Improving Inventory Management Performance Using a Process-Oriented Measurement Framework

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Abstract. Enterprise Resource Planning systems have been introduced to support the efficient and effective execution of business processes. In practice, this may not fully succeed. This also holds for inventory management (IM), part of the sub-field within logistics termed supply chain management. By analyzing the IM business process, eleven potential benefits are indicated. Next, by using a Business Intelligence approach, key performance indicators (KPIs) are selected to measure the performance of sub-processes. Putting this together yields an IM framework that is used to obtain a generic, coherent picture of IM processes in different organizations. The proposed framework is tested using experts' opinions and two case studies. The experts' comments yielded a list of top-10 KPIs. The case study results show that some of the potential benefits are also observed in practice. Future research may reveal that comparable performance improvements are possible in other ERP domains based on similar measurement frameworks.

Keywords: Enterprise Resource Planning, Inