective high service levels are important. The sales department wants to offer their clients the best service. Running out of stock is thus not desirable, and therefore seen from this perspective, high safety stocks seem a perfect solution and not a problem. The management on the other hand needs to satisfy several different objectives: where customer service is being just one of them. Management often wants to reduce costs as much as possible in order to generate more profit or be more competitive. Maintaining large inventories costs money and consumes working capital that can also be applied for other means.

Additionally an inventory manager also has another perspective on the matter. The inventory manager responsible for purchasing raw materials might for instance be evaluated by his superiors on the prices he pays for purchased goods. In that case buying large quantity is more beneficial, but additional stock might be the result. From his own perspective he might judge that the purchases are done perfectly, but the stock levels might become too high and in the end cost more money. There will always be tensions between different perspectives and therefore a universal answer to the question 'what is the correct amount of stock?' cannot be given.

3.3.4 Stock level calculation theories

The strategy and business model require a specific service level and inventory management strategy. Once these strategies are set, different kind of methods are available to calculate the correct amount of stock for each item and the corresponding order-time interval. The point at which new items are ordered is important for good stock control. This point is crucial, because ordering too early could cause overstocking which unnecessarily creates costs, whilst ordering too late may cause a certain item to become out of stock and may cause missed sales. The point at which is ordered is therefore most crucial in creating a good balancing between customer satisfaction and excess inventory levels (Wild, 2002).

The simplest way to manage a stock would be to use a minimum and maximum stock level. A minimum has to be set in order to create a buffer against the various uncertainties that exist (Coyle et al., 2003), as described earlier. A maximum is set to ensure that not too much stock is kept, because that would be unnecessary. Once the minimum level has been reached, items have to be reordered until the maximum is reached again. In practice however it mostly takes a while before ordered goods are actually delivered, therefore a review level is also necessary to ensure that the stock will not fall under the minimum level. The review level makes sure that goods are ordered before the minimal level is reached, in such a way that the ordered goods are delivered just in time when the stock approaches the minimum level. If the review level is reached, items are ordered a due to the delay they will be delivered just at the point where the stock level is at its minimum. The minimum stock is also referred to as safety stock. The safety stock forms an ultimate buffer to cope with uncertainties (e.g. in delivery times and varying demand). The more reliable the supplier and customer demands are, the lower the safety stocks can be. Figure 8 depicts the relationship between review level, safety stock, minimum and maximum stock level and supply lead time, as described above.

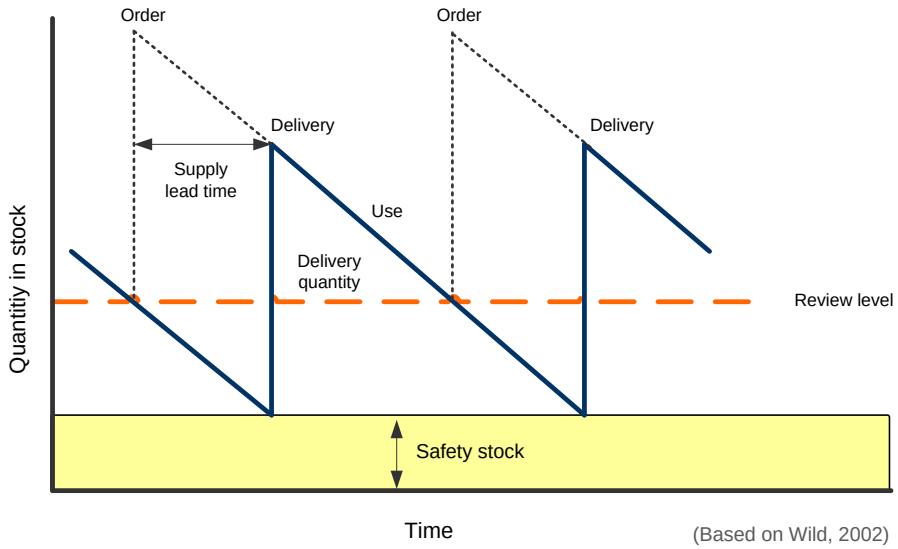


FIGURE 8 STOCK CONTROLS

This figure assumes a perfect periodical demand and a smooth decrease of stock; in practice the supply and demand will be irregular. If the stock develops like Figure 8 depicts, it is easy to see what the supply lead time should be and how much should be ordered. With a more irregular pattern this will however become more difficult. Various calculation techniques can then be used to 'predict' the upcoming demand in order to order new goods in time and in the right quantities. To keep the stocks low, it can sometimes be useful to shorten the supply lead time and order only small quantities at the time. This tactic however requires higher supplier reliabilities. Various calculation methods exist to calculate the optimal supply lead times and order quantities (Wild, 2002). Also a lot is written on the calculation of safety stocks. For this research it will suffice to know how this process works, and that safety stocks, supply lead times and order quantities play an important role in managing optimal stock levels. ERP originated from MRP as mentioned in the previous chapter, and therefore within ERP optimal stock level calculation algorithms are automated. In this research only the performance (outcome) of such a MRP-run will be considered, but not a detailed description of how it works. The calculation methods that are available to optimize forecasts are therefore not further investigated in more detail, because it involves a whole different field of research which lies outside the scope.

Stock level calculation and forecasting is often the first business process step in inventory management. The next chapter will analyse all sequential process steps and identifies where potential benefits can be gained by using ERP to support inventory management. The automated optimal stock level calculations within ERP, called MRP-runs, are one example hereof.

3.4 WINDING UP

In this chapter the position and function of inventory management was described, together with the reasons why the focus is on this small part of logistics. It can be concluded that optimal inventory management chases two goals: offering a high service level, against the lowest costs. Different strategies exist which can influence the balance of this dilemma, but in general these targets form the main goals of inventory management. This is necessary to keep in mind in order to construct a good performance evaluation tool later on, because it should measure the right things that match with the main objective.

In the next chapter the business processes that are followed in order to achieve these goals are analysed in more detail. Also with the knowledge from the previous chapter, possible ERP benefits are linked to each process step.

PART II. ANALYSIS

4 PROCESS AND HYPOTHESIS ANALYSIS

"It is absolutely essential that one should be neutral and not fall in love with the hypothesis" – David Douglass

The previous two chapters provided background information. In this chapter this background information is used to perform a detailed analysis of inventory management. First the typical business processes taking place at inventory management are analysed and mapped. This mapping is then used to formulate hypotheses on the possible contribution ERP might bring to inventory management. Also the business process steps identified during the analysis form the basis for the development of a performance measurement tool later on.

Interviews conducted with thee experts (see Appendix A) provided important input for this chapter. One interview was done with a logistics expert from KPMG Eindhoven to work out the different business processes of inventory management. A subsequent interview with a logistics and SAP consultant from KPMG Den Haag was conducted to verify the identified process steps. Finally during a third interview with another SAP and logistics expert from KPMG Den Haag as well, the potential benefits of ERP concerning the inventory management process were discussed. All three interviews were semi structured: general questions formed the basic input for these interviews. The questions were mainly open and left room for additional discussion. The first interview was really explorative and therefore it was least structured. The process identified during this interview served as a basis for the second and third interview.

4.1 TYPICAL INVENTORY BUSINESS PROCESSES

Within inventory management, several activities take place. *Forecasting* is the first activity that is performed. Forecasting is done based on orders: both previous amounts ordered and on (expected) upcoming orders (Visser & Goor, 2004). MRP-parameters, defined upfront, decide the levels for safety stock, review level etc. The order history for example is used to calculate the turnover rate which determines the point at which one should purchase new goods in order to prevent out of stocks. Furthermore orders that are already placed are also added to the forecast, because for those orders materials have to be purchased for certain. These parameters form the inputs for the forecast calculation. The forecast is used to decide whether goods have to be purchased in order to complement the stock to a secure level again (Wild, 2002). How high this secure level must be depends on various parameters, as the previous section pointed out.

If it turns out that the current stock is too low, compared to the advice generated through forecasting, goods are *purchased* to replenish stocks. At a certain moment these *goods are received* and are *stored*. Upon receipt of goods, goods are sometimes first temporarily stored in *quarantine* to acclimatize for instance. Quarantine is optional. Finally a *quality check* takes place upon receipt of goods, after which the goods are stored.

In between during storage, stocks are sometimes *moved* to other places. Finally *goods will be issued* that are going to be used either for a) operations where the goods are being consumed immediately (i.e. consumables), or b) manufacturing in order to use the parts to build a greater structure, or c) direct distribution and shipment to the client. The goods issue is always triggered by an order, because the goods are necessary or required to fulfil a certain order.

The above process steps are illustrated in Figure 9 below; this image is based on literature, expert interviews (as mentioned at the beginning of this chapter) and personal experiences. All the same, the processes displayed in this picture for a large part match with what is being described in literature (see (Waters, 2003) for example).

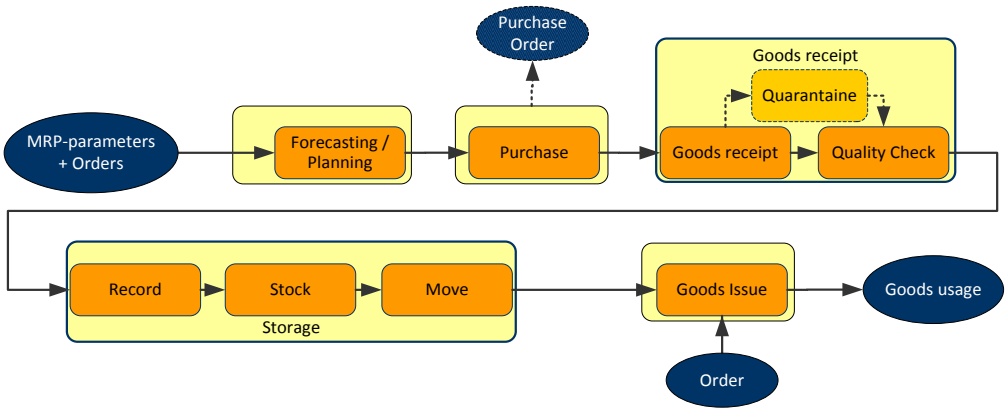


FIGURE 9 INVENTORY MANAGEMENT PROCESS STEPS

The yellow blocks represent the main processes; within each main process one or more processes take place which are displayed in orange. The quarantine process has a different colour, because this process step is optional. The dark blue oval blocks represent in- and outputs. By MRP-parameters only the MRP I system is referred to: MRP II, which incorporates the planning of human and machinery capacities as well, is not part of the input. An order triggers the goods issue process and finally the goods are used which forms the output in this process.

The forecasting, goods receipt, storage and goods issue processes are described in more detail in the proceeding sections. These are the four major processes taking place in inventory management and these can all very well be managed using an ERP application (Appendix A: KPMG advisor, 2009). The purchase step is only considered very basic, although there are various theories about how purchase should be performed. In this case purchase will only be considered as goods being ordered; how and when and according to what strategy is not taken into account because that falls outside the scope of inventory management and this research. Purchase strategies are not directly part of the operational process and are therefore the purchase order is displayed in another colour, with a dotted arrow towards it, in Figure 9.

4.1.1 FORECASTING

In the above model forecasting is the first process step. The previous section showed the stock level developments over time. Forecasting is necessary to anticipate on what is coming in order to maintain a continuous production or service level. Furthermore forecasting is closely related to scheduling and planning (Coyle et al., 2003). Within the above process forecasting and planning are considered one and the same process. Forecasting is considered the most important process, because this is where the real money can be earned: if forecasts are wrong the stocks will be too high, which costs money or even worse if the stock become too low this may cause problems at the distribution. Distribution problems can eventually even cause a domino effect: production stops and clients do not get their products. This would mean major loses in income. The forecasting process is thus a very important process step in inventory management.

Forecasts are almost never perfect, because there are generally too many uncertainties that need to be taken into account: it is not possible to incorporate all these uncertainties into the forecast (Ploos van Amstel, 2008). Forecasting over a shorter period is often easier however and therefore more accurate as well. For instance when daily forecasts are being done, anticipation to sudden developments in the demand can be much faster. Several steps exist within forecasting. First one has to determine what has to be forecast (which items, what level of detail and over what time scope). Secondly available data has to be gathered (e.g. historical data). Next a forecasting model has to be selected. Accordingly the forecast has to be done and finally this forecast has to be monitored and evaluated.

Different forecasting methods are available to select from. First of all qualitative methods can be used: this incorporates forecasts generated subjectively by the forecaster. Some examples of these methods include: executive opinion, market research and the Delphi method (Reid &

Sanders, 2007). Secondly quantitative forecasting methods such as time series model and causal models can be used (Reid & Sanders, 2007). Causal models assume relations between different variables which lead to the eventual behaviour. Time series typically assume that all the needed data can be found in historical series or events. Four basic patterns can be found in time series: level, trend, seasonality, and cycles. Methods to make an estimate of the upcoming time series (based on previous time series), may make use of simple mean, simple moving average, weighted moving average or exponential smoothing methods for example. The aim of forecasting is to estimate the upcoming need as good as possible; the mean squared error-method can be used afterwards to evaluate to what extend the forecast matched the actual demand. The forecast serves as input for the purchase process, which in this case will not be described in more detail. After purchase, the goods are delivered at a certain moment.

4.1.2 Goods receipt

When new goods are delivered to the location where the stock is kept (i.e. a warehouse mostly), several checks take place. Firstly, the price and quantity are compared to the purchase-order to see whether the delivered quantity and price match. In ERP there exists a link to information from the purchase department at this point. For some materials, the quality is also checked before adding the goods to stock. In some special cases the delivered goods even have to stay in quarantine for a while (e.g. to stabilize after transport or to acclimatize) before the quality is being checked. Because the quarantine process is optional, this block is dotted in the picture. Additionally the completeness of the order is often checked and the delivery date is registered. This information is used to keep track of the reliability of suppliers. Additionally, partial deliveries can be monitored using this information.

4.1.3 Storage

When all checks for received goods are passed, the goods are finally added to the stock. Again information is stored; at least the added number of materials or the amount of material is registered (in ERP for example). Additionally the location where the goods are stored is registered and eventually special characteristics are also registered like value, size or best-before dates for instance. The registered information from storage is linked back to forecast and used to do new forecasts with: based on the present amount of stock it is decided how many new articles should be ordered for instance.

When stock is stored, stock movements actually form the most important activity at this point. Stock movements may be required for several reasons. Goods are needed at another location for example. Each movement is registered and the location is updated in the system. Decayed or damaged goods also cause the amount of goods held in stock to mutate; this mutation also has to be registered. Usually the aim is to keep entire stock costs as low as possible. Stock mutations (movement or writing off) cost money and therefore not only the stock levels should be kept low, but also the number of movements as well.

ERP can be used to real-time monitor which amount (quantity and value) of a certain material is in stock and at what location(s) it is stored. Also using the information extracted from ERP it is possible to analyse which goods have a high cycle time and which products lay ‘still’ in stock and are thus not being used but do cost money/consume space and form a risk. For cheaper items this is no problem, because they represent a smaller value, but for expensive parts this becomes very interesting. Materials that are unnecessary being kept in stock can also be traced using the information stored in ERP. Finally ERP is used to optimize the safety levels (the minimum amount of stock).

4.1.4 Goods Issue

Finally goods have to be issued, usually for two reasons: depending on the environment. In a warehouse for example items may be picked to fulfil an order placed by a client. In a production environment items are retrieved from stock because they are required for production. The environment is mostly determined by the basic structure, i.e. make-to-stock vs. make-to-order for instance. When goods are retrieved from stock this is again registered (in ERP for instance) together with the date and amount that was taken from the stock. In an ERP environment the

actual stock levels are immediately updated after the goods issued are scanned, registered or written off in the system. Other departments can thereupon in real-time see the newly (changed) stock levels.

4.2 Potential ERP benefits

ERP should in theory be able to improve the inventory process at several points as the conceptualization part of this research indicated earlier. ERP-vendors claim that various improvements in terms of efficiency and process optimization are possible. This section is aimed at the identification of these benefits and locates them onto the business process depicted in Figure 9. Based on an interview with a SAP and logistics expert from KPMG Den Haag, an analysis is performed as towards where the improvements of ERP within the above process can be found. The interview was semi-structured: the process depicted in Figure 9 served as a basis and some open questions with a lot of room for discussion formed the starting point of this meeting.

In total eleven potential benefits are identified and related to a process step. Below, Figure 10 shows the inventory processes complemented with blue circles indicating at which points in this process ERP is able to offer potential improvements. A larger view of this same picture can be found in Appendix B. Also the interrelated connections between different departments are indicated with light-blue texts. Within an ERP environment the information between departments can be shared more easily through the centralised storage. The light-blue connections indicate the points at which information is shared with other departments; ERP should be able to support this as well.

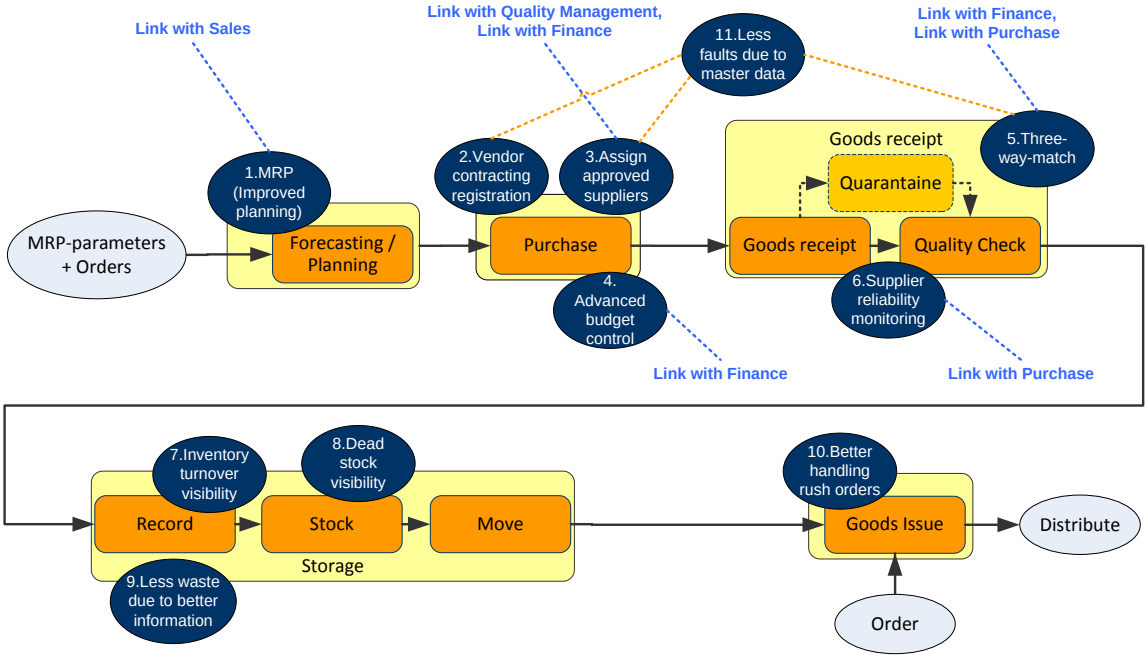


FIGURE 10 POTENTIAL ERP BENEFITS

Eleven points are identified: next an explanation of each point is given.

1. MRP (Improved planning)

As Chapter 2 indicated earlier, ERP software packages originated from Material Resource Planning (MRP) solutions. In most ERP packages thus advanced MRP capabilities are included. According to what the ERP-vendors claim, ERP software should be able to make more accurate predictions, because of their years of experience with MRP algorithms and calculations. Also due to the link with finance and sales within ERP, the software is able to take more factors into account, and as a consequence do better forecasts based on previous sales for instance as well. Using stand alone modules to perform MRP-runs can be more difficult, because less external factors can then be incorporated into the calculation. ERP-vendors claim that their MRP

solutions are strength of ERP as well and may offer significant benefits at the forecasting process.

2. Vendor contracting registration

ERP can support and streamline the purchase process due to the registration of contracting vendors. Typically if a large number of contracts with vendors need to be managed it is very useful to use software for this. Performing vendor contracting within an ERP environment provides benefits in terms of sharing information between departments: finance can use the same data (see advantage 11) when invoices have to be paid which is the result of purchase buying goods. Price negotiations are incorporated in new orders and budgets immediately as well. Due to the registration of delivery times within the software it is also better to observe whether the engagements are met. (see point 6).

3. Assign approved suppliers

Approved suppliers are suppliers which satisfy certain quality standards and products ordered with them are for instance immediately accepted at the quality check. Furthermore only certain suppliers might be 'approved' because they have proven to be reliable in terms of on time delivery of their products. Assigning approved suppliers within ERP therefore forms an easy control to manage quality and budgets. Within ERP approved suppliers can be configured and shared amongst other departments (see point 11 as well) quit simply. It is useful to assign approved suppliers for preselecting suppliers that are reliable. It can concern a financial matter: for example only a few suppliers might be approved, because finance made contracts with those parties in order to bargain for discounts. Also only a selected group of suppliers may be approved, due to quality restrictions.

4. Advanced budget control

Within ERP it is possible to create hard restrictions concerning the budgets. This is not a unique characteristic, but when these restrictions are made in real time by the finance department for example it does become a unique aspect of ERP. To prevent purchase from overrunning their budget, it can sometimes be necessary to create a hard restriction in the software: within ERP this can be managed easily.

5. Three-way-match

The so called three-way-match is a strong characteristic of ERP where the integration of different departments becomes very clear. The three-way-match is a check between the ordered goods (at purchase), the receipt goods (receipt at the warehouse location) and the invoice (which usually is delivered at the finance department). The type, number and quality of ordered goods have to match with the delivery done by the supplier and the invoice the supplier sends accordingly. If this information is stored across different software packages, it can be more difficult to match this information (see point 11 as well) and in the most inconvenient case these checks have to take place by hand. ERP can improve and automate[7] this because it is possible to monitor the whole process from ordering to delivery to the payment finally.

6. Supplier reliability monitoring

Due to the integration of the goods receipt and the purchase department within ERP it is easy to evaluate when a purchase was done and at what date the goods were actually delivered. A simple check between the promised arrival date and the actual date is a good measure of the supplier reliability. This information can be used when selecting supplier. In some cases the delivery times might be very critical and a good history of each supplier is than useful to select the ones that have proven to be reliable.

[7] In SAP for instance this can be checked automatically by configuring the write settings.

7. Inventory turnover visibility

With ERP it is possible to monitor the inventory turnover more easily, because the relevant information is available in one central database and can be combined in real time. Information about the average inventory is needed, as well as the sales statistics: within an ERP environment this information is stored in the same database. A low turnover means that goods are kept longer in stock and therefore this indicates a waste of capital (i.e. the capital is tied up in inventory and cannot be used for other purposes).

8. Dead stock visibility

Related to the turnover ratio, also 'dead stock' or slow moving stock can be made visible more easily. Because information from sales and inventory can be combined it is relative easy to see what goods are moving fast, and which goods are slow moving or even only are being used very scarcely.

9. Less waste through better information

If the expiration date of certain goods is passed, these goods have to be thrown away and this is a waste of products and capital. With less waste the expiration of goods is indicated in this case; not waste of packing materials. Typically waste of products only due to the fact that they have been lying around for too long is very inefficient and costs unnecessary money. Monitoring what articles have to be used first and when they will expire is a good thing to monitor and combined with automatic alarming could save money. Because of better managing the information around the inventory, the waste of goods due to expiration can be prevented. Stand-alone software, specially written for inventory management, is also able to do this. But because it is also a feature of ERP and provides benefits to the process as well it is worth mentioning over here as well.

10. Better handling rush orders

Before implementing ERP, first the processes taking place have to be analysed, because these have to be logical and are used to configure the ERP software. This requires that the processes are described and defined as clear as possible. Due to the streamlined processes that have to be thought trough before implementing ERP, rush orders can be better handled afterwards. It can be easier to go from one process step to the next in ERP than in an unstructured stand alone software environment. Also the number of orders that classify as rush orders can be reduced, because due to the optimised process rush orders can easily follow the normal path through the system as well.

11. Less faults through master data

Information that is used very often can be stored centrally in ERP software: within SAP this information is called the master data. Contact detail and specifications like payment addresses of vendors can be stored centrally. This master data about vendors can subsequently be used by both the purchase and the finance department. Mismatches in naming vendors can be eliminated for example in this way, because this information does not need to be retyped but is copied from the master data.

The eleven points identified and described above form hypotheses for the potential performance improvements caused by ERP, towards inventory management. In case an ERP application is used, better performances should eventually be visible at the identified process steps. In order to test these hypotheses a suitable technique needs to be selected first: this is done in the next chapter. Thereupon the selected performance measurement technique is described in more detail and used to develop a measurement framework. The framework is used in two case studies in order to evaluate both the framework and the above hypotheses.

PART III. TECHNIQUE SELECTION

5 PERFORMANCE MEASUREMENT TECHNIQUES

"You get what you measure. Measure the wrong thing and you get the wrong behaviours" – John H. Lingle

The aim of this research is to measure and compare the performance between two situations, in order to evaluate the potential benefits gained by ERP identified in the previous chapter. Several methods exist to perform performance measurement and therefore this chapter provides an overview of the different, most commonly used, methods available. A suitable method is selected in the end, which will be used for development of the framework afterwards. The arguments for choosing a specific method will be described as well.

5.1 DIFFERENT APPROACHES

To be successful in the long run, every organisation needs a clear and explicit vision which is formulated by top-management (Waal, 2002). This vision defines how the company should evolve and where it should position itself in the market on the very long run. This vision forms the basis for development of the strategy and objectives of the organisation. The strategy is subsequently translated to the lower levels of the organisation: examples are unit plans, budgets, and operational action plans. As described in section 3.2.1, the objectives of good inventory management are twofold: namely offering a good service level against the lowest possible costs. Measuring reliable and adequate performance is critical for steering, business success and achieving the goals (e.g. like the two mentioned above for inventory management) in the end (Fawcett et al., 2007). Measuring performance is also a useful means when evaluating certain changes made to the business (e.g. an ERP implementation for example).

To make good performance measurement for inventory management possible a good measurement technique has to be found first. Literature is consulted to create an overview of the most commonly used techniques available to measure performance. The following techniques are found: Key performance indicators (KPIs), Balanced scorecard (BSC), Return on investment (ROI), Net present value (NPV) and Critical Success Factors (CSFs). From these methods KPIs are selected, because they are basically key to most of the other measurement techniques as well, as will be explained during the following sections. Each method is shortly discussed in each of the following sections. From these sections it also follows why KPIs are the most suitable measure to use in this case.

5.1.1 KEY PERFORMANCE INDICATORS

Key Performance Indicators (KPIs) are quantifiable measurements, agreed to beforehand, that reflect the critical success factors of an organisation. KPIs are quantifiable metrics which are usually defined and measured over a period of time or during a specific time interval. KPIs were first introduced in 1961 by D. Ronald Daniel and Jack F. Rockart. A KPI mostly satisfies the SMART principle, therefore a KPI must be: Specific, Measurable, Attainable, Relevant and Time-bound.

KPIs can be of totally different nature, for instance financial-, social-, production- and innovation-KPIs exists. KPIs can differ very much, depending on the type of organisation, department or industry that is looked at. Some KPIs are however more general than others and are used in most organisations: total expenses and revenues are an example hereof. But a call centre, handling customer's questions, may have deviant KPIs defined. For example the number of calls answered within the first minute needs to be monitored to measure the quality offered by the call centre. In inventory management the total value of items held in stock is an important measure, because this is related to working capital and storage costs which are very important as we saw earlier.

KPIs are very useful measures for ERP: KPIs generate the input for ERP software. Based on the measured inputs, statistics and management reports are generated. KPIs thus basically form the basis of ERP systems, because they determine what the in-/output will be (Pairat & Jungthirapanich, 2005). ERP software, including the inventory management module for example holds information about the whereabouts of materials. Based on the registered information, ERP

can subsequently support the generation of management reports which provides an overview of the performance scored on different criteria. This way KPIs are a helpful means for an organisation to define and measure progress toward organisational goals. In logistics most of the measurement is done using KPIs as well. KPIs are the general standard. The Supply Chain Council (SCC) constructed a descriptive reference framework called SCOR that uses KPIs as well for instance (SCC, 2006).

5.1.2 Balanced scorecard approach

The Balanced Scorecard (BSC) is a performance management tool that is able to measure whether the smaller-scale operational activities of a company are aligned with the larger-scale objectives in terms of vision and strategy. The BSC performance measurement technique was first published in 1992 (Kaplan & Norton, 1992). Kaplan and Norton introduced this method. The balanced scorecard method is typically designed to monitor business processes (Rosemann & Wiese, 1999). Kaplan and Norton (1992) developed the balanced scorecard technique as a supportive tool to map more than just 'tangible' measures in different categories. The BSC is in principle based on KPIs as well. The only difference however is that the BSC method adds something new to it, namely four different categorised perspectives to classify the KPIs in (Kaplan & Norton, 1992). These four perspectives are as follows:

- Financial(/cost)
- Customer
- Internal processes
- Innovation and learning

The BSC is used to represent both financial and nonfinancial PKIs in a user-friendly format (Waal, 2002). The idea of this scorecard is that all perspectives have to be taken into account and therefore the general performance measurement will be 'balanced' (and not only financial for example). Although they present different categories that could be measured, the users have to decide amongst themselves what they find important and where they want to keep track of.

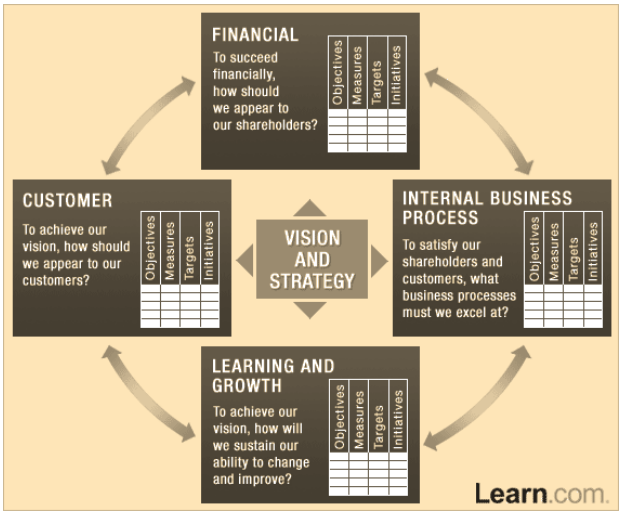


Figure 11 Balanced Scorecard Overview

5.1.3 Return on investment

A less balanced method to measure business performance is the return on investment (ROI) method. This method is also referred to as rate of return, rate of profit or sometimes just return. ROI is the ratio of money gained or lost on an investment relative to the amount of money invested. Mostly ROI is expressed as a percentage rather than a fraction. In the early 1920's DuPont and General Motors first introduced decentralised divisional structures with profit centres. As support for these reorganisations they introduced the 'DuPont chart' and with it the ROI concept (Goor & Weijers, 1998). The management was now also held responsible for the achievement of budgeted ROI and therefore they could no longer only focus on measures of margin and net income (Waal, 2002). There is however common academic agreement that measurement of ROI only is insufficient (Jones, 2009). Current literature tends toward the use of both qualitative and quantitative variables (Waal, 2002).

5.1.4 Net present value

A variant related to ROI, is the Net Present Value (NPV) calculation technique. This is sometimes mentioned as a performance measure technique as well, although NPV is not very suitable to continuously monitor performance. NPV is also a sole financial measure. NPV is used to value what a project is worth if future incomes and expenses are translated to current time. Future incomes and expenses are basically return on investments. These ROIs are estimated for each

year the project will be running, and accordingly they are discounted to the current time and summed up, resulting in a single value: the Net Present Value. NPV is generally used to compare the financial performance of one project to another beforehand: the project with the highest NPV value will be the more beneficial one in the end. NPV is thus not very usable for continuous monitoring, because than ROI would be more suitable. Because of the prospective nature of this method, NPV is more useful to measure the expected performance of an upcoming project.

5.1.5 Critical Success factors

A performance measurement technique that is different from the above methods is the Critical Success Factors (CSF) technique. CSFs were first described in a study in 1979 as a means to improve management control (Waal, 2002). CSFs are qualitative goals or measures which an organisation wants to achieve. A good definition provided by Rockart (1986) states that ("CSFs are the limited number of areas in which satisfactory results will ensure successful competitive performance for the individual, department or organisation. CSFs are the few key areas where 'things must go right' for the business to flourish and for the manager's goals to be attained". In accordance with CSFs, also Critical Failure Factors (CFF) can be defined, which logically form the opposite of CSFs (Pairat & Jungthirapanich, 2005). A critical success factor is different from a KPI in the sense that it is qualitative. CSFs are vital elements or goals for a strategy to be successful; KPIs are the quantifiable measures to evaluate the scale on which a certain critical success factor is met (Rockart, 1979). The following example provides a good example of the distinction between CSFs and KPIs:

KPI = number of times the server is unreachable (measurable)
CSF = Appointment of an chief information officer to better incorporate IT-interests into management (target/goal)

A critical success factor is thus something that needs to be in place to achieve a certain objective; in this case for example a CIO needs to be in place to achieve the goal of better representing IT-interests in the management.

5.1.6 SCOR

SCOR, which is an abbreviation for Supply Chain Operations Reference-model, is a very common used performance benchmark technique in logistics. SCOR is a product of the Supply-Chain Council (SCC, 2006). SCOR is the industry standard for benchmarking entire supply chains. The SCC is an independent, non-profit, global corporation with membership open to all companies and organisations interested in applying and advancing supply-chain management systems and practices. The SCOR-model captures the Council's consensus view of supply chain management. The SCOR-framework aims to integrate business process with metrics, best practices and technology features. The SCOR reference model is often used to compare companies with each other. SCOR takes a very broad perspective and focuses on the whole supply chain (SCC, 2006). SCOR explicitly takes a very broad perspective and therefore does not provide a detailed view on inventory management, because that is only one small aspect within the whole supply chain (and the SCC's framework). Only some of the KPIs that are listed in SCOR relate to inventory management, but it are only a few. For the specific purpose of looking at a detailed part, like inventory management, the SCOR model is too high level.

5.2 Method Selection

Basically incomes and expensed are actually both (financial) KPIs; the return on investment method is thus also based on the KPI measurement technique. Therefore ROI and NPV can thus both be related back towards KPIs. The disadvantage of ROI and NPV is their purely financial nature; this is too limited to measure the performance (Kleijnen & Smits, 2003), (Gunasekaran et al., 2001). Theory also suggest that the use of both financial and nonfinancial performance measures is better, because it is more in line with the managers' actions and objectives (Wier et al., 2007). The BSC tries to solve this unilateral (financial) view by introducing a framework in which different categories have to be considered. The BSC is however not entirely new, because it just uses KPIs as well, only this time they are arranged in different categories. We have seen that CSF (and CFF) is also a well known method to measure performance. However because this

method is only qualitative it is less applicable in this case, because quantified results are key to this research. We have seen that SCOR is a logistics benchmarking tool that is already available. Unfortunately due the high perspective which SCOR takes, this reference model is not very suitable for viewing the internal performance of inventory management in detail for an organisation. A selection of only the KPIs relevant for inventory management needs to be made to correctly let the measurement model correspond with the focus of this research.

5.2.1 Conclusion: KPIs

The best suitable method for this research, which provides quantifiable measures on various criteria, is thus Key Performance Indicators. A categorization that fits the inventory environment can be chosen freely with KPIs, which is ideal (in this case). All other methods discussed above (expect CSF) are based on KPIs.

Neely (2003) also mentions more recent performance measurement systems, like the performance prism, economic value added (also known as economic profit), activity-based costing and self-assessment techniques. The performance prism is again based on KPIs, classified in different categories, only this time even all stakeholders are incorporated. Finally, economic value added and activity-based costing are again measures solely based on financial KPIs. KPIs thus clearly form the basis for a great deal of quantified performance measurement systems. It comes as no surprise then that KPIs are also used to measure performances in logistics as well and are even adopted as the standard in SCOR, which is the reference model used in logistics (SCC, 2006). Using KPIs in this research therefore nicely fits the logistics' standard as well.

5.2.2 Limitations to KPIs

There are several limitations to the selected method that have to be taken into account. First of all KPIs can be hard to measure in some cases. It has to be clearly defined what is exactly measured and how this should be measured exactly. This limitation is however generic to most measurement techniques and is therefore not a limitation that is specific to KPIs. Selecting another method will therefore not solve this limitation. Additionally KPIs have to be defined unambiguously, to prevent that the wrong things are eventually measured. Measuring the wrong things will in the end also generate the wrong results as well. This statement does however also hold for any measurement technique and is not only a limitation of KPIs.

A second limitation to KPIs is that they can be chosen freely which may cause a lack of coherence between KPIs (Kaplan & Norton, 1992). This is issue is addressed by the balanced scorecard. Because KPIs are chosen freely and can be classified in any possible way, this may form an additional point for discussion. On the other hand the unbound character of KPIs may also provide benefits, because no predefined structure has to be followed and therefore only relevant KPIs can be used.

Finally it can be undesirable to measure KPIs for several reasons. Measuring KPIs often costs time and therefore also money. There has to be a balance between the costs made to measure certain KPIs and the benefit it creates for monitoring and steering a certain process. KPIs must contribute to gain more control and therefore better output in the end, otherwise measuring KPIs is useless. Measuring KPIs can also be undesirable because it may stimulate the wrong behaviour (de Bruijn, 2008). De Bruijn (2008) mentions the example of universities, where employees' performance is measured by the number of publications. This performance measure can form an incentive to add each other's name on publications. In this way KPIs may lead to undesired behaviour. This limitation however is not specific to KPIs; other performance measurement techniques also face these issues.

Overall KPIs still form a suitable means although there are some limitations to take into account. The next section describes the KPIs in more detail, together with their relation to ERP. Additionally KPIs useful to inventory management are presented.

5.3 Key Performance Indicators

To measure performance, it is necessary to know first what should be measured or what is relevant measuring: therefore corresponding KPIs need to be identified. Additionally it is necessary to know how these KPIs will have to be measured in practise. In the following sections, KPIs will be explained shortly, next a list of KPIs useful to inventory management is put together and it is described how the scoping of this list is done to select the most important ones.

5.3.1 KPIs and ERP

KPIs are measures or metrics used to help an organisation define and evaluate how it performs. Key Performance Indicators reflect organisational goals. A KPI typically does have to be quantifiable in some way. KPIs are a suitable means for measuring both financial and non-financial performance of an organisation. Some measures are easy to define, like costs for example. Other, non-quantifiable measures, like customer-satisfaction for example are far more difficult to measure.

ERP is able to capture data of financial and nonfinancial nature (Wier et al., 2007): both measures are of importance (Sedera et al., 2001), (Kaplan & Norton, 1992). KPIs can automatically be calculated using information already available within the software. Some measures are however more difficult to measure: customer satisfaction for example. The input for ERP-software, usually concerns KPIs as well. KPIs are thus strongly related to ERP because they provide the input for ERP packages, as well as the output.

5.3.2 Relevant metrics

KPIs relevant for inventory management are collected (See Appendix C). Literature research was done and a long-list of KPIs was put together. As Gunasekaran et al. (2001) indicate, metrics can be identified on different levels: strategic (long-term), tactic (mid-term) and operational (short-term). The focus of this research in on the development of a BI-tool for measuring operational performances and therefore only operational metrics were collected. Various sources of literature were consulted in order to gain as much information as possible and make cross-validation checks possible (data triangulation, see (Denzin, 1978)). An overview of all the metrics that were collected from various sources of literature are presented in Appendix C: this appendix also shows the sources where these KPIs were found.

Appendix C is far from exhaustive. It would be impossible to create an exhaustive overview, because the number of possible measures can be almost limitless (Fawcett et al., 2007), and one would have to read all literature on this topic to collect all metrics. However familiarities can be seen between these seven different sources of literature already. Due to these similarities it is not interesting to search any further, because that would most probably only show more overlapping KPIs and would presumably not provide much different or new inputs. Also the list consists of nearly one hundred KPIs which seem sufficient to select the most important ones from.

The scoping of this list is done using the inventory process overview depicted in Figure 9: the KPIs on this long-list are mapped to the different process steps. The long-list shows overlap, which was logically eliminated when selecting KPIs for each process. Also KPIs that are mentioned by several authors were selected more easily because of their appearance in various literatures it is assumed that they are therefore more commonly used and are thus more important to measure. Furthermore based on literature and knowledge gathered through expert interviews (two SAP experts from KPMG and periodical meetings with the supervisors) the less familiar KPIs were also screened. Also expert judgment was necessary to identify KPIs that are missing on this long-list. Finally based on literature, own intuition and expert-judgements to evaluate the outcomes of that, a performance measurement framework is designed. The next chapter elaborates on the designing and the resulting framework.

PART IV. DESIGNING

6 PERFORMANCE MEASUREMENT FRAMEWORK

"It is the framework which changes with each new technology and not just the picture within the frame" – Marshall McLuhan (1911-1980)

After selecting a suitable method and identifying relevant metrics for inventory management in the previous part, the knowledge that was acquired is now used to design a framework in this section. The framework represents a theoretical view on reality. In this case the framework is a combination of the business processes identified earlier and the KPI-method applied to that. The framework is a useful tool which provides a structured way of measuring the performance of inventory management. Based on the process-steps taking place at inventory management, depicted in Figure 9 and the KPIs that were identified and scoped as described in the previous chapter, the framework is designed as a combination of those. The framework offers a useful tool to measure how well the inventory processes are managed; the framework indicates what to measure and compare if one would like to benchmark several situations. According to the hypotheses described in Chapter 4 (and shown in Figure 10) different performances are expected.

The final framework is presented below in Figure 12 which is the result of literature review, scoping KPIs and expert judgements[8]. Appendix D presents the final framework in more detail, with a detailed description of each KPI.

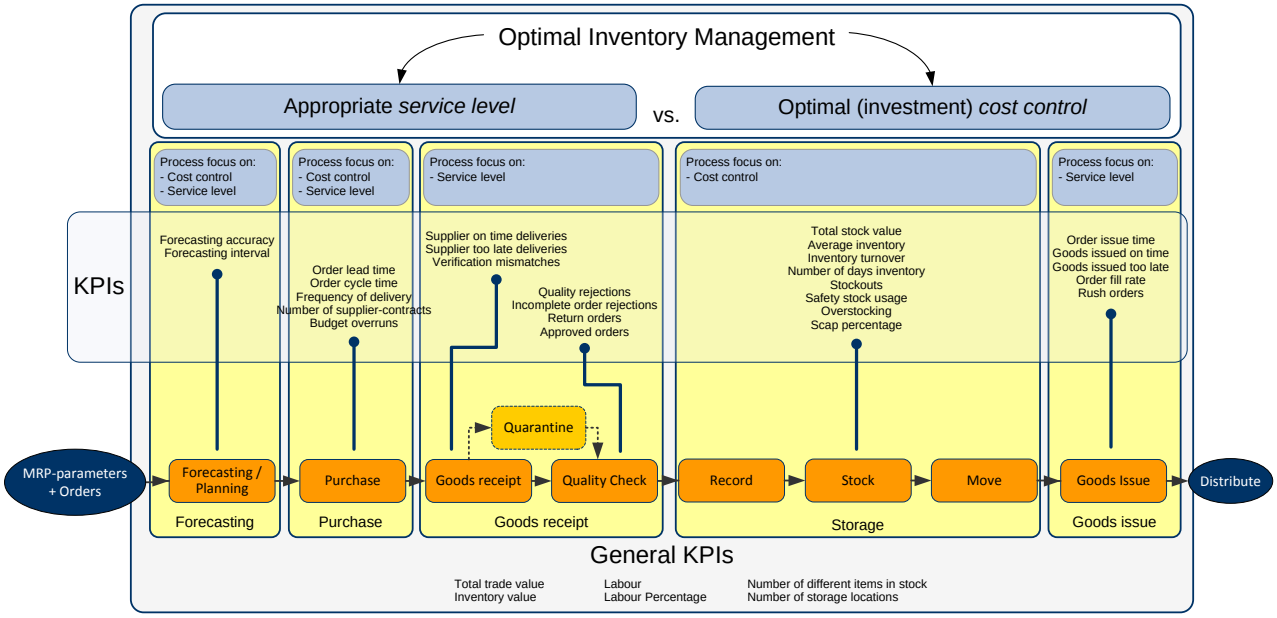


FIGURE 12 INVENTORY PERFORMANCE MEASUREMENT FRAMEWORK

The dark blue oval blocks represent in- and outputs. The MRP input in this case concerns only the Material Requirements Planning (MRP) and not the Manufacturing Resources Planning (MRP II) which incorporates human and machinery capacities as well. The distribution can be of all different kinds: both to internal, external destinations or to the client for example. The light blue blocks on top represent goals which needs to be achieved by good inventory management. The yellow blocks represent the main processes; within each main process one or more processes take place which are displayed in orange. The quarantine process has a different colour, because this process step is optional.

The framework can be viewed top-down or bottom up. At the top of the framework the main goal is represented: optimal management of inventory. In general it can be stated that optimal

[8] Three experts from KPMG IT Advisory commented on the framework. All three employees have years of experience with supply chain management and ERP, and have done projects in this field (or still do).

management of the inventory can be subdivided into two (sub)goals. The first goal is to fulfil a good service level. Typically most organisations cannot afford their inventory department to frequently fail the deliverance of goods that are required for operations. Occasionally an item might not be available in stock, but in order to maintain a good level of service this issue may not occur too often. Secondly inventory management aims to keep their (investment) costs in control. Of course if a year-supply of each item is held in stock, the service level is very high (i.e. 100%), but than a lot of money is needed to finance the whole inventory. As mentioned before (in section 3.2.1), inventories can tie up large amounts of working capital which can be perfectly used for other purposes as well. Huge inventories are also a source of risks and therefore not desirable. Therefore an optimum has to be found between the desired service level and the related costs. The dilemma between service level and (investment) costs is also underlined in literature by Reid & Sanders (2007) for example, and also by others like (Wild, 2002) and (Dijk et al., 2007). Often a third goal is mentioned as well, namely the operating costs of inventory which includes costs of buildings, personnel costs and energy costs for example. This is only marginally included in the framework (i.e. only the number of personnel is included), because this third goals is far less directly related to the performance of inventory management and concerns secondary performance metrics which are not related to the operational process. This third goal therefore does not have any impact on physical operations and it is thus unnecessary to include in this model.

Following the top-down view, and going from the sub-goals downwards to the bottom of the model, the next thing that is presented are the process steps. In order to achieve the goals on top of the model, each process-step has to perform well. On top of this, the framework indicates which of the two goals the focus is within each process-step; the next section elaborates on this. The inventory process-steps (which were found during the analysis in Chapter 4) are depicted at the bottom. Attached to each process step, the relevant metrics (KPIs) are indicated. There are also metrics that are more general and cannot be attached to a specific process step. For these KPIs a separate level is introduced in which the general metrics of importance are listed: in the framework this is depicted by a separate layer in the background, covering all activities.

By following the above approach, not only one specific part of inventory management is taken into account, but the whole process from forecasting to deliverance of goods. This is necessary, because the uncertainties discussed earlier (in section 3.2.3) exist across the whole process and have their effect on processes downstream. For this reason the scope of the framework is on the whole chain of activities which makes this a more valuable framework. Also different perspectives are taken into account by incorporating various process steps. As mentioned in section 3.3.3 different ideas about inventory management may exist and someone at the warehouse may have totally different goals than the people at forecasting. For this reasons the model incorporates KPIs from the whole process and as a consequence all actors along this process are represented as well. As a result the framework offers a complete picture which enables the users to see or investigate the coherence between different activities or alterations to the process (e.g. using optimizations or new technologies). This framework is typically designed to monitor operational metrics on weekly or monthly basis. A more strategic or tactical level could be placed above the current layer of KPIs and might form a dashboard for achieving targets on the long run. This is however not what the current design is aimed for and therefore those levels are not worked out in the design.

6.1 Detailed description

Not all KPIs are direct measures for internal processes, but also KPIs that measure external factors are incorporated. As mentioned in Chapter 3, uncertainties play an important role in inventory management. Both external and internal causes of uncertainty should be taken into account; therefore for some of the KPIs it is difficult to link them to the performance of internal processes. These metrics are however important indicators to look at if operations are not running smoothly: external factors may form a cause of that and then it is very useful to have metrics that give insight in those external causes. Due to the way the KPIs are presented, it might

look like each process step can be viewed separate from the other steps, but this is not the case. Dependency do exists between the different processes, as the following sections will describe.

Problems at the forecasting can lead to too much stock, or too little stock according to the direction of the bias. This is also the reason why the focus in this process step is on both cost control and service level. If one would forecast too much, this causes unnecessary stocks. Forecasting too little may lead to stock-outs at the warehouse and that will affect the service level negatively. Here the dependency between operations is immediately visible. The other way around, delivery times are incorporated in the forecast to cope with the latency of delivery and in that way forecasting is influenced as well.

At the purchase step, the order lead times, order cycle times and frequency of delivery are metrics that may cause problems further on in the process if these numbers start to increase. If the order lead times and order cycle times are increasing, it may mean that the goods are delivered later and the stock is already depleted. These metrics are therefore strongly related to the offering of a good service level, whereas budget overruns and the number of vendor-contracts have more to do with costs. Purchase thus concerns both goals as is depicted in the framework.

At the goods receipt process step all metrics are concerned with the service level eventually. Whether goods are being delivered on time and in good quality are the main drivers here. Monitoring of supplier performance is indirectly done by monitoring on-time and too late deliveries and the number of approved/returned orders. It is interesting to measure these metrics, because it is an indication how well the suppliers are performing. If their performance is bad it could indicate a cause of bad service levels as well.

The metrics related to storage are almost all concerned with costs. Only the number of days of inventory and the number of stock outs are metrics influencing the service level, all others concern costs. Although two metrics influence the service level in the end, the main focus still is on cost control at this process step. The metrics at this process should together indicate whether the amount of stock that is kept, is efficient. For instance the number of stock outs should not be to high (actually zero), whereas the total stock value, average inventory and the number of days of inventory which might prevent stock outs if they show higher values, should not be too high on the other hand as well. Additionally the safety stock should be used occasionally, because if it is never used that might point to overstocking. Finally if products have to be scrapped this is a waste of capital and generates undesired costs. The metrics at this process step are however less related to other process steps and are thus independent.

In the final process step, the goods issuing part, the focus is on offering a good service towards the client[9]. Actually this is the only focus of this process step. Order issue times indicate how long it takes to deliver a product that was ordered by the client. Furthermore it is interesting to monitor what orders are on time and what orders are too late or incomplete (i.e. order fill rate). The rush order metric has a more external nature, as it is interesting to monitor this metric, because it may negatively influence the other metrics if too much rush orders have to be handled.

6.2 Measuring Hypotheses

In Chapter 4 hypotheses are formulated. The same process steps are again used in the framework. In order to measure and evaluate the identified hypotheses the KPIs shown in the framework should match in a sense that by measuring a certain KPI something can be said about the validity of the hypothesis. Next will be explained how the selected KPIs match with the evaluation of each hypothesis identified earlier:

[9] Whoever that maybe; e.g. an internal or external client.

1. Forecasting/planning: MRP (Improved planning)

Through measuring the *forecasting accuracy* the improvements at this point can be made visible. According to this hypothesis, ERP software has automated MRP functionalities, which should result in better forecasts and planning: the accuracy, which compares the forecast to the actual demand a measure to evaluate how the forecasting process' performance is improving (or worsening).

2. Purchase: Vendor contracting registration

Better vendor contracting should result in a structured way of dealing with contracts. As a consequence fewer faults can be made and therefore the ordering process is running smoother. The *order lead times* in this case should improve as a consequence. Also less *personnel* is needed because vendor contracting is fixed within the system which should reduce the amount of work (register vendors, looking up contracts and prices etc.). Also if all vendors are registered correctly and in the same way, the *number of supplier-contracts* can be reduced. This is because correct and centralised registration creates more insight in the active contracts and this prevents redundant activities from occurring.

3. Purchase: Assign approved vendors

The *number of contracts* might be reduced, because only a selected group can be used. The *quality, completeness* and *on time delivery of orders* should improve as well. Only a few vendors which proved to be reliable on the above criteria are approved and therefore these metrics should improve as well.

4. Purchase: Advanced Budget control

Because budget overrun restrictions can be build in ERP the *number of budget-overruns* should decrease.

5. Goods receipt: Three-way-match (between purchase, goods receipt and invoices)

Because the three-way-match can be performed automatically within ERP there should be fewer mistakes at this point. This improvement should yield an increased *number of verification mismatches* and therefore fewer *personnel* as a consequence, because much more can be done automatically instead of manually.

6. Goods receipt: Vendor Reliability monitoring

If the vendor reliability is monitored frequently and correctly there will be sufficient data about each vendor. This information can be used in price negotiations for example. Also if a vendor for instance fails to deliver good quality or quantity products, or deliveries frequently arrive too late, these failures can also be discussed and are grounded by the collected data. As a consequence vendor reliability monitoring should eventually lead to better *on time delivery*, less *quality rejections* and less *incomplete orders*.

7. Storage: Inventory turnover visibility

Within ERP it is much easier to calculate turnover rates, because all information needed is available in real time. In theory the turnover can thus be better monitored which should result in smaller *safety stocks* and therefore less *overstocking*. If the turnover rate is very low, there does not need to be a very large amount in stock and the *average stock* and *number of days of inventory* can be lower.

8. Storage: Dead stock visibility

This point of improvement is strongly related to the previous point. Because ERP provides better insight in the turnover rates, it is easier to identify dead stocks. Dead stocks are actually stocks that are constantly overstocked: stock is kept that does not need to be there. Removing or lowering this stock eventually also should lower the *total stock value*.

9. Storage: Less scrap due to better information

Less scrap can easily be measured by looking at the *scrap percentage*: with ERP this value should decrease.

10. Goods Issue: Better handling rush orders

Less *rush orders* could be a result, because of the optimised processes (within the software). But In the end better handling of rush orders might especially be seen in the *number of personnel* that is needed. If it is difficult to process a rush order, either more people are needed or the processes should be arranged otherwise to cope with this. With ERP the processes can be optimised, which should eventually result in a lower requirement of people in theory.

11. General: Less faults due to master data

In general this hypothesis states that there might be fewer faults, because all data is stored centrally. Most of the time faults have to be corrected manually. If there are less faults it seems logical that also a decreased *number of personnel* is required.

In the next chapter the two case studies are described. The case studies are used to evaluate the designed framework and test the given hypotheses as an illustration that the designed framework actually works in practice.

PART V. DESIGN TESTING

7 DESIGN TESTING

"Inventories can be managed, but people must be led" – Ross Perot

The framework presented in the previous chapter is mainly based on literature and expert interviews. This chapter tests the framework on its applicability and practical value. In order to do this, three experts reflected on the framework and additionally two case studies are done.

With the two case studies a first attempt is made to reflect on the hypotheses and see what improvements ERP might bring, simultaneously the framework is tested on applicability.

7.1 EXPERT JUDGMENT

Four experts[10] with experience in the field of logistics/inventory management and ERP reflected on the framework in order to provide one additional validation check towards the design. The experts were asked to judge the framework in general and rate the KPIs in each category on its importance: percentages are assigned to each KPI in a specific category by every expert. Appendix F provides an overview of all weights that were assigned. Below the major comments made by the experts are elaborated.

All of the KPIs in the model are considered useful. No single KPI was scored with 0% by any of the experts, which was an option. The average inventory received the lowest score, but this is also the result of many KPIs being in the same category: as a consequence the percentages per KPI are lower because 100% had to be divided over more KPIs. In general the experts agreed that the model seemed correct. There were however a few small comments:

Mr. Hoogewerf commented that some KPIs are actually the same; therefore only one of the two should be measured. For instance the *number of orders too late* measures the same as the *number of orders received on time* only seen from the other side. If only one KPI would be measured this reduces the number of KPIs. This duplication was however used, because it is sometimes very practical to have both metrics, because that gives direct insight and one does not have to calculate anymore: at a single glance both figures can be observed.

Mr. Ploos van Amstel agreed that the model is very suitable for the monitoring of inventory management's performance on an operational level. It was discussed that this framework actually only represents the operational level and therefore might be extended in the future with a more strategic dashboard, which aggregates the operational metrics to a higher level. Considering the framework, the only KPI which he found to be missing was the number of backorders (the orders which the warehouse was unable to deliver and have to be ordered at the supplier). This KPI is strongly related to the order fill rate, but is especially practical to know for the manager at the warehouse, because the backorders represent the articles which need extra attention. Because this metric is not directly part of performance measurement as an output (the order fill rate KPI namely already is in place), this metric is not incorporated in the model.

Furthermore the list of 33 KPIs seemed very long and in total this is a lot that has to be measured. In an ERP environment this should not be very difficult, because a query has to be built once, but in a less integrated environment the calculation of this many KPIs becomes difficult. For this reason it is interesting to know what the most important KPIs are to calculate if one has only few resources (i.e. time, personnel and money). For this reason a TOP-10 is selected, including the ten KPIs that received the highest percentages: in practice this meant 25% or higher which then resulted in a top-10 list. The TOP-10 of most important KPIs can be found in Table 2[11].

[10] Ir. Jacqueline Rutten (Consultant at KPMG IT Advisory); Drs. ing. Frederik Kooistra (Consultant at KPMG IT Advisory); Ramon Hoogewerf, MBA (Manager at KPMG IT Advisory); Jhr. Dr. Walther Ploos van Amstel (Senior Logistics Consultant at TNO Mobiliteit en Logistiek).

[11] The KPIs are presented arranged by the process steps. The order of importance is therefore random, for more details on the exact importance of each KPI, see Appendix F.

TABLE 2 TOP-10 MOST IMPORTANT KPIS

Process step	KPI Number	KPI description
Forecasting	7	Forecasting accuracy
Forecasting	8	Forecasting interval
Purchase	9	Order lead time
Goods receipt	14	Vendor on time deliveries
Goods receipt	15	Vendor too late deliveries
Goods receipt	16	Verification mismatches
Quality check	17	Quality rejections
Quality check	19	Return orders
Goods issue	32	Order fill rate
Goods issue	33	Rush orders

These top-ten KPIs combined are very useful already and can serve as a good start. The other 23 KPIs can be added later to gain even more insight in each of the process steps. By implementing the above KPIs, several quick-wins can be gained in performance measurement. It is remarkable that there are no KPIs from storage in this TOP-10 which is mainly because the big wins are not gained at that point in the process. It is the activities taking place before the actual storage which determine the efficiency and therefore it is logical that no KPIs from storage are seen in the above table.

7.2 CASE STUDIES

Besides the expert judgment, also case studies were performed at two different hospitals in the Netherlands. First the type of industry will be described shortly. Next the situations and findings from each hospital are described. Accordingly the results from the two case studies are presented, after which the results will be compared and discussed.

7.2.1 INDUSTRY

The case studies were performed at two hospitals. Although with inventory management one would probably think of production companies at first, inventory management is an important topic in hospitals as well. Traditionally production companies are the classic example in most literature and books, see (Visser & Goor, 2004), (Wild, 2002), (Reid & Sanders, 2007) and others. This comes as no surprise, because ERP originated from production: the planning and coordination of resources and production. Nevertheless hospitals are chosen, because logistics in this industry are studied far less and are becoming more and more important.

Recent developments in this sector make this sector very interesting to investigate. Due to increasing competition in this sector the health care providers are forced to work efficient and at low cost, but on the other hand have to maintain a high quality service level as well (Fluent Zorgadvies, 2009), (Ede, 2009). The Dutch government introduced a new health care system in the Netherlands which is aimed at stimulation of more competition in this market (Ede, 2009), (NVZ, 2006). Hospitals are therefore aiming to become more efficient and focus as much as possible on their core business (NVZ, 2006). Due to the introduction of more competition, hospitals aim to offer higher services against the lowest possible costs. Optimization of processes is a means to reduce costs and offer more efficient services to their clients. In order to reduce costs also optimal inventory management and logistics operations should be in place. Studies estimate that small changes in inventory management, purchase and logistics could theoretically easily yield hundred millions of Euros per year (NVZ, 2006), (TPG, 2004). The importance of good inventory management is growing due to the increased pressure on prices. Within the health care industry, quality is very important and therefore a high service level is usually expected from the logistics department. At first (before the competition) the availability of goods was found more important than efficiency and therefore overstocking was not seen as a problem (Logistiek.nl, 2009). Inventory managers were evaluated on the number of goods that they were *not* able to deliver from their stocks. This stimulated the behavior of ordering too many goods

instead of an efficient amount. Hospitals are moving away from this principle and are currently more focused on optimization of processes.

Most hospitals are looking for cost optimizations and service level improvements; IT is a means to achieve these goals (Fluent Zorgadvies, 2009). Because most hospitals have started to embrace more and more IT in their organisations only the last decade, there are still many differences among hospitals. This makes the hospital-industry perfectly suitable to evaluate the impact of ERP. Among hospitals (especially the regional ones) there are still ones that use separate software applications for different tasks and departments and on the other hand there are also hospitals which implemented ERP already a while ago. These are all reasons to perform case studies at hospitals. Basically three types of hospitals exist:

- *General hospitals* treat various kinds of diseases and have various different kinds of departments.
- *Academic hospitals* (or university hospitals) also treat various kinds of diseases and have many different specialties. The difference with general hospitals is that they are linked to a medical school and therefore combine nursing with teaching to medical students.
- *Specialised hospitals* focus on a specific audience (e.g. a children's hospital) or deal with specific medical needs (dermatology is a good example hereof).

Both hospitals used as a case study are located in the Netherlands and both hospitals are classified as general hospitals in this case. The operation excellence strategy is dominating at both hospitals[12]. Both hospitals aim to provide good care against low costs. Their aim is not to see people coming back, or focus on low prices only for instance. As a consequence inventory has to comply with this strategy as well. Out of stocks for instance might be crucial for a patient and therefore inventory service levels play an important role in these organisations.

Using interviews with purchasers and logistics managers the results from the hospitals are acquired and compared subsequently using pattern matching. At both hospitals a purchasing agent and a logistics manager were interviewed. The framework served as a basis, but the interviews were semi-structured: there was a lot of room for the interviewees to tell their own story about what is going on at their department. During the interviews the KPIs from the framework were discussed and measured if possible and assessed otherwise. Next to interviews, pattern matching is used as a *qualitative* method to structure the processes of both cases and see whether inventory management is done entirely different when ERP is applied, or not. Furthermore *quantitative* pattern matching is performed on the corporate data that is calculated, following the KPIs identified in the framework. If data about a specific metric was not at hand an expert assessed the value as good as possible (occasionally by consulting other employees in the organisation too). The next two sections describe the outcomes found at the two case studies.

7.2.2 Hospital A: Non-ERP

The first hospital that is researched is a medium sized hospital with around 390 beds. The hospital counted around 1500 employees (or 1000 fte's in this case) in total, and about 120 specialists in 2008. The hospital is growing rapidly: typically 10-15% per year. The hospital has one building, located near the city centre. Inventory is kept within the building at two warehouses next to each other: the sterile goods are kept separate for the non-sterile goods.

Inventory management forms a part of the Purchase & Logistics-department. This department is responsible for the transportation and (partly) deliverance of all good, except food and persons, required for normal business operations within the hospital. Their aim typically is to reach a service level which is as high as possible, because especially a high quality of service is very important within a hospital. The service level includes on time delivery of orders and the completeness of these orders (correct order fulfilment).

[12] See section 3.3.1 for more details.

At Hospital A the software that is currently used to support the warehouse and purchase-department is called Vila, which is provided by Getronics. The financial department however uses SAP CO and SAP FI. Financial aspects are therefore not integrated in the same software package and are dealt with separately in another package. The implementation of SAP FI/CO on the financial department was only done recently. Due to this development and Vila no longer being supported, Hospital A now stands for the decision whether to proceed with Vila-software, or switch to SAP at this department as well. SAP MM and SAP SRM would eventually be the modules that need to be implemented to replace Vila and support purchase, logistics and inventory management operations. As indicated Hospital A does not have an integrated ERP solution and therefore will function as the non-ERP example. Hospital A wants to know what the functionality of SAP is compared to Vila: whether they are minimal the same as those in Vila. Furthermore they are interested in the possible benefits ERP may provide, also when the link with finance is finally made. This is a good first situation to test the framework with.

In order to see where the advantages of ERP can be found, first the whole process is described in detail in the next section, in order to compare the situation at Hospital A with Hospital B later on. This helps to identify the improvements in a *qualitative* manner first. Secondly using the framework several metrics were determined at Hospital A and listed in a table in the next section. Using these results the *quantitative* comparison can also be made secondly.

Detailed process steps

In total, three interviews were conducted with two experts from the Purchase & Logistics department: with the head of purchase and a logistics manager. After consulting these experts it turned out that the five main process steps, already identified earlier, proved to be correct. However these steps still seemed very high level and within each process step a number of activities take place as it seemed during the interviews. For this reason a more detailed model is constructed which provides an in-depth view on the way of working at Hospital A. The resulting process overview is depicted in Figure 13 below. The process steps that are executed automatically within the software have *blue* accents, whereas the manually activities are coloured *red*. Figure 13 is followed by a description.

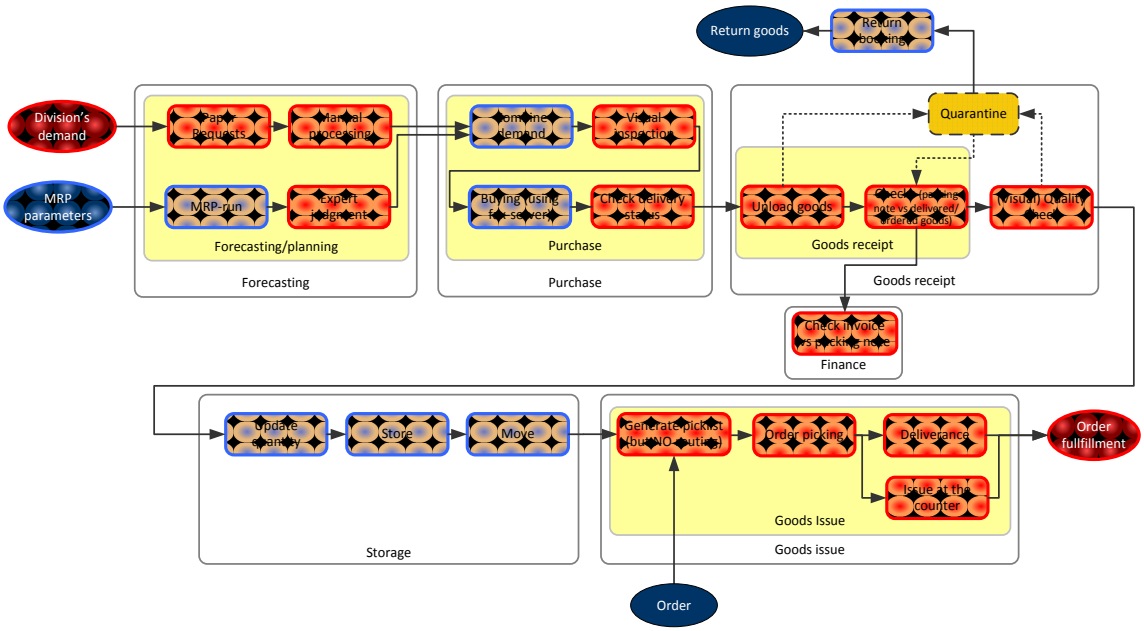


Figure 13 Detailed Process steps at Hospital A

Forecasting

Forecasting in this case does not consist of one 'path' as displayed in the framework, but two paths. First of all a weekly MRP-run is being done in Vila at the warehouse. Tuesday is usually their order day, so every Monday-evening the MRP-run is done. This MRP run generates an advice which is then being evaluated by three experts who (manually) judge the predictions

made by the Vila software. The advice (including the adjustments by experts) is then electronically passed to purchase. Besides the demand generated by the MRP-run at the warehouse, purchase also receives textual-requests (usually written on a note). This is the second source for demand. Each department within the hospital may request goods that are required for operations. They usually write their request for specific goods on a paper note. The textual requests are handed in at the purchase department. These notes are then manually processed and typed into their software.

Purchase

The MRP-advice and the processed paper-requests are further handed over to purchase. At Purchase both sources of demand are combined into one order list, which automatically aggregates all goods to be ordered per supplier. Combining both inputs is done automatically once the paper requests are processed. One large order list is generated because combining orders is more convenient for the supplier and the hospital as well. Combining orders results in fewer orders and therefore less order numbers and deliveries/movements around the hospital. In the end, fewer deliveries and fewer order-numbers which have to be registered, lead to less work. Tuesday is the order-day at Hospital A; all paper requests are therefore aggregated for one whole week and then all ordered at once.

After both sources of demand are combined per supplier, the purchaser will thereupon examine the list of items to be ordered visually. The purchaser checks the list for irregularities (e.g. in prices or amounts). If everything seems correct the orders are placed with the suppliers. This is done with 'one click' of a button: a digital fax server is present which faxes the orders to the suppliers automatically. Subsequently the purchase-department has to check manually whether all orders are delivered correctly. If one or more faxes cannot be delivered they can be sent again or printed and faxed manually. After this the purchase is completed.

Acquiring suppliers and negotiations about prices are additional activities of the purchase department as well. However these activities are secondary to the process above: these actions take place around the normal operation of ordering goods, replenishing supply and making sure all goods required above are present. For this reason these activities are not shown in the overview.

It turned out that budget overruns are an irrelevant measure at the purchase department. Actually budget overruns were not a relevant measure to the entire inventory management process. At Hospital A several people at the different departments are assigned to control the department's budget. For those people budget overruns are a strict measure: the less the better. For the logistics and purchase department however they only get a request for certain articles from the budget-controller and are not concerned in this case with how much of the budget is already consumed. As a consequence budget overruns were found irrelevant in this case.

Goods receipt

After a while the ordered goods are delivered at the warehouse. Here the goods are unloaded first. Some goods may need to acclimatize first and are therefore immediately put in quarantine (held separate from the rest of the stock). This scenario was however not seen at Hospital A. Upon receipt, several checks take place by the people working at the warehouse. They check whether the delivered goods match with what is listed on the packing note and what was actually ordered. If there are irregularities found between these documents, then the head of the department is informed. He will take actions depending on the situation. If for example too much is delivered and it concerns an expensive good, the excessive goods are usually sent back to the supplier. Upon receipt of goods also the quality is controlled visually: the received packages are inspected on dents and damages (e.g. water damage of damage caused by a fall). Sterile goods need to be entirely intact, whereas non-sterile goods may still show small damages. A box of pencils for example will still be accepted if the box shows small damages, but a box of hypodermics will not be accepted in a dent-condition.

Along with the delivered goods also (after a period of time) an invoice is received at the finance department. At this point the process description at Hospital A deviates from what was identified in the framework, because the financial settlement is not incorporated over there. At Hospital A the finance department has a separate software package for the financial processes: SAP FI/CO, as mentioned earlier. As a consequence matching the invoice with the packing note and purchase-order has to be done manually: the purchase orders are not known in SAP and therefore no automatic match can be made. The controls done at the finance department are therefore manual as well.

Returning goods is also shown in the model; this is not present in the framework as well. If goods need to be sent back to the supplier (i.e. because the quality is insufficient or the wrong goods are delivered, etc.) a return procedure is used. The goods are again kept separate from the rest of the stock (in quarantine).

Storage
The process steps at storage correspond with what was identified in the framework. If all checks at the goods receipt process step are passed correctly, the products are registered and the quantity in Vila is then updated automatically. Next the goods are stored at a specific location in the warehouse. Occasionally it is possible that the goods need to be moved.

Goods issue
Upon the requests placed by departments an order pick-list is generated by the software. At this point the goods are also written off in Vila. Next someone makes a round through the warehouse and collects all goods listed on the pick-list and puts it in a cart. Additional, while the orders are picked, the order-picker also checks the available stock: on the pick-list the number of goods that should be there is printed which should match with the number of goods that is actually there. If differences are noticed the head of department is informed to find out what is wrong. Because this is not part of the main process and therefore irrelevant for this research, it is not displayed in the process overview.

The goods issue step as displayed in the framework turned out to actually consist of two separate activities. Some of the goods are brought to the department who requested the goods by the logistics-department. Other goods are just waiting at the desk in the warehouse to be picked up by someone from the department requesting the goods.

Measuring KPIs

After discussing the activities at this Hospital and creating a complete view on all process steps, also the metrics from the framework were discussed. An attempt was made to measure all metrics from the framework. This was however difficult as it turned out. Gathering data was not very easy in this case, because not much data was registered within Vila. Vila did generate nice figures about the achieved service level, but that was about the only information that could be generated through their software. Some figures about the reliability of their suppliers were available also, but not for all suppliers and mostly only when they suspected that a supplier was not delivering according to the agreed terms. A report made by an external consultant provided some additional figures, but in the end still a lot of the metrics had to be assessed by the interviewees. It was striking to see that most measures where only monitored on occasion and no real performance measurement was done periodically (except for the service level figures). Detailed measurement was only done when they suspected a certain situation not being entirely correct, but this happened only after something went wrong for example. Whereas measuring periodically could possibly indicate problems beforehand and in general provides more insight in the performance.

The results of the measured values are listed in Table 3, together with the results from Hospital B: this makes a fast comparison per metric possible. In the table it is also shown per KPI whether the listed value is measured or assessed by the interviewed expert. Next the situation at Hospital B is described. After that the metrics of both case studies are compared to see where the main differences are.

7.2.3 HOSPITAL B: WITH ERP

The second hospital which is researched at is also a medium sized hospital, but is marginally bigger than the first one with around 450 beds (compared to 390 beds at Hospital A). As a consequence Hospital B also counts more personnel: close to 2100 employees (this corresponds with just over 1600 fte's in this case). Part of this number is specialists, in case of Hospital B there are approximately 200 specialists. Hospital B has two locations: one central location where most of the people are stationed and a much smaller location in one of the surrounding villages. The external (smaller) location can be seen as a department, only it is located outside the main building. The supplies for this location are provided by the central location: the smaller external department has its goods delivered just like any other department in the main building only the distance is bigger. Inventory is kept within the main building at two places. There is a warehouse for sterile goods, and a separate warehouse for the non-sterile goods.

Hospital B uses SAP-software: a German ERP software package, described earlier[13]. SAP is used on the financial and logistics department and partly on other departments as well, for ordering goods for instance. Inventory management is thus managed with SAP as well. The hospital uses two modules to coordinate inventory and purchase: that is SAP MM and SAP SRM. Hospital B's policy is to be an innovative and progressive hospital. The use of IT is therefore in an advanced stage and ERP is incorporated throughout the whole hospital. The people at logistics have years of experience in working with SAP and are well capable of using the software. This makes Hospital B a good choice for the ERP-case variant. As the interviews with two experts indicated, the purchase & logistics department is really run like a business and they are therefore very concerned with costs control and high service levels. In order to reduce the costs even more, Hospital B is looking into the possibilities of cooperating with two other hospitals as well. Combining inventory management creates economies of scale and should yield additional cost reductions.

For Hospital B the same thing is done as for Hospital A: the processes were mapped in more detail. This mapping is a simple way of comparing both cases (i.e. easier than comparing two descriptions). Within this process overview it is indicated where ERP is used by the blocks coloured in blue. Because part of the process matches with Hospital A, the focus will mostly be on the differences that were noticed. The next section presents the processes at Hospital B. This helps to identify the improvements in a *qualitative* manner first. Secondly, according to the framework, several metrics are measured and listed. This forms the *quantitative* analysis of Hospital B. Both situations are thereupon benchmarked to each other in the final section.

DETAILED PROCESS STEPS

A more detailed model is constructed which provides an in-depth view on the way of working at Hospital B. The resulting process overview is depicted in Figure 14 on the next page. The process steps that are executed automatically within the software have *blue* accents, whereas the manually activities are coloured in *red*.

[13] See section 2.1.1 for a detailed description and an example in which SAP is used.

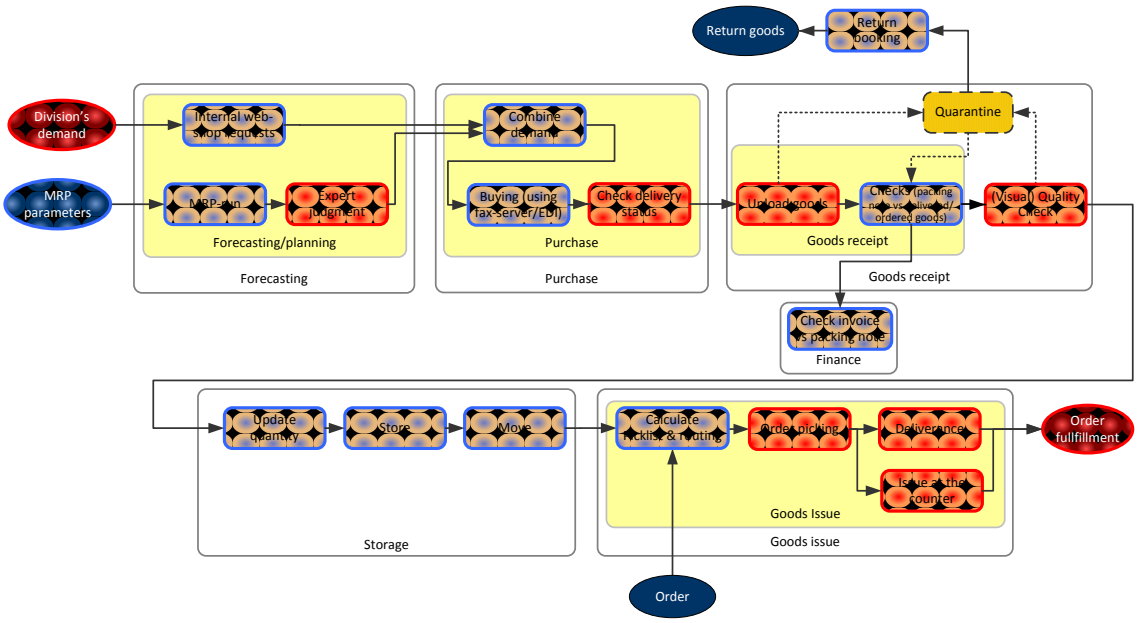


FIGURE 14 DETAILED PROCESS STEPS AT HOSPITAL B

Forecasting

The demand coming in at forecasting (/planning) also has two sources at Hospital B. First a MRP-run is done every night, which results in a buy-advice every morning. By running this every night the hospital is better capable to anticipate on sudden events. If a certain article is suddenly consumed very fast due to certain circumstances, the MRP-run will notice this and adjust the advice. Per article it is possible to define the restrictions according to which the optimal stock level should be determined. Finally an expert (purchaser) will manually evaluate this MRP-advice in the morning and judges whether the advice is correct. Based on experience the amounts are adjusted up or down. With the adjustments made by the expert the order-list is passed to purchase.

The second source of demand is the requests posted by the departments. If a department needs certain items which are needed to execute their work, they can go to an internal website. This website is a part of SAP as well. On this website they have to login first. After logging in they see a catalogue where they are able to select the articles they need. This website looks like a web-shop (like Bol.com for example). The order status can also be read at this website. The catalogue has three different categories to choose from. First there is the department's assortment to select from. These are the articles that are frequently required by the logged in department. Next to the department's assortment also the whole assortment can be seen. Here all goods that can be ordered, and for which the hospital has contracts with suppliers, can be seen. Finally if an article is required that cannot be found in the total assortment, a so called 'tekstaanvraag'[14] can be put in. The purchase department investigates the need and finally processes the 'tekstaanvraag' as well. Articles ordered via the web shop are delivered on fixed delivery days (which vary per department).

Het requests from the internal web shop are automatically processed and directly registered in SAP as well. Here Hospital B differs from Hospital A, because the requests coming from departments where handled mostly manually there. Finally both sources of demand are passed on to purchase.

Purchase

At purchase quite the same happens in Hospital B as was seen at Hospital A. The two sources of demand are combined automatically. Only in this case *no* visual inspection takes place. The combined order-list is sent to the suppliers by the purchase-administration at settled order-days (which are fixed per supplier in SAP). A digital fax-server is used, the same principle as Hospital A

[14] A 'tekstaanvraag' is a request for a certain article that is not present in the standard article-catalog.

uses. After digitally faxing all faxes the delivery status is checked manually: if a fax is undeliverable it can be sent again or even a copy can be printed and faxed the old-fashioned way. EDI[15] belongs to the possibilities as well. In SAP, per supplier can be chosen how the order should be delivered. Most orders are currently placed through the digital fax-server; however EDI can also be selected in SAP and might be used in the future, which can create additional benefits[16]. In SAP other agreements made with suppliers, such as prices discounts, deliver-days are registered in as well. This master data is managed by the purchasers.

Just as was seen in Hospital A, budget overruns turned out to be of no relevance at Hospital B as well for the same reasons as with Hospital A. The people controlling the budgets for ordered goods where not from the purchase & logistics department. Furthermore price negotiations with the suppliers are registered in SAP and therefore ordering a specific article for a higher price is not possible and a budget overrun metric was unnecessary.

Goods receipt
After a while the goods are receipt. At Hospital B the packing note is automatically matched with the purchase order. If fewer items are receipt than was ordered, that number is just booked in the system. On the other hand if more items are receipt it is not allowed to book all items in the system, but only the ordered amount. For the remaining items the purchase department is consulted what to do next, i.e. sent them back or add them to the stock as well. A visual quality inspection takes place after checking the documents. If there are problems the goods are shipped back. Within SAP a return booking is done. Along with the goods that are receipt also an invoice comes in at the finance department. The invoice is taken over in SAP, after which an automatic check takes place between what has to be paid and what is delivered. Next payment is done automatically if this matches (with marginal differences allowed up and down until 3%). Currently the invoice is not electronic, but the next step would be to receive this digital as well (e.g. via EDI). In that case, there is no need for any paper documents at this point in the process as well.

Storage
If everything is correct the goods are booked in SAP and the goods are stored in the warehouse. At the warehouse the article numbers have different prefixes for the different main location (sterile/non-sterile). Also the shelves are numbered alphabetically. This is useful for calculating order-picking routes (see goods issues). Next to these practical differences the process steps at storage are exactly the same as with Hospital A.

Goods issue
At the final process step there is only one big difference. As mentioned shortly the shelves are codified with successive codes. SAP automatically generates a list of goods that need to be picked from the warehouse in order to issue them to the internal client. Using the codified shelves a logical path through the warehouse is calculated. As a consequence the order-picker does not have to walk up and down the warehouse in order to search for all goods listed on the order-pick-list.

MEASURING KPIS

Data retrieval was much easier in this case than at Hospital A. There was already an excel sheet available with several measurements from the last months. It was however difficult to validate the measurements on this sheet and therefore it can only be assumed that the measurement were done correctly. Overall it turned out that Hospital B was much more concerned with measuring certain values in their process; this already formed a good first attempt to create more insight in their performance. Hospital B actively monitors thirteen metrics each month in the following four categories:

[15] EDI stands for Electronic Data Interchange and is an electronic form of communication between different software applications and firms.
[16] Using EDI the orders are electronically placed directly in the system of the supplier, which saves time and effort at the supplier-side: in the end this should result in lower prices.

- Finance
- Client
- Innovation
- Internal

Some examples of the metrics that are measured are:

- Purchase results: money saved on the purchase process.
- Complaints by clients.
- Throughput times.
- Client satisfaction.
- Number of request and order lines.
- Efficiency of bundling orders.
- Supplier reliability.
- Number of supplier reduction.

Using queries in SAP the data is extracted from the software and placed in excel, which is then used to plot the results in nice charts and graphs to make it more visual. Following the framework, metrics were measured. A lot of the metrics could directly be used from their own excel sheet. Some metrics that were missing could easily be measured using a query in SAP as well, and a few metrics still had to be assessed by the experts at the department, because there was not enough time to create a query for all metrics and extract all required data from SAP.

The measured results are listed in Table 3 in the next section, right next to the results from Hospital A. Again the table shows for Hospital B what KPIs are actually measured and what KPIs are assessed by the logistics experts that were interviewed.

7.2.4 Benchmarking

Having both cases described and presented, the results are now compared to each other in the following sections. First the focus will be on the qualitative difference between both processes. Next a quantitative comparison will be made between the KPIs measured according to the framework and finally hypotheses are tested.

Comparing Processes

Looking at the two process overviews that were constructed for both hospitals, several things can be seen[17]. First of all the five main process steps that are identified in the framework matched with what was found in the case studies: the five procedures of forecasting, purchasing, goods receipt, storage and goods issue are found at both Hospitals as well. Following the pattern matching principle (Yin, 1994) the same pattern was thus found in practice, as was designed in the framework beforehand.

It turned out however that within each of these five processes an even more detailed picture could be constructed, which was done. In general the processes taking place at both hospitals largely look the same. Nonetheless three major differences can be observed:

- **At forecasting:**

At the forecasting it turned out that also requests from different departments formed a separate stream of input (see snapshots in Figure 15). In the ERP case this process was totally automated via an internal web-application (as a part of SAP SRM), whilst in the non-ERP case (Hospital A) a lot had to be done manually concerning these demands which is a labour-intensive job and therefore requires more personnel and thus more money.

[17] See Appendix E for a larger view on both processes simultaneously.

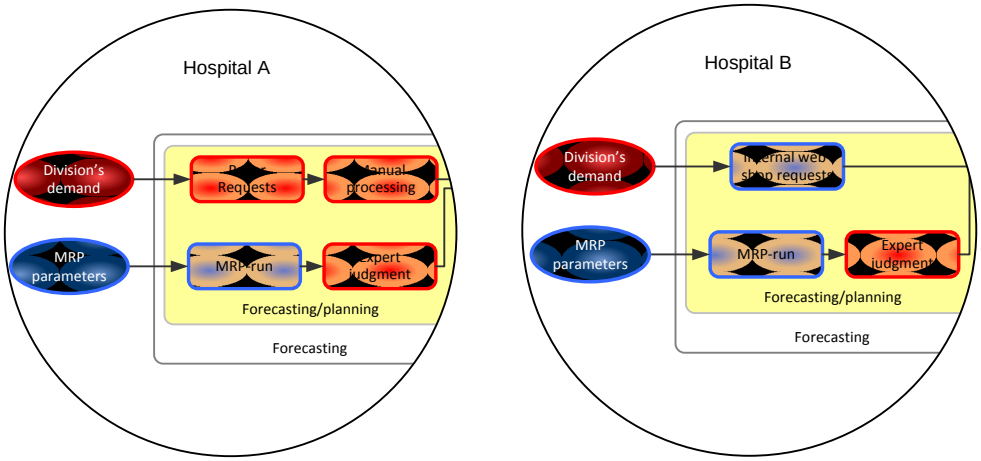


FIGURE 15 BENCHMARKING: DIFFERENCES AT FORECAST

- **At goods receipt:**

At the goods receipt process there was a difference also at the checks that take place, see Figure 16. At Hospital B, with ERP, the check between the purchase order and the delivered goods takes place automatically. Also the invoice is automatically compared to the delivered goods (i.e. numbers/items). No manually checking takes place at this point anymore, whereas without ERP, occasionally faults are made and the finance department then has to check with purchase what went wrong. This costs time and money. In the ERP case this process was automated and it is harder to make a mistake, which is a huge advantage.

Although this difference between cases might look likes a simple blue block in the process overview it is indeed a significant advantage in practice. The error rate can be lowered which saves a lot of money. And because this process is running much smoother a lot can also be saved on personnel cost. The only problem with this advantage is that it is hard to measure or prove how much money is actually saved. This is difficult to indicate if two cases are compared, because other factors influence this process as well and might well be the cause of an improvement instead of this automation.

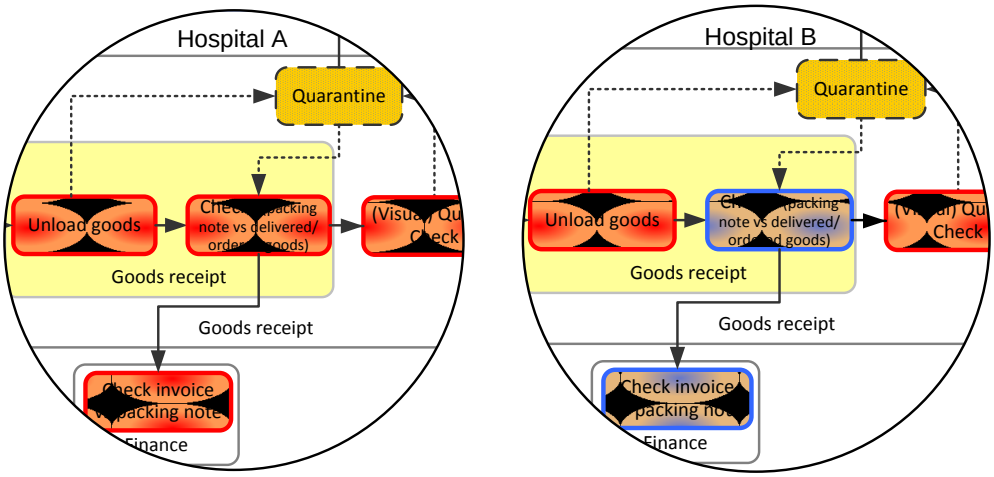


FIGURE 16 BENCHMARKING: DIFFERENCES AT GOODS RECEIPT

- **At goods issue:**

Finally the third difference between both process overviews is at the goods issue process step, see Figure 17. At Hospital B it was seen that not only pick-lists were generated by SAP, but also the routing is taken into account. This saves work for the people working at the warehouse and picking the orders, because the routing is calculated and the pick-list is sorted by that, thus a logical path through the warehouse can be followed which saves time and effort.

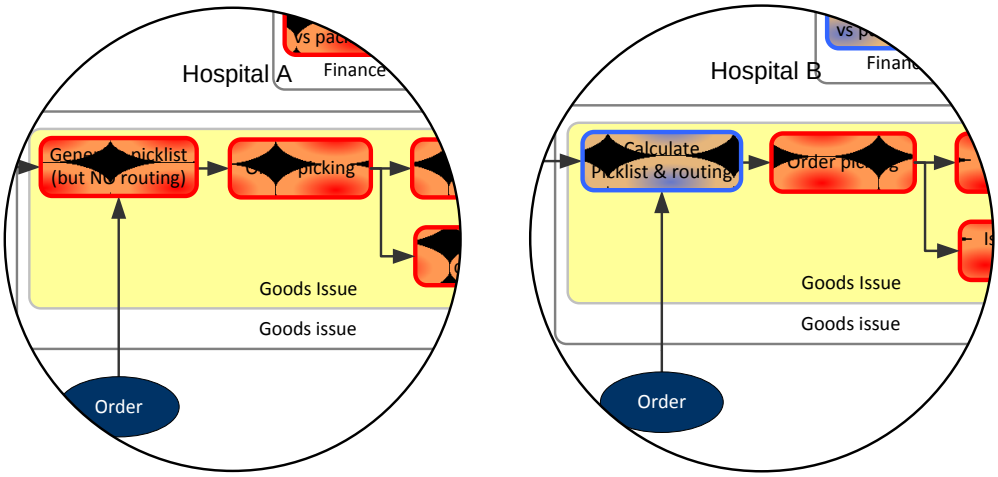


FIGURE 17 BENCHMARKING: DIFFERENCES AT GOODS ISSUE

These were the three major differences that were seen if the situations are compared on a (qualitative) process level. Next the metrics according to the developed framework are viewed in detail. This is done for two reasons. First to see how easy it is to apply the framework and second to make a first attempt to carefully say something about the improvements ERP might cause (i.e. to test the hypotheses).

COMPARING METRICS

The measured values from both hospitals are listed in Table 3 below. Next to each value it is indicated whether the value was actually measured or assessed by the experts at the hospital. The values in Table 3 are measured as prescribed by the framework[18]. Due to the lack of data about certain KPIs and the restricted time, which prevented measuring all the missing data, not all metrics could be measured as the framework prescribes. Therefore some KPIs are assessed rather than measured: after each value it is indicated whether the value was actually measured (M) or is based on an assessment (A) of an interviewee from the purchase & logistics department.

TABLE 3 COMBINED HOSPITAL DATA

Metric	*Value Case A*	*Measured/ Assessed*	*Value Case B*	*Measured/ Assessed*
Case specific metrics				
Number of beds	386	M	449	M
Number of personnel	1,511	M	2,075	M
Number of personnel (fte)	1,017	M	1,642	M
Number of specialists	117	M	154	M
General metrics				
1. Total trade volume	€ 108,267,000	M	€ 154,720,646	M
2. Inventory Value	0.35%	M	1.07%	M

[18] Take a look at Appendix D for a detailed description of each KPI.

3. Personnel	Total: 20.4 fte Purchase: 4.6 fte Warehouse: 16 fte	M	Total: 19 fte Purchase: 10 fte Warehouse: 9 fte	M
4. Personnel percentage	53.4%	M	11.4%	M
5. Number of different items in stock	Sterile: 448 Non-sterile: 1490	M	Sterile: 250 Non-sterile: 800	M
6. Number of storage locations	2 (sterile/non-sterile)	M	2 (sterile/non-sterile)	M
Forecasting				
7. Forecasting accuracy	95.0%	A	100.0%	A
8. Forecasting interval	Weekly	M	Daily	M
Purchase				
9. Order lead time	2-3 days	A	1-2 days	A
10. Order cycle time	7 days (Weekly)	M	7 days (Weekly)	M
11. Frequency of delivery	Weekly	A	Weekly	A
12. Number of supplier-contracts	460	M	310	M
13. Budget overruns	*<irrelevant>*	--	*<irrelevant>*	--
Goods receipt				
14. Supplier on time deliveries	95.0%	A	95.0%	A
15. Supplier too late deliveries	5.0%	A	5.0%	A
16. Verification mismatches	*<unknown>*	--	0%	M
Quality check				
17. Quality rejections	0.1%	A	1.0%	A
18. Incomplete order rejections	20.0%	A	2.5%	M
19. Return orders	3.0%	M	<1.0%	M
20. Approved orders	97.0%	M	99.0%	M
Storage				
21. Total stock value	€ 386,000	M	€ 1,663,030	M
22. Average inventory	*<unknown>*	--	*<unknown>*	--
23. Inventory turnover	*<unknown>*	--	*<unknown>*	--
24. Number of days inventory	*<unknown>*	--	*<unknown>*	--
25. Stock outs	*<unknown>*	--	*<unknown>*	--
26. Safety stock usage	*<unknown>*	--	*<unknown>*	--
27. Overstocking	*<unknown>*	--	*<unknown>*	--
28. Scrap percentage	<1%	A	<1%	M
Goods issue				
29. Order issue time	1.4 days	M	Within 4 days	M
30. Goods issued on time	88.9%	M	95.0%	A
31. Goods issued too late	11.1%	M	5.0%	A
32. Order fill rate	86,6%	M	95.0%	A
33. Rush orders	*<unknown>*	--	2.0%	A

It was not possible to measure or assess all 33 KPIs; therefore some values are listed as <unknown> in the above table. Especially at the storage part it was really difficult to get actual values, because the above KPIs are usually not measured. Assessing the values at that point was also not possible, because it depends heavily which article it concerns. Also because there are over 300 articles in the warehouse of both hospitals it is very hard to make a good assessment for a few goods. In the ERP case (Hospital B) it should have been possible to construct queries in SAP in order to measure these KPIs, but due to the time constraint and the time it would take, this could not be managed. The cooperating hospital was limited in their time and eventually could not provide these numbers. Using the other values that are measured or assessed each

hypothesis is discussed below. The hypotheses are evaluated based on the metrics that were identified and addressed as important in section 6.2 earlier on (e.g. improvements are considered to be seen on the KPIs described in that section):

1. Forecasting/planning: MRP (improved planning)

According to this hypothesis, ERP is superior in performing MRP-runs and is therefore very accurate in its performed forecasts. The *forecasting accuracy* between both cases should be compared: for the two cases, a better performance can be seen at Hospital B which uses ERP. An important remark immediately needs to be placed at this observation, because both accuracies are assessed by the interviewees and are therefore not very reliable. According to the numbers presented in Table 3 above there is however no evidence that falsifies this hypothesis: this hypothesis is therefore not rejected.

2. Purchase: Vendor contracting registration

To validate this hypothesis the *order lead times* and *number of personnel* should be compared between situations, which should indicate whether processes are running smoother. The number of personnel at Hospital A in proportion of the total inventory, compared to the number at Hospital B is almost five times as high. This means that for the same amount (value) of inventory that has to be managed, Hospital A has five needs five people, compared to one at Hospital B. The order lead times are also shorter at Hospital B. Both these measure could point to an improvement at this point. The same remark as with hypothesis 1 has to be made here: the order lead times are assessed and therefore not entirely reliable. The reduced amount of personnel may not only be caused because vendor contracting registration reduces the amount of work, but might well be the result of other factors as well. Based on the number of *supplier contracts* (which is far less at Hospital B) and the observations done during the interviews it can be acknowledged that Hospital B is more concerned with selecting a smaller group of suppliers than Hospital A does and handles its supplier-contracts in a much more structured (centralised) way which eliminates redundant work.

3. Purchase: Assign approved suppliers

Only allowing articles to be bought at approved (preselected) vendors was actively done at Hospital B. The reduction of vendors was monitored as a KPI and formed a separate goal at Hospital B. The number of *supplier-contracts* could very well be measured and is significantly lower at Hospital B. In terms of *quality rejections* and *too late deliveries* no real difference exists between the two situations. In the end, ERP thus shows no real noticeable significant benefit at this point if the two test cases are compared.

4. Purchase: Advanced budget control

Both Hospitals indicated that budget control lies outside the scope of their activities at inventory management. It is the responsibility of the department that requires specific articles to keep an eye on their own budget. Because budget control lies outside the scope it is difficult to say something about this hypothesis. No hard numbers can be given at this point, but Hospital B did indicate that with an ERP package the departments get more insight in their remaining budget and consumed budget, because of the integration these numbers can be registered and viewed in real-time by the ones who manage the budget.

5. Goods receipt: Three-way-match (between purchase, goods receipt and invoices)

The number of *verification mismatches* at Hospital A is unknown. However during the interviews at Hospital A the interviewee already indicated that occasional meetings with people from the finance department were necessary to solve lack of clarities. At Hospital B the matching process went automatically (with an automatic fault margin for deviations in price of 3%) and therefore the number of mismatches is very low (the interviewee even indicated zero percent) and no such meetings were necessary. As indicated before Hospital B uses fewer personnel for the same amount of inventory. Overall it can be stated that this hypothesis is plausible; the automatic three-way-match reduces faults and required personnel.

6. Goods receipt: Supplier reliability monitoring

For testing this hypothesis one should look at *quality rejections*, *on time delivery* and the number of *incomplete orders* as indicated earlier. The percentage of on time deliveries is the same in both cases. The percentage of quality rejections does not deviate very much from each other as well, although case A shows a slightly better score here. Finally the number of incomplete orders is a measure to see whether the suppliers are more reliable as a consequence of better monitoring and selecting suppliers. As measured at Hospital B (with ERP), only 2.5% is rejected because the order is incomplete. At Hospital A an interviewee estimated this number at 20% which is much higher. Actively monitoring supplier reliabilities was not only done in both cases when a certain supplier was suspected of not offering good service: in those cases the supplier was monitored for a while in order to use this data in the next negotiations.

7. Storage: Inventory turnover visibility

No data about the KPIs required to test this hypothesis was received and therefore nothing can be said about the validity of this hypothesis.

8. Storage: Dead stock visibility

Due to better insight of stocks using ERP, according to this hypothesis it should be better possible to identify dead stocks and with that reduce the *total stock value*. If the total stock value of both cases is considered, it can be observed that Hospital B has much more stock. Even if the total stock value is expressed as a percentage of the total trade value, which is also bigger at Hospital B, Hospital B still has three-times as much stock as Hospital A has. According to this hypothesis that better insight using ERP should reduce the total stock value is thus not found to be true in this case. There is too little information to explain what causes this larger amount of stock. Assembly when the size of an organisation increases, the uncertainty will also grow and to cope with that the Hospital in this case needs to keep bigger stocks. This might be an explanation of this difference.

9. Storage: Less scrap due to better information

Both were very keen on not wasting any products, because that costs money. Both hospitals therefore kept a strict FIFO (first in – first out) system. Both percentages are less than one, only in case of Hospital B they were also able to measure this value using their ERP software. Based on the two cases, this hypothesis should be rejected.

10. Goods issue: Better handling rush orders

Rush orders and the *number of personnel* form indicators for the ability to deal with rush orders. Hospital A had no data about the number of rush orders. Hospital B estimated the number of rush orders at 2 percent, which is a low percentage, because this means that 98% follows the regular path through the process. The number of personnel is much less at Hospital B (as indicated several times before), which might be caused by the reduced amount of rush orders, although this cannot be said with any certainty. Significant proof for this hypothesis is lacking and therefore this hypothesis is rejected.

11. General: less faults due to master data

Whether less faults are made, is hard to measure, but as a result of less faults, less personnel is required to handle errors or mistakes. Again the *number of personnel* is a measure for this hypothesis together with the number of faults itself, but as indicated that is hard to measure, because then all activities would have to be registered and monitored which is very intensive and often not feasible. It can only be observed that Hospital B requires far less employees to handle the same amount of inventory than Hospital A does. This hypothesis is rejected as a result.

WINDING UP

Overall it was difficult to acquire all data and therefore not a valid comparison can be made, but only an indication can be done towards the improvements that are seen by ERP. In general it can

be said that Hospital B uses far less people to handle the same amount of inventory, but what exactly the causes are of this is quite unclear. However, improvements were seen at the forecasting accuracy, vendor contracting registration and three-way-matching process.

Looking at all the metrics from the two case studies the results do not deviate very much from each other. This can actually be considered quite logical, because both hospitals have the same goals. How process and activities in between are organised may be different, but in the end they get judged by the number of goods they are able to deliver or not, so at the final results no big differences are seen. Only the operations in between might be running smoother and therefore less personnel is required. Hospital B showed a much smaller number of personnel compared to Hospital A and that might therefore be an indication that they benefit from their ERP solution. Looking at the inventory management related metrics no real improvements have been seen.

7.3 Recommendations for both Hospitals

Based on the case studies and the expert judgments several observations are done. Below the recommendations per hospital are discussed, arranged according to the different process steps to make the recommendations better readable.

Hospital A

During the interviews and the measurement of the KPIs in the framework, the following points of improvement are identified:

Forecasting/demand

- An online (internal) ordering system for all the departments could yield a big improvement at the forecasting side. Automation of this process reduces the paper work and as a consequence saves money on required personnel cost.
- An online ordering system for articles also creates more insight towards the (internal) client, because they are than able to see for themselves whether goods are already delivered or not. Currently a lot of questions concerning the delivery times are raised and the purchase department is very occupied with that. Communication via an online ordering system can streamline this communication and create much more clarity within the hospital.
- With an online ordering system the processing of purchase orders can be automated as well, currently a lot of manual work has to be done at this point. If this part would be automated the demand from the departments can be automatically combined with the MRP-run advice.

Purchase

- Centralised management of supplier-contracts should be required. Currently the purchase department does not have clear overview of all the contracts that are maintained. Combining all contracts creates a better negation position (e.g. to enforce discounts) and saves redundancy within the organisation.
- Currently suppliers have a duplicate listing: at the purchase & logistics department and at the finance department. This redundancy causes faults and additional work.

Goods receipt

- A digital check between the purchase order and the received goods (at the warehouse) would save a lot of work. Automating this step would save time and effort.
- If the invoices are received automatically from the suppliers as well, the check between ordered goods, delivered goods and the invoice can even be automated as well. This forms a next step in even further automation of this process. This lies a bit out of the scope of inventory management, but would clear a lot of vagueness.

Goods issue

- Calculate optimal routings would increase the efficiency of the warehouse personnel. The warehouse at Hospital A was not gigantic, but the hospital is growing fast and getting used

to calculate routes at this point would be ideal and necessary if the hospital continues to grow even bigger in the future and the order picking process becomes more complex.

General

- Most KPIs now need to be extracted manually. Only metrics about the service level are currently available, but this represents only one aspect of the whole inventory management process. Several consultancy reports are available which contain lists of KPIs, but these kinds of reports are only done occasionally. It is highly advisable that more KPIs can be extracted automatically on a periodic schedule.
- It would be good to give feedback to the budget holders at the different departments in some way. Currently they have only little information about how much of their budget they have consumed. Using an online ordering system more insight can be created towards the control of their budget. This improvement will however not directly be seen in the metrics of the framework, because this falls somewhat outside the scope of the framework.
- SAP is already available at the finance department; therefore a logical successor to their current outdated Vila software package, would be to implement SAP. Licensing is already present and therefore this will not result in very high additional costs. Integration between departments will then be possible.
- SAP can support all the activities that are currently being performed in Vila; by changing to SAP, no functionalities will therefore be lost compared to the old software.

HOSPITAL B

Hospital B was in a further advanced stage of using SAP (finance, purchase, logistics and internal ordering all worked with SAP), but still some improvements were identified which might improve their process even further:

Purchase

- The purchasing is currently done by a fax server. This could be replaced by EDI. The orders would then electronically be received in the system of the suppliers. This saves time and money at the suppliers which should result in shorter delivery times and lower prices on the long run.

Goods receipt

- The checking of the invoice with the purchase order is still done manually. An improvement at this point would be that the invoices are received electronically (via EDI) and automatically matched with the purchase order: this would improve the checking process and thus save time and money.

General

- Although Hospital B was already using queries and extracting data from SAP, this was still done too little. More key metrics and thorough analysis of those could reduce the total amount of inventory or at least indicate the reasons why this is not possible anymore.

7.4 GENERAL RECOMMENDATIONS

In general it would be a good recommendation to both hospitals to do periodical measurements of KPIs. It is strongly advised to at least measure the TOP-10 KPIs in order to gain more insight in their own process: this should be done periodically, ideally on a monthly basis. Hospital B already did a monthly check up on some KPIs and therefore has already taken the first step. Using SAP and automatic queries, the calculation of KPIs on a monthly basis is of course far easier than in the case where a lot of information has to be gathered and calculated manually.

This chapter focused mainly on the differences between two cases and the usability of the model. Above specific recommendations to the hospitals were given. The next chapter will reflect on this research and the results in general, followed by the conclusions of this research in chapter 9.

PART V. CONCLUDING

8 REFLECTION

Before jumping to the final conclusions, this chapter first reflects on the outcomes (i.e. the framework and the performed case studies) and shortly on the research process itself.

8.1 APPLICABILITY

First the limitations of the framework are described, followed by opportunities to generalise the framework to other industries and technologies than the ones used during this research. Finally this section also describes the potential practical use in business of the developed framework.

LIMITATIONS OF THE FRAMEWORK

The framework is developed based on various kinds of literature and expert interviews. As indicated in chapter five, the list of KPIs that was comprised was not exhaustive. One might wonder whether the number of KPIs from which a selection was made is complete. Related to this it is hard to proof that the framework includes all necessary metrics. This lack of proof might form a limitation to the developed framework, because situations can occur that require a different set or very specific KPIs which are currently not in the framework.

It is however very hard and probably even an impossible job, to create a framework that is complete towards all situations and scenarios. Due to time constraints the selection of KPIs was limited to the number described in Appendix C. Possible other KPIs can be thought of as well. The *maximum amount of stock for a specific article* for instance might be an example of an important KPI. This metric was however not mentioned in any of the literature and therefore not incorporated in the final model. The case studies and expert interviews functioned as a validation for the framework and it can only be assumed that the framework is therefore complete. Even if the framework is not complete, it still proved to be very useful as it is now; this is most important and therefore full completeness of the model is considered an utopia which is very hard to achieve and probably unnecessary as well.

Another interesting point of comment on the framework which might form a limitation in certain situations is the underexposed role of costs within the model. The cost structure is not directly incorporated in the model, but in a more indirect way. Indirectly the measures like personnel and average storage, dead stock and turnover can be related to costs, but costs are not further made explicit in the framework itself. But because the model is really intended to monitor operational inventory process this is however less important. If one wants to do an investment this model is not suitable: a NPV or business plan has to be written in that case instead. The framework is really aimed at monitoring daily operations and therefore it is considered sufficient to have the metrics as they are right now and the explicit choice was made to keep the costs only indirectly present within the model. If the daily operations are monitored and managed in an efficient and effective way, the costs will be lowered automatically as a consequence (which is finally reflected in a lower number of personnel and lower average inventory value).

GENERALIZATION OPPORTUNITIES

The framework is used to test several hypotheses with. The framework is applied at two hospitals and to evaluate the performance of ERP. Interesting to know is whether it is possible to generalise the framework to other technologies and industries as well: the answer will likely be yes. Using the framework to evaluate inventory management in other industries should presumably be no problem at all, because at a production company or grocery store for example the same five main basic processes take place. Although strategies or other production models might be used for instance, the five main process steps that were identified have to be walked through in most cases. Because the framework represents inventory management at a relatively high level the framework should be applicable to various types of industries. One small comment however is that in a production company, besides the purchase process also a production process might form a source of goods, as depicted in Figure 18 below. Accordingly in a production environment the goods are not (always) distributed at the end but might be also re-used in another part of the production process.

These differences however form only small nuances that do not affect the performance measurement of each step. If the production process, parallel to the purchase process, is seen as a separate supplier as well, the same framework can be used again in the same way as before. The framework will thus be very well applicable to production companies also. Actually most literature that is used focuses on a production environment and thus a lot of the KPIs that are collected where supposed for production companies. Therefore the validation of a different industry has theoretically partly taken place, already: looking at inventory management in the hospital industry is not very common. This then already represents a validation in itself, because the set of KPIs that is used are mostly intended for production companies, but turned out to be applicable to inventory management at hospitals as well.

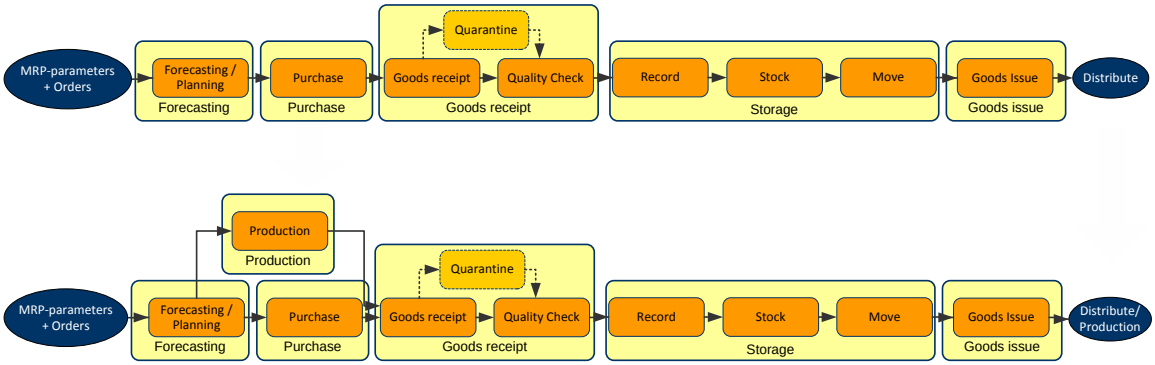


FIGURE 18 ADJUSTED FRAMEWORK IN A PRODUCTION ENVIRONMENT

A second interesting opportunity for the framework lies in its possibility to test other technologies as well. In this research the framework is used to validate hypotheses concerning the improvements caused by ERP. Yet it is quite well possible to use the framework for studying the effects on inventory management caused by other technologies too. The steps that were implicitly taken to evaluate ERP were as follows:

- Formulate hypotheses about the impact of a certain technology.
- Describe what KPI(s) in the framework are expected to improve or be affected.
- Measure all KPIs.
- Reflect on the outcomes and test each hypothesis.

Following these steps it should be possible to investigate the effects of other technologies as well. For instance the effect of RFID[19] on inventory management can be considered.

Taking RFID as an example, one should see improvements at the deliverance of goods; less verification mismatches can take place because human errors are eliminated. Automatic scanning requires less time and personnel is required and the order issuing times can be shortened as well. Furthermore the data from stored goods can be made more up-to-date using this technology which should provide even more insight in slow moving and dead stocks. The scrap percentage can theoretically be reduced as well, if the goods equipped with RFID give a signal if they are about to expire. In theory with the use of RFID the inventory is able to become more active, instead of the passive stocks right now. Of course this is only a theoretical example, but it indicates what metrics can be used to see the improvements of RFID. Naturally more research should be done on this, but this first indication above shows that the framework should be capable of evaluating other technologies as well. Anyhow there are no indicators that are strong enough to prove this statement otherwise.

In this research the framework is used to compare two organisations, but an opportunity for the framework would be to analyse changes over time too. It is advisable to do performance

[19] RFID: Radio frequency identification. RFID is "using short range radio technology to communicate digital information between a stationary location (reader) and a movable object (tag)" (IEEE, 2007). RFID technology can be used to "track products in a manner similar to using bar codes for product identification, but RFID also carries additional benefits. RFID does not require line of sight to read the tag, has a longer read range than bar code reader, and tags can store more data than bar codes" (IEEE, 2007).

evaluation on a regularly basis in any case, but besides periodic monitoring the framework can very well be used to compare 'before and after' situations within a single organisation to see what changes a certain adjustment causes. Because the framework is then used within one organisation a comparison is also easier, because differences in culture, size, personnel, etcetera play a far less important role in that case. These external factors are much more influential when a comparison is to be made between organisations instead.

Practical Business-use

The above generalization opportunities are still quit theoretic, but because this research has been written with the support of KPMG, it is interesting to describe what the practical use for them might be. First of all, one of the things KPMG does is helping its clients to gain more insight in their own business by extracting relevant information from the clients' system (e.g. SAP or Oracle) and generating (control) reports. The designed framework might offer KPMG a structured way to measure the operational performances at a client. Additionally KPMG might use the framework to implement it as a dashboard for operational monitoring of the inventory management process at a client. Additionally the framework might be used during their commercial activities. The TOP-10 of most important KPIs for instance might form an interesting trigger for a client to allow the implementation of the full framework or a performance scan which incorporates all KPIs from the framework. Using the TOP-10 list of most important KPIs it can be shown to the client what the possibilities are and this might help to convince a client to actually perform a full scan or allow the implementation of the full dashboard with all the KPIs from the framework.

Furthermore, as indicated the framework might very well be applied to different industries and therefore KPMG also might use or implement such a measurement framework at different clients within different industries. The possible range of clients where the framework could potentially be applied is therefore quit large. For the organisations that have reached a certain maturity level towards the use and implementation of their ERP-software, this framework is probably less interesting, because they mostly already have some kind of performance measurement dashboard in place. However this framework could provide new insights to them as well. The framework will especially help the organisations which are less mature and which have less experience with ERP and performance measurement. Also to organisations which are starting to implement ERP or are looking to gain more from their current system(s), this model provides a structured approach about what to measure and how to measure it.

8.2 Research process

In this research besides the development of a framework, also an explorative attempt has been made to evaluate the impact of ERP on the inventory process. This comparison should really be seen as a first attempt to compare performances; a more thorough analysis is needed to make the results more valid. In general no real deviations were seen between the both cases. It seemed that the ERP-case performed just a little bit better, although it is very hard to say this based on the limited information that was available: more quantitative measurements need to be done instead of experts' estimates for a more reliable validation of the conclusions.

Finding case studies

Finding comparable cases for the case studies also formed a difficulty. It turned out to be very difficult to find two companies that are comparable (in product, goals, size, strategy, culture etc.). Most large companies do already have some kind of ERP solution implemented (some use older versions, but these are ERP as well). Smaller companies often work with separate software packages and do not have ERP. However a large and a small company are very hard to compare due to the differences in structure, culture and business focus (e.g. local vs. international). This in itself already says something about the extent to which ERP is adopted and implemented in most large companies. This does however not say anything about inventory management improvements. Implementation was often done for financial reasons as Hospital A is currently doing too. Mostly they extend their ERP to other areas later, therefore the wide spread adoption of ERP in large companies is not immediately a good indicator for benefits in inventory management as well. The health care industry finally solved the comparability issue.

As mentioned shortly before, finding different cases that can be compared turned out to be difficult because of the many different kinds of external factors that may influence the final results. Finding cases that are equal enough to make a good comparison and getting them to cooperate with the research process was difficult in this research. Regional hospitals however were found that have more or less the same targets and goals and thus formed a reasonable solution to this problem.

Planning

Overall the research progression seemed quite satisfying, but the total research time might even have been shorter if suitable cases where found earlier in the process. This turned out to be harder than was assumed beforehand and therefore this consumed more time than was actually planned for upfront. Also the summer holidays made it harder to reach the right people, which formed a cause of the delay as well. Meetings were planned on a regular basis, which formed a convenient way of keeping track of the progress.

Personal Experience

It turned out that it is rather complex to compare organisations with each other. I experienced that there might be a lot of disturbing factors which make a good comparison difficult. More effort could have been made to acquire additional case studies in other industries also. However due to time constraints this was only considered, but not performed in the end. I am still very pleased with the number of KPIs that I was able to measure, considering that is very hard to get organisations to cooperate and provide the required information (which seemed not always available as well).

The interviews were a great experience for me as well and I got better at finding out the exact information I wanted. It was interesting to experience how inventory management is performed in different organisations and how software is used to support their activities. During this research I learned a lot about inventory management and the different process steps taking place. The field of inventory management was new to me and it was therefore remarkable to see that the principles of inventory management can be understood quite easily, however some details can become very complex very fast (forecasting models for instance).

My research complements existing literature by presenting something new and following an out of the ordinary approach. My thesis has become quit theoretical; I could have elaborated more on the practical use of my research I think. Also due to time constraints this was not investigated very extensively and could be described in more detail. Altogether I enjoyed working on this topic and research, and I am very proud of the final result.

9 CONCLUSION AND FURTHER RESEARCH

This chapter will return to the research goal stated at the introduction of this report: Designing a tool to assess Inventory Management's Performance. Furthermore recommendations towards future research are provided.

9.1 CONCLUSIONS

Conclusions concerning the framework and hypotheses that are tested in two case studies using the framework are described respectively.

CONCERNING THE FRAMEWORK

The aim of this research was to develop a performance measurement tool for inventory management. As a result a unique framework is developed which enables organisations to measure their operational inventory management's performance. The final framework is shown in chapter six and (a larger version in) Appendix D. The framework consists of five business process steps and attached to each process step KPIs that are useful to measure. The framework provides a specific set of metrics, categorised along the whole process from beginning to the end. This enables its users to see the coherence between the different aspects of inventory management. The framework also enables performance measurement of inventory management in a structured way, due to the pre-described set of metrics. The framework presents a unique approach towards performance evaluation of inventory management, because of the way the model is built up. The framework provides two main advantages over previous measures or models.

First of all, contrary to existing literature the model provides a business process overview of inventory management and the relevant metrics. The structure provided by the framework gives organisations something to hold on to. With the model the inventory process can be evaluated from beginning to the end. This way issues and causes of problems can be better investigated. Uncertainties along the process, which form an important reason for keeping inventories, can be investigated for instance using the structured approach presented in the framework.

Secondly, different actors are represented by the framework due to the span of the framework. This is a good thing, as it makes sure that the accent is not on a single process or output only. Cost drivers for instance are not the only KPIs to steer on and therefore it is useful to measure a whole set of KPIs in order to trace and tackle problems and finally achieve an optimal result which scores good on all goals and towards all parties. Along with the framework, also a first attempt was made to test the benefits of ERP and the framework in practice. The results thereof are discussed below.

CONCERNING THE HYPOTHESES

Along with the framework, a secondary goal of this research was to see how ERP tends to improve the inventory management process. The analysis provided insight into the process taking place at inventory management, which can be seen as a result of this research as well. Figure 19 below shows the results of this analysis. The structured allocation of the potential benefits provided by ERP within the inventory process steps created the hypotheses which were accordingly tested using the framework. Case studies were performed to test the framework with and see how it performs in practice when the framework is used to test hypotheses. Two cases were selected with a different way of working. A situation in which an ERP application is present and an environment where separate software applications are used were investigated. From the case studies it can be concluded that the framework provides a useful tool to make standardised comparisons between situations. The theoretical framework matches with practice and it turned out that all metrics proved to be valuable and relevant.

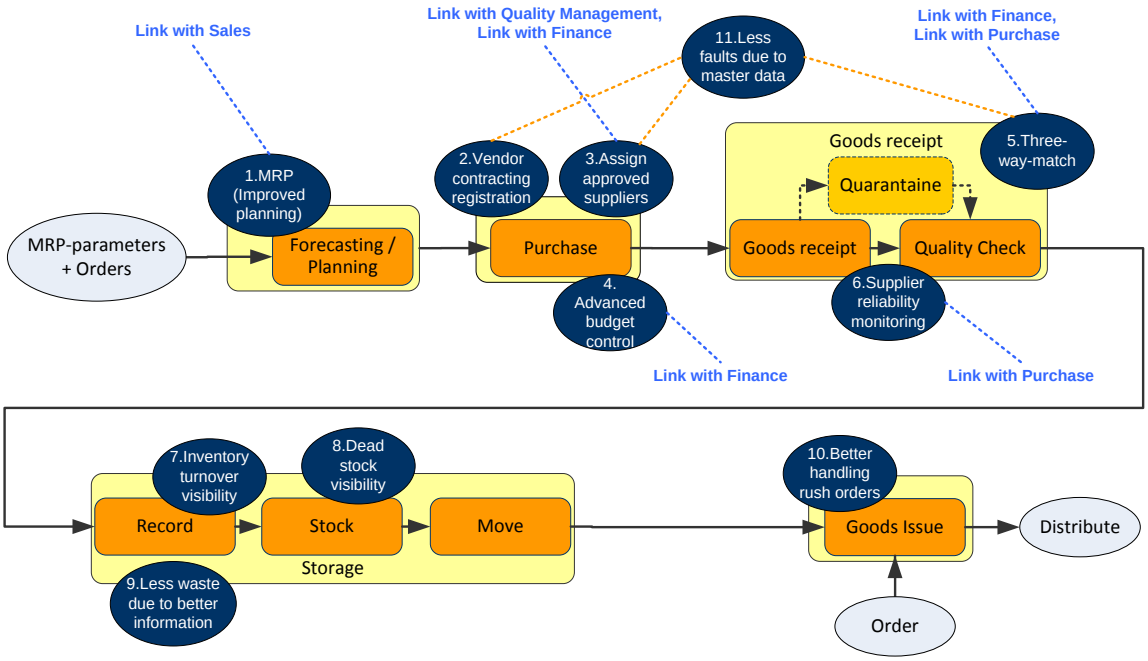


FIGURE 19 POTENTIAL ERP BENEFITS

Additionally the framework proved to be usable for verifying hypotheses towards the use of ERP software. Due to the limited amount of data however the evidence that was found is not very strong. Despite of the somewhat limited proof, the measurement in both cases, using the framework, indicates that three hypotheses were not rejected, namely:

ERP improves forecasting
The forecasting performance of ERP showed better results compared to the non-ERP case study. In the ERP situation also daily forecasts were done which increases the accuracy.

ERP supports better supplier contracting registration
It seemed acceptable that ERP helps to organise the supplier contracts. The hospital with ERP has significantly less people working at the department which is an indication that operations are better managed and are more streamlined. Also the negotiations with suppliers were centrally registered in ERP, which creates the advantage that they have more oversight on all their contracts. This is something which the non-ERP hospital did not have: it was unclear how many contracts with suppliers they had.

ERP simplifies the three-way-match process
The so called 'three-way-match' between the purchase order, packing note and the invoice was much more automated in the ERP case and did show nil faults. In the non-ERP case the interviewees honestly indicated that still a lot of mismatches are seen between these three documents and therefore a lot has to be corrected manually, which requires more personnel as the resulting metrics from the framework also show. Although the metrics at the ERP-hospital do only partly show improvements on this point the interviews pointed out that a lot of time (and money) can be saved by automating this process: ERP enables this due to the tight integration of different departments.

In general to both cases it was remarkable that only a few metrics are currently measured. As a consequence, because the large number of metrics in the framework might seem a lot to implement and measure all at once, a TOP-10 list of most important KPIs has been put together, based on logistics experts' judgments. The KPIs in the TOP-10 represent the most important metrics and together form the quick-wins.

WINDING UP

Overall it was not possible to validate all hypotheses due to a lack of data. However several hypotheses were not rejected and the framework did provide a very good hold when comparing situations. It is strongly recommended to measure at least the TOP-10 KPIs and if possible all the metrics present in the framework to gain the best insight in inventory management processes.

Overall the framework provided a structured way to measure the performances in two cases and made an orderly comparison of the results possible. As a final conclusion it can be put that the strength of the developed model lies within the structured, holistic measurement approach which the framework represents.

9.2 FURTHER RESEARCH

Based on the above statements, the opportunities and limitations described in the previous chapter, it has become clear that there is still some room left for further research. First of all the framework is only applied once in this research; more research to validate the framework and find more evidence would create a more solid basis for the validation of the model.

Secondly research aimed at the applicability of the model in other industries would be very useful. Although chapter eight already indicated that the model could very well be used in other industries as well, this still needs to be validated in an additional research. Creating an overview of the suitable industries where the designed framework can all be applied would be very useful and make the framework even more valuable.

Thirdly the framework is currently only used to make a first attempt at finding the quantifiable benefits of ERP; a more extensive research could extend the proof and make better validation of all hypotheses possible. Currently only SAP was researched, but it would be interesting to take a closer look at other ERP packages too. Also only hypotheses concerning possible benefits were formulated; it would be interesting to investigate the possible disadvantages in a further research as well.

Another interesting topic for further research would be to broaden the scope towards other parties in the supply chain. As the introduction argument, the focus of this research is on inventory management at a single organisation only: it might be very interesting to research the applicability of this model if it would be applied to a supply chain. A possibility would be to have a measurement framework in place at several actors in the supply chain, and see what happens and how the different actors influence each other: a reflection of the activities should be seen in the metrics of the different frameworks accordingly.

The designed framework currently only focuses on measuring operational performances. Further research might be aimed at finding a method to aggregate the results and therewith create a dashboard on a higher level: a strategic level. Aggregating the different results towards a single score will however not be easy and will require extensive research. A way to achieve this might be the ranking of each metric on the same scale and aggregate the scores accordingly, however this does have several implications (e.g. when do you assign a low or a high score) and therefore needs further investigation. The strategic dashboard might for example have only three stages: red, green and orange, which immediately indicate the status. However if a certain indicator turns red in that case, the underlying metrics are necessary to investigate the source of the problem after all and one has to revert to the model presented in the research.

Finally it would be interesting to research external factors, especially the human factor in more detail. This was left outside the scope of this research, but human experience can certainly influence the measures of the model in a drastic way. Finding a way to standardize this influence would make comparisons between organisations more reliable and provides even more insight.

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APPENDIX A. INTERVIEWS

The following table presents the interviews that were conducted with experts. For privacy reasons, some names of the interviewees are kept private in Table 4: the interviewees are mentioned by their function (function descriptions are mentioned in English and are displayed in italic). All interviews were set up in a semi-structured way: basic questions or a model served as basis for the meetings and there was additional room for in depth detailing and discussions.

Besides the meetings listed in Table 4, in between several other meetings (with supervisors) and weekly discussion-sessions where held as well. These meetings are not listed however because they where periodical and where more concerned with the progress and process of the research instead of the contents.

TABLE 4 CONDUCTED INTERVIEWS

Interviewee	Organisation	Date	Time	Subject
Ramon Hoogewerf, *Manager**	KPMG, ITA Den Haag	07-04-2009	16:00-16:45	Brainstorm about demarcation of subject: inventory management.
Dennis van de Wiel, *Consultant**	KPMG, ITA Eindhoven	27-04-2009	14:00-16:00	Inventory management in general: inventory processes, performance measurement and supply chain optimization scans.
Ben Leijdekkers, *Manager* & Maarten Veldman, *Consultant**	KPMG, ITA Eindhoven	13-05-2009	14:00-16:30	Performance measures & Case study possibilities.
Maurice op 't Veld, *Senior Manager* & Jochem van Schooneveld, *ICT Manager*	KPMG, ITA Eindhoven & Fabory	07-07-2009	15:00-15:30	Conference call KPMG/Fabory: case study orientation. Exploring the possibilities to do a case study at Fabory.
Ramon Hoogewerf, *Manager*	KPMG, ITA Den Haag	08-07-2009	15:00-15:45	Framework (process) validation check.
Jacqueline Rutten, *Consultant*	KPMG, ITA Den Haag	13-07-2009	10:00-11:00	Framework validation check.
Stan Aldenhoven, *Senior Manager*	KPMG, ITA Arnhem	14-07-2009	14:00-14:30	Health care sector / Case study orientation discussion.
Hoofd Inkoop, *Head of Purchase*	Hospital A	22-07-2009	13:45-14:30	Case study orientation
Frederik Kooistra, *Consultant**	KPMG, ITA Den Haag	22-07-2009	14:30-15:00	Framework validation check
Teamleider Logistiek*, *Logistics Manager*	Hospital A	21-08-2009	10:00-11:00	First interview with logistics manager.
Hoofd Inkoop*, *Head of Purchase*	Hospital A	02-09-2009	08:30-09:30	Interview with purchase manager: discussed the purchase process.
Teamleider Logistiek*, *Logistics Manager*	Hospital A	02-09-2009	09:30-10:30	Discussed and assessed as many KPIs as possible (viewed available.
Inkoper, *Purchaser* & Logistiek Manager, *Logistics Manager**	Hospital B	03-09-2009	12:45-15:00	Discussed process steps and the use and support of ERP at each step.
Walther Ploos van Amstel, *Senior Logistics Consultant*	TNO Mobiliteit en Logistiek	17-11-2009	13:00-15:00	Framework validation and reflection on other models (from literature and practice: e.g. Staples).

* The interviews marked with an asterisk are entirely worked out: full interview-reports of these meetings are available at request. To check for correctness the interview-reports were sent afterwards to the interviewees for feedback. The interviewees were able to correct their answers or provide any other advice concerning the interview-report as well. This was done to validate the answers and make sure the provided information is reliable (data triangulation (Denzin, 1978)).

APPENDIX B. ERP BENEFITS

Below, Figure 20 shows an enlarged overview of the inventory processes with the blue circles indicating at which points in this process, ERP is able to offer potential benefits. Eleven potential points of benefit are assigned. Also linkages with departments other than logistics are shown.

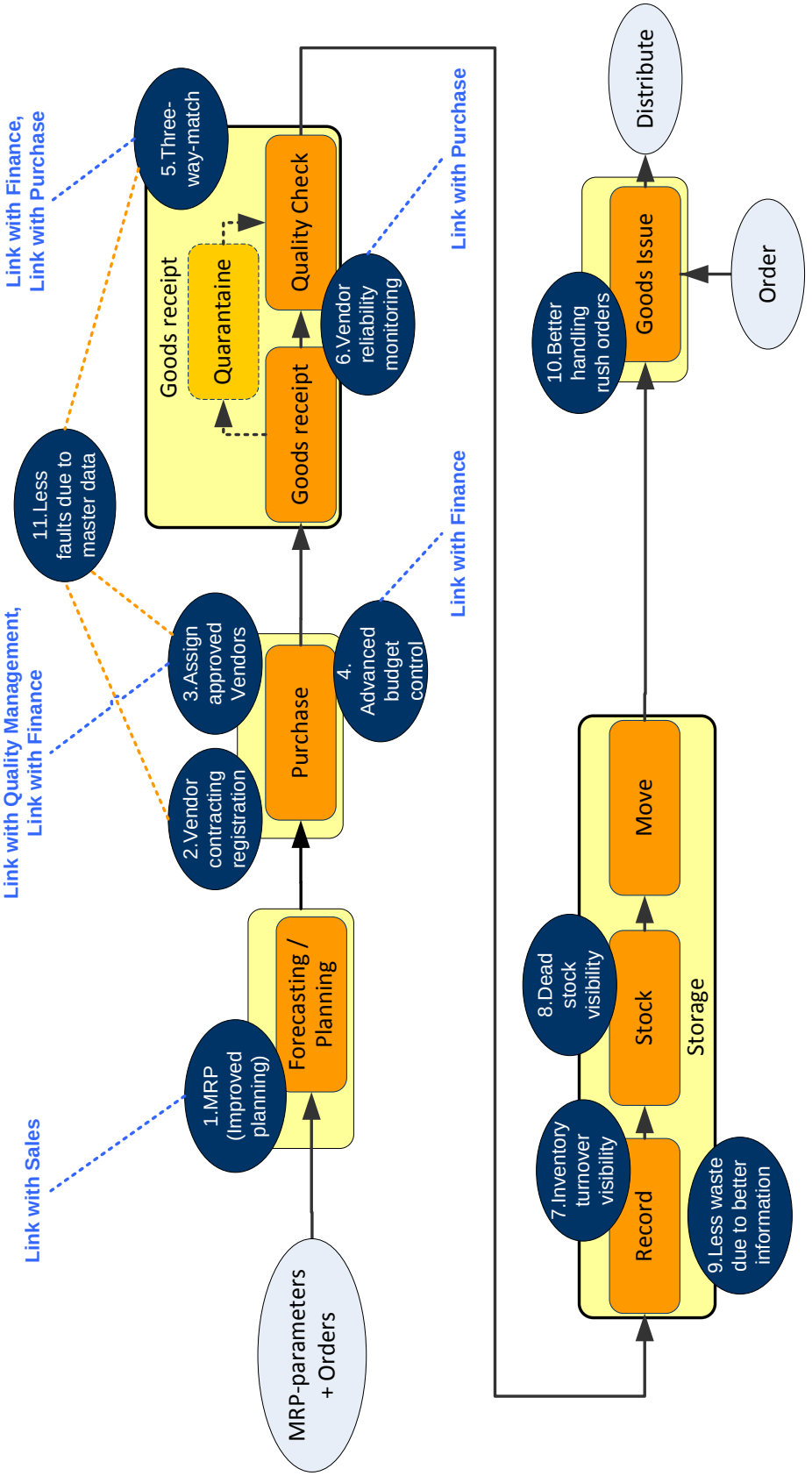


FIGURE 20 POTENTIAL ERP IMPROVEMENT (LARGE OVERVIEW)

Appendix C. Listing inventory KPIs

Below and on the next pages a long-list of KPIs gathered from different sources of literature is displayed:

Nr.	Measure	How to measure	Description
Source: Veldman & Leijdekkers (2009)			
1	Intentory in warehouse percentage	Average inventory in the warehouse(s) / total average inventory, at cost	<not specified by authors>
2	Days of inventory on hand	(1/inventory turnover)*365	<not specified by authors>
3	Inventory turnover	Net sales/average inventory at retail	<not specified by authors>
4	Average inventory per square foot	average inventory at retail / total number of square feet of selling space	This metric also points to excess inventory levels and deteriorating inventory agings.
5	Vendor on time delivery	Annual dollar value of shipments received within purchase order due dates/ total annual dollar value of purchase orders received	This ratio may point to issues relating to vendor performance, vendor relationships or the company's dat processing capabilities.
6	Distribution Centre Inventory Turnover	annual cost of inventory distributed by the DC/ average inventory (at cost) held at the DC	This is very important measure for 'pick from stock' retailers and consumer product companies. This measures the overall efficiency of logistics support.
7	Order fill rate	number of orders shipped from the DC with all units filled as ordered / number of orders shipped from the DC	This ratio identifies problems with inventory postitions at the company's distribution centre, buying (replenishment) or logistics operations or vendor problems.
8	Vendory accuracy of delivery percentage	Annual dollar value of shipments received as orderder / total annual dollar value of purchase orders received	This ratio may point to issues relating to vendor performance, vendor relationships or the company's dat processing capabilities.
9	Return to vendor percentage	Items (euro amount) of inventory returned to vendors / items (euro amount) of inventory received from vendors	This assists in evaluating vendor qualityk, customer murchendise acceptance, etc.
10	Number of vendors	The total number of active vendors. A vendor is typically considered active if purchases have been made within the last year	A large number of vendors may point to opportunities for vendor partnering, which could increase turns, margin, reliability etc.
11	Replenishment order cycle time	Number of days from placing order until the merchendise is received at the DC or store	This measures how quickly a retailer is able to replenish inventory. This measure may point to issues regarding vendor performance, vendor relationships and/or a company's data processing capabilities.
12	Weeks of supply	<calculation, 4 steps>	This calculation represents the number of weeks to deplete inventory using future weeks' retail sales plus future weeks' markdowns.
13	Customer returns	Gross returns / Gross sales	This ratio may identify problems with the quality of vendor goods, customer relations or pricing issues.

Nr.	Measure	How to measure	Description
Source: Veldman & Leijdekkers (2009) <continued...>			
14	Inventory turnover	Cost of goods sold / average inventory	Number of times inventory turns . This provides information about the liquidity of inventory; a higher turnover implies that the inventory is more liquid. It may also be an indicator of the efficiency of the company's inventory management. The higher the ratio, the shorter the time a company holds idle inventory, which has a positive effect on liquidity.
15	Number of days to sell inventory	365/Inventory turnover	Average number of days inventory is on hand (see discussion on inventory turnover above.)
16	Conversion period	Number of days to sell inventory + accounts receivable collection period	Days it takes for inventory to be converted to cash. A longer conversion period decreases liquidity
17	Net trade cycle	Days to sell inventory + accounts receivables collection period - days payables outstanding	The higher the net trade cycle, the larger the required investment in working capital
18	Sales to inventories	Net sales / average inventories	A low turnover rate may indicate overstated inventory, overstocking, obsolete or slow moving inventories, overestimates of sales, etc. A higher than normal turnover rate may indicate inadequate inventory levels to meet sales deman.
19	Sales growth	(current year sales - prior year sales) / prior year sales	Increase in sales over the previous period. As sales increase, inventory and accounts receivable generally increase.
20	Inventory growth	(end Inventory - begin inventory) / beginning inventory	Generally, inventory growth will mirror sales growth. If inventory is growing much faster than sales, this may be an indication that inventory is not selling well or is obsolete
Source: Hendricks et al. (2007)			
21	Order cycle times	<not specified by authors>	The longer it takes to issue a specific order, the more working capital is needed to fund the whole process
22	Customer response times	Order fulfillment date - order placement date	Better response times create more customer satisfaction
23	Delivery speeds	<not specified by authors>	
Source: Kleijnen & Smits (2003)			
24	Fill rate	Orders delivered on time / total number of orders	The percentage of orders delivered 'on time'; that is, no later than the delivery day requested by the customer
25	Confirmed fill rate	<not specified by authors>	The percentage of orders delivered 'as negotiated'; that is, delivered no later than the day agreed between the customer and the supplier (the supplier may discover - upon planning a specific order - that the requested day cannot be realized).
26	Response delay	<not specified by authors>	<not specified by authors>
27	Stock	<not specified by authors>	<not specified by authors>
28	Delay	Actual delivery day - confirmed delivery day	Note that a fill rate (see (i)) less than 100% implies some delay; metric (v)me asures the size of that delay. As with metric (iii), management is interested only in the probability of exceeding a specific threshold value.

Nr.	Measure	How to measure	Description
Source: Krauth et al. (2005)			
29	On-time delivery performance	<not specified by authors>	<not specified by authors>
30	Perfect order fulfilment	<not specified by authors>	<not specified by authors>
31	Inventories	<not specified by authors>	<not specified by authors>
32	Human resource cost	<not specified by authors>	<not specified by authors>
33	Response time	<not specified by authors>	<not specified by authors>
Source: Gunasekaran et al. (2001)			
34	Order lead time	(non-financial)	<not specified by authors>
35	Supplier lead time	(non-financial)	<not specified by authors>
36	Level of supplier's defect free deliveries	(non-financial)	<not specified by authors>
37	Delivery lead time	(non-financial)	<not specified by authors>
38	Delivery perfromance	(non-financial)	<not specified by authors>
39	Accuracy of forecasting techniques	(non-financial)	<not specified by authors>
40	Purchase order cycle time	(non-financial)	<not specified by authors>
41	Deliver reliability	(financial/non-financial)	<not specified by authors>
42	Total inventory (incoming stock level)	(financial)	<not specified by authors>
43	Efficiency of purchase order cycle time	(non-financial)	<not specified by authors>
44	Frequency of delivery	(non-financial)	<not specified by authors>
45	Inventory carrying cost	(financial)	<not specified by authors>
Source: Fawcett et al. (2007)			
46	Raw materials inventory levels	<not specified by authors>	<not specified by authors>
47	Raw materials inventory turns	Cost of goods sold durint a time period / average inventory valued cost during the time period	Average inventorie needs to be determined using as many data points as possible.
48	Inventory obsolescence	<not specified by authors>	<not specified by authors>
49	Inventory turns	<not specified by authors>	<not specified by authors>
50	Inventory days supply	<not specified by authors>	<not specified by authors>
51	Inventory carrying cost	<not specified by authors>	<not specified by authors>
52	Warehousing labor costs	<not specified by authors>	<not specified by authors>
53	Order to delivery cycle	<not specified by authors>	<not specified by authors>
54	Fill rate	<not specified by authors>	percentage of customer demand which is satisfied immediately off-the-shelf (from on-site inventory)
55	On-time delivery	<not specified by authors>	<not specified by authors>
Source: Klundert (2003), SSC (2006)			
56	*Delivery performance*		
57	% late deliveries	<not specified by author>	<not specified by authors>
58	% late items	<not specified by author>	<not specified by authors>
59	% late sales order lines	<not specified by author>	<not specified by authors>
60	% late sales value	<not specified by author>	<not specified by authors>

Nr.	Measure	How to measure	Description
Source: Klundert (2003), SSC (2006) <continued...>			
61	*Fill rate*		
62	% incomplete deliveries	<not specified by author>	<not specified by authors>
63	% incomplete items	<not specified by author>	<not specified by authors>
64	% incomplete sales order lines	<not specified by author>	<not specified by authors>
65	% incomplete sales value	<not specified by author>	<not specified by authors>
66	fines	<not specified by author>	<not specified by authors>
67	*Perfect order fullfillment (on time, complete, and according to specs)*		
68	% perfect deliveries	<not specified by author>	<not specified by authors>
69	% perfectly delivered items	<not specified by author>	<not specified by authors>
70	% perfectly delivered order lines	<not specified by author>	<not specified by authors>
71	% perfectly delivered sales value	<not specified by author>	<not specified by authors>
72	fines	<not specified by author>	<not specified by authors>
73	*Order fulfillment leadtime*		
74	Average time between order reception and delivery	<not specified by author>	<not specified by authors>
75	% of orders delivered before n days after reception	<not specified by author>	<not specified by authors>
76	*Supply chain response time*		
77	Response time to specific changes in volume and product mix	<not specified by author>	<not specified by authors>
78	*Supply chain management cost*		
79	As percentage of overall supply chain cost	<not specified by author>	<not specified by authors>
80	*Cost of goods sold (COGS)*		
81	Production costs	<not specified by author>	<not specified by authors>
82	Inventory costs	<not specified by author>	<not specified by authors>
83	Logistics costs	<not specified by author>	<not specified by authors>
84	*Warranty costs or returns processing cost*		
85	As total or percentage of product cost	<not specified by author>	<not specified by authors>
86	*Cash-to-cash cycle time*		
87	In days	<not specified by author>	<not specified by authors>
88	*Inventory days of suppy*		
89	*Asset turns*	<not specified by author>	<not specified by authors>
90	Sales value/asset value	<not specified by author>	<not specified by authors>
91	*Obsolescence cost*		
92	Cost of unsold goods	<not specified by author>	<not specified by authors>

APPENDIX D. FRAMEWORK

This appendix presents the final inventory management performance measurement-framework, together with a description and detailed explanation of each KPI.

FINAL FRAMEWORK

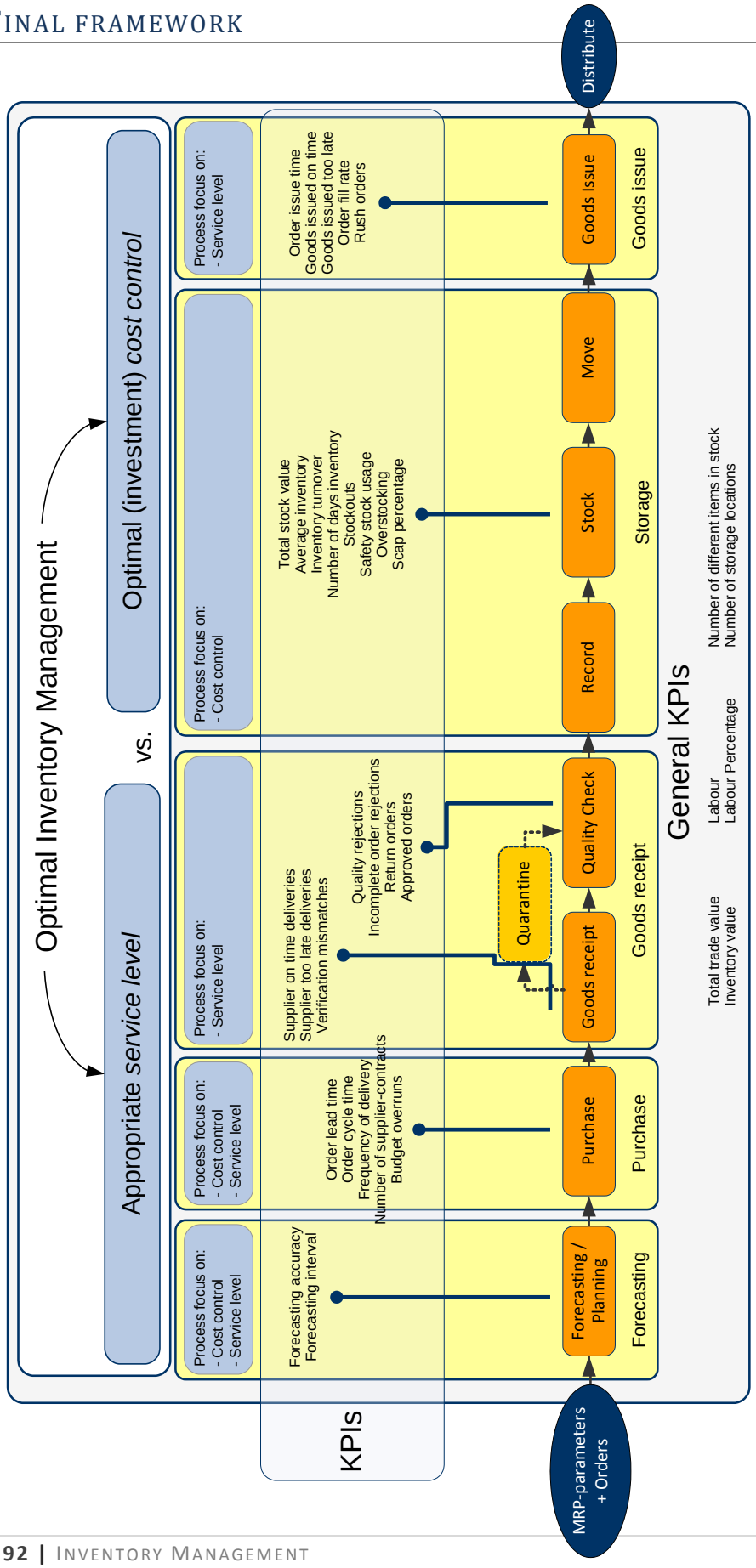


FIGURE 21 FINAL FRAMEWORK (LARGE OVERVIEW)

FRAMEWORK DESCRIPTION

The framework uses the inventory process-steps as a basis, which is depicted by the orange blocks showed at the bottom. A long-list of metrics was composed using literature (see Appendix B). From this long-list of metrics the most important PPIs were selected and related to a specific process-step. This formed the conceptual framework. Additionally this conceptual framework was presented to three experts and discussed with them. Their input was used to construct the final model as presented above.

The framework consists of several 'layers'. The square at the top represents the main target: "optimal inventory management". This target can be divided into two separate targets which contribute to the main target: namely a good service provision against acceptable costs. Accordingly each process step has a focus on one of these targets, and occasionally on both of these targets. Each process-step has one KPI which should indicate on a scale from one to five how well this part of the process is performing. The names used here are just to identify these KPIs. One layer deeper the PPIs can be found on which the KPI is based. Finally the lowest level represents all individual process steps. Next each process step will be discussed briefly and the most important PPIs to each process will be described as well. Also an explanation will be given on which targets the focus will is and why.

Forecasting

A forecast is typically done to make sure that (also) in the future goods are ordered on time and stocks are not being depleted because eventually that will cause items to be out-of-stock. The accuracy which can only be evaluated afterwards is an important PPI for the forecasting process, because this is a direct indicator of how well the forecasts matched with the actual demand. It is important make accurate forecasts in order to keep the costs in control (i.e. not keeping too much stock) and maintaining a good service level (i.e. having the required issues in stock).

The forecasting interval is another interesting PPI, because issues with out-of-stocks may already be caused in the beginning of the process due to bad forecasting. If forecasts are only done once a year the uncertainties usually become bigger over time (i.e. not for goods that have a very constant demand) and there is a great risk that there will be too many or too less stock in the end of the year. A too short forecasting interval is however also bad, because trends can hardly be detected in that case, due to the short time horizon. Forecasting intervals should thus lie somewhere in between: each month is mostly fine to detect trends and also not to make predictions too often.

Purchase

At the purchase process both cost control and maintaining a good service level are important goals. Good price/quality ratios, within budget and in appropriate proportions are important metrics for purchase. Orders need to be place on time for example, because it takes some time before goods are delivered. Furthermore a purchase department often uses budgeting. Budgets are very important: this is usually the metric on which purchases are finally being evaluated. Order lead times, order cycle times and the frequency of delivery can influence the succeeding processes if the performance on these PPIs is low and they are therefore interesting to measure as well. Finally the number of supplier-contracts is an interesting measure of the complexity the purchase department has to deal with; maintaining more different contracts makes it more difficult to maintain all contacts. With many different supplier-contracts is more difficult to negotiate good prices, because the order quantities at each supplier are insignificant to create a strong negotiation position. Too few suppliers however could however make an organisation very depended on the suppliers and that is therefore also not desired.

Goods receipt

The goods receipt process is most concerned with the delivered goods being in order and therefore the focus at this process step, as displayed in the model, is at service level. The main goal is to check incoming orders and only let the correct ones pass this process: all irregularities

should be noticed. For this reasons some important PPIs to mention are quality and quantity (incomplete) order rejections, the number of return orders and the number of approved orders.

Storage
At the point where goods are actually stored, the focus is usually mainly on costs. Only in cases where goods can go bad or have an expiry date the focus is on service level as well (in terms of quality). With fresh fruits or medications for example this might be the case. The scrap percentage is the only metric which provides insight in possible bad management of expiry-good.

The total stock value, average inventory, number of days inventory, safety stock usage and overstocking are all metrics to monitor the efficiency of the storage. Typically the total stock value should not become too big, because that also requires a large investment which is not desired. The average inventory therefore should be reasonable as well, without any stock outs. In principle every stock out is a bad thing, unless the priorities are low and suppliers are able to replenish these goods within a reasonable amount of time. Stock outs are not desired, but conversely the use of the safety stock every now and then is a good thing, because that is where the safety stock is for. If the safety stock is never used for example, this may point to overstocking: meaning that there is constantly too much stock available.

One of the most important metrics during the storage process is the inventory turnover. The turnover provides information about the liquidity of inventory; a higher turnover implies that the inventory is more liquid. It may also be an indicator of the efficiency of the company's inventory management. The higher the ratio, the shorter the time a company holds idle inventory, which has a positive effect on liquidity.

Goods issue
The goods issue process is mainly concerned with offering a good service to the succeeding processes (e.g. operations, production or distribution). Therefore important metrics are the number of goods issued on time or too late: these metrics are good indicators of the deliverance performance. The order fill rate is an important metric related to the on time deliveries, because although an order might be on time, it is not always obvious that this order is fulfilled for 100%. An order might be issued two days before the negotiated date for example, but only half the number of required goods could be delivered: the order is then delivered on time, but the order fill rate is only 50%.

Order issue times are an indicator for the time it takes to issue a required good; shorter times are better because the operations following upon the issued goods can then start earlier or do not have to wait. Finally the number of rush orders are an interesting metric, because this might form an indicator that the (ordering) processes are not running well (e.g. bad communication) or that ‘normal’ inventory management is constantly being disturbed by last minute orders coming in.

The following table shows a detailed description of each PPI used in the framework: for every PPI it is defined how this metric should be measured:

Type	Measure	How to measure	Unit	Description
General characteristics				
1	Total trade value	Total trade value on a yearly basis	€/yr	The total trade volume on a yearly basis indicates the size of the organization.
2	Inventory Value	Total stock value (euro) / total trade value (euro) * 100	%	This value is an indicator for the total size of inventory that is kept.
3	Labour	Number of personnel occupied with inventory management; expressed as a percentage of the total stock value in ten-thousands of euros	fte	The number of fte's indicates how many people are (full time) occupied with inventory (the figure includes forcaster, purchasers and stock-employees).
4	Labour percentage	(labour (fte's) * average cost per fte) / total stock value * 100	%	How many employees are occupied with inventory management as a percentage of the total inventory value.
5	Number of different items in stock	Number of unique items	#	Number of different items held in stock.
6	Number of storage locations	Number of stocklocations	#	Number of locations where stock is kept.
Fore casting				
7	Forecasting accuracy	Forecasted demand / actual demand * 100	%	How precise was the forecast, that was done beforehand in a percentage; higher percentages represent better forecasts. 100% means a perfect forecast.
8	Forecasting interval	AVERAGE (Forecast(n) - Forecast(n-1))	days	Averge time between two seperate forecasts. Forecasts become inaccurate over time, therefore doing more forecasts (shorter periods) will yield better results; however too much forecasting is not good as well.
Purchase				
9	Order lead time	AVERAGE(received day - day ordered)	days	Number of days from placing (normal) orders (without any rush) with the supplier until the merchendise is received at the warehouse (on average).
10	Order cycle time	Order placement day - previous order placement day	days	Period between placing one set of orders and the next at the supplier (working days
11	Frequency of delivery	Number of deliveries (on average)	#/wk	It is interesting to know what the behaviour is of the supplier.
12	Number of supplier-contracts	The total number of contracts with different (active) vendors	#	A vendor is typically considered active if purchases have been made within the last year. A large number of vendorcontracts may point to opportunities for vendor partnering, which could increase turns, margin, reliability etc. and contract management.
13	Budget overruns	Total expenses per year/total budget per year	%/yr	The percentage the budget is overrun during a year. More budget overrruns indicate poor purchase performance.

Type	Measure	How to measure	Unit	Description
Goods receipt				
14	Supplier on time deliveries	Annual value (euro) of shipments received within purchase order due dates / total annual value (euro) value of purchase orders received	%	This ratio may point to issues relating to vendor performance, vendor relationships or the company's dat processing capabilities.
15	Supplier too late deliveries	100% - Vendor on time delivery	%	This ratio shows how many orders were received after the agreed delivery date.
16	Verification mismatches	Number of mismatching-orders found / total number of received orders	%	A three-way check takes place between purchases (negotiated price and articles), goods receipt (quantity and delivered articles) and invoices (price and articles). A larger number of mismatches might indicate miscommunications or unreliable vendors.
Quality check				
17	Quality rejections	Total quality rejections / total orders received * 100	%/yr	Occasional low quality of delivered goods points to an unreliable supplier.
18	Incomplete order rejections	Number of incomplete orders / total orders received * 100	%/yr	Wrong quantities point to an unreliable supplier.
19	Return orders	Items (euro amount) of inventory returned to vendors / items (euro amount) of inventory received from vendors	%	Percentage of orders that is returned to the vendor due to quality, quantity or other issues. This assists in evaluating vendor quality. More return orders indicate poor vendor performance.
20	Approved orders	100% - Return orders	%	This percentage indicates how many orders are approved.
Storage				
21	Total stock value	sum(Number of items in stock * value/item)	€	Summed up value of all items in stock.
22	Average inventory	Stock level from beginning each month / 12	#	This value can also be used to calculate the average stock value.
23	Inventory turnover	(Total quantity sold goods * value) / Average inventory	# of turns	A measure of how quickly inventory is sold. A high turnover means that goods are sold quickly, while a low turnover means that goods are sold more slowly.
24	Number of days inventory	(1 / inventory turnover) * 365	days	The number of days it takes to sell/use all inventory of a specific object.
25	Stockouts	Number of stockouts / year	#/yr	Not enough inventory creates costly disruptions in production/order fullfillment or causes a lower .
26	Safety stock usage	Number of times the stock level is below the safety stock level /year	#/yr	It is good to use the safety stock every once and a while, because that is what it is for. If the safety stock is never used, it may indicate overstocking of an item.
27	Overstocking	Inventory turnover < 2 and the safety stock is never used	y/n	Overstocking ties up capital, which is a waste.
28	Scrap percentage	Value that is scrapped / total stock value	%	More scrap indicates problems in the monitoring and inventory process. A high scap percentage is a wast of money.

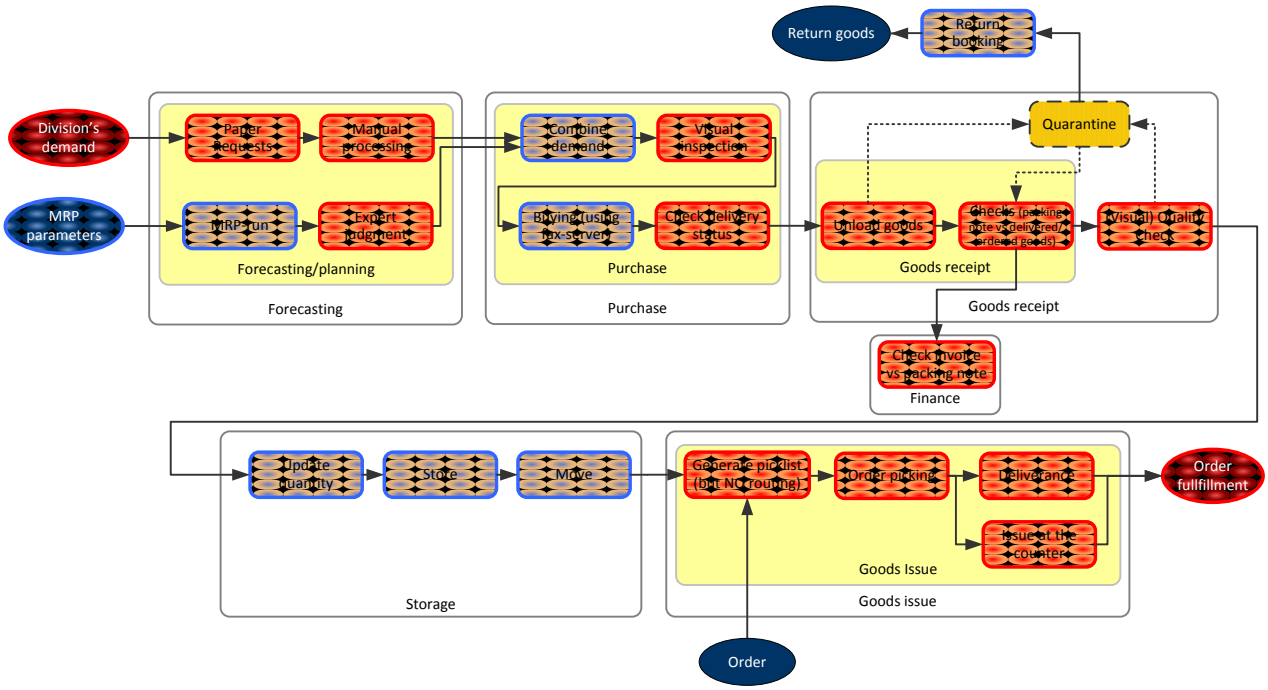
Type	Measure	How to measure	Unit	Description
Goods Issue				
29	Order issue time	AVERAGE(day the order is issued - day the order was internally placed)	days	If it takes longer to issue an item from the warehouse that is requested for production, it might indicate problems in inventory management (e.g. out of stocks, wrong purchases or bad handling)
30	Goods issued on time	Total orders delivered on time / total orders deliverd per year	%	Goods issued before or on the agreed or required date. Goods issued on time is good, because this prevents problems in the proceeding process.
31	Goods issued too late	100% - Goods issued on time	%	Goods issued after the agreed or required date. This forms a problem for the following processes (e.g. production or services that require the goods)
32	Order fill rate	Number of orders shipped with all units filled as ordered / total number of orders shipped * 100	%	This ratio identifies problems with inventory postitions at the company's distribution centre, buying (replenishment) or logistics operations or vendor problems. The difference with goods issued on time is that an order may be issued on time, but it might be incomplete: this metric indicates such issues.
33	Rush orders	Number of rush orders / total number of orders shipped * 100	%	Rush order percentage. More rush orders may cause problems in inventory management, because they are harder to predict and have higher priorities.
	This can only be measured for individual items and therefore ideally has to be measured for two (different) stock-items.			

The KPIs in the above table were found in literature (selected from the long-list op KPIs). Unfortunately not all KPIs had a clear description in literature and therefore most of the descriptions and measurement-definitions are defined based on experiences and logic reasoning. Some descriptions were present in literature and are therefore not altered, but just used as presented in literature.

Appendix E. Cases

Below respectively the business processes from Hospital A and Hospital B are display for comparison. An explanation of the shapes and colours is provided at the next page.

Hospital A: non-ERP



Hospital B: with ERP

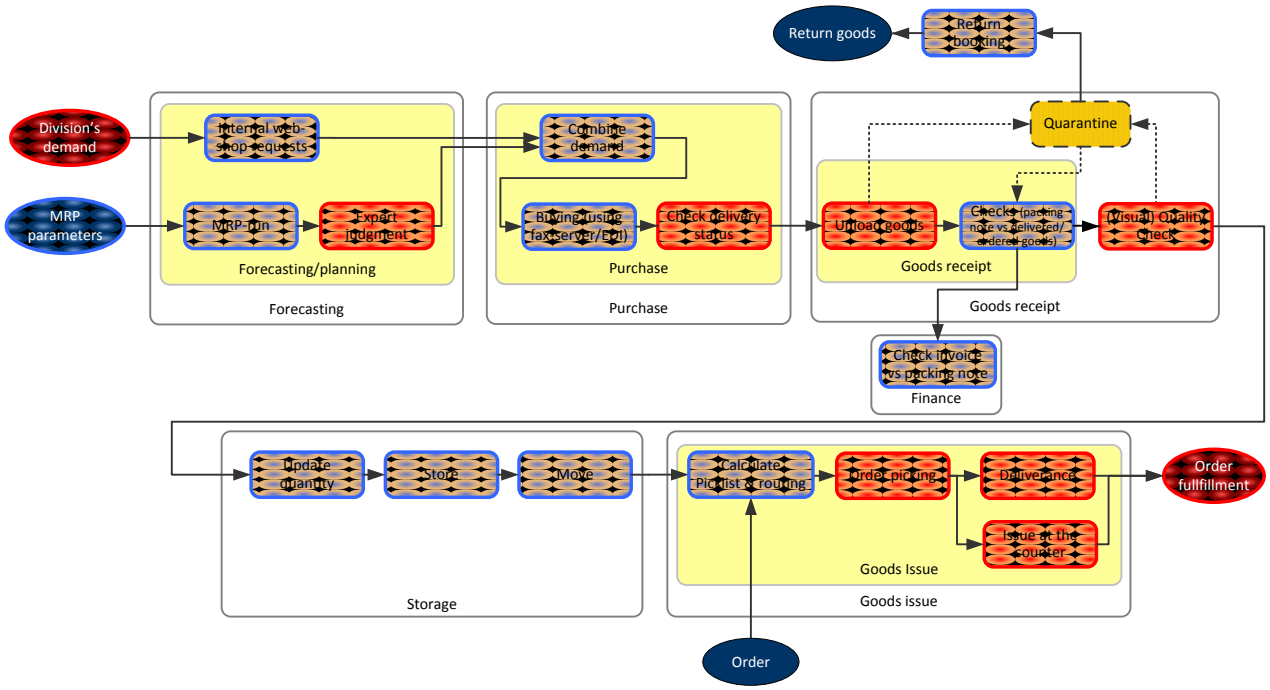


Figure 22 Business Processes Hospital A & B (large, combined overview)

LEGEND

In general: shapes which have a blue colour represent automatic information or processes, whiles red indicates a manual action.

The oval shapes represent in- / outputs. The oval shapes have different colours also:

- Red ovals are manual in-/outputs.
- Blue ovals are automatically generated or processes in-/outputs
- Dark blue ovals are undefined in this picture and can be both manual and automatic: this is however not relevant for the main process and therefore coloured dark blue to indicate this.

The yellow rectangle represents an optional process step. Basically only quarantine satisfies this status. Also dotted lines indicate this optional character.

The white rectangular shapes represent the five main process steps; within each of these process steps several smaller processes can be identified.

APPENDIX F. WEIGHTS BY EXPERTS

Below the KPIs from the framework, together with the assigned weights (of importance) from the three experts is displayed:

TABLE 5 KPIS WEIGHTED BY EXPERTS

			W 1	W 2	W 3	Average Weight	Top-10
	Measure	Unit					
General characteristics							
1	Total trade value	€/yr					
2	Inventory Value	%					
3	Labour	fte					
4	Labour percentage	%					
5	Number of different items in stock	#					
6	Number of storage locations	#					
Fore casting			100%:	100%:	100%:		
7	Forecasting accuracy	%	67%	83%	60%	70%	x
8	Forecasting interval	days	33%	17%	40%	30%	x
Purchase			100%:	100%:	100%:		
9	Order lead time	days	40%	66%	30%	45%	x
10	Order cycle time	days	7%	13%	15%	12%	
11	Frequency of delivery	#/wk	6%	7%	15%	9%	
12	Number of vendor-contracts	#	7%	7%	15%	10%	
13	Budget overruns	%/yr	40%	7%	25%	24%	
Goods receipt			100%:	100%:	100%:		
14	Vendor on time deliveries	%	45%	67%	40%	51%	x
15	Vendor too late deliveries	%	33%	11%	30%	25%	x
16	Verification mismatches	%	22%	22%	30%	25%	x
Quality check			100%:	100%:	100%:		
17	Quality rejections	%/yr	33%	25%	40%	33%	x
18	Incomplete order rejections	%/yr	17%	33%	15%	22%	
19	Return orders	%	33%	34%	30%	32%	x
20	Approved orders	%	17%	8%	15%	13%	
Storage			100%:	100%:	100%:		
21	Total stock value	€	13%	17%	15%	15%	
22	Average inventory	#	4%	4%	10%	6%	
23	Inventory turnover	# of turns	20%	17%	15%	17%	
24	Number of days inventory	days	17%	16%	10%	14%	
25	Stockouts	#/yr	17%	16%	15%	16%	
26	Safety stock usage	#/yr	8%	4%	10%	7%	
27	Overstocking	y/n	8%	13%	15%	12%	
28	Scrap percentage	%	13%	13%	10%	12%	
Goods Issue			100%:	100%:	100%:		
29	Order issue time	days	7%	6%	10%	8%	
30	Goods issued on time	%	20%	27%	25%	24%	
31	Goods issued too late	%	7%	7%	20%	11%	
32	Order fill rate	%	33%	33%	30%	32%	x
33	Rush orders	%	33%	27%	15%	25%	x

GLOSSARY

General Abbreviations

BI	Business Intelligence
BSC	Balanced Scorecard
CFF	Critical Failure Factor
CRM	Customer Relationship Management
CSF	Critical Success Factor
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
ERP II	Successor to ERP
e-ERP	Extended Enterprise Resource Planning (successor to ERP)
ES	Enterprise Systems
FIFO	First in – First Out
fte	Fulltime-equivalent
HR	Human Resources
JIT	Just In Time
KPI	Key Performance Indicator
KOOP	Klantorderontkoppelpunt (in English: Decoupling point or Push/Pull-boundary)
MRP	Material Requirements Planning
MRP II	Manufacturing Resources Planning (successor to MRP)
NPV	Net present value
RFID	Radio Frequency Identification
ROI	Return on Investment
SAP	SAP AG is a German company; SAP is the German abbreviation for 'Systeme, Anwendungen, Produkte in der Datenverarbeitung'
SCC	Supply Chain Council
SCOR	Supply-Chain Operations Reference(-model)
SCM	Supply Chain Management
SRM	Supplier Relationship Management

SAP R3 Module Abbreviations

ASM	Asset Management
CO	Controlling
FI	Financial Accounting
HR	Human Resources
IS	Industry Solutions
MM	Materials Management
PP	Production Planning
PM	Plant Maintenance
PS	Project Systems
QM	Quality Management
SD	Sales and Distribution
SRM	Supplier Relationship Management
WF	WorkFlow
WMT	Warehouse Management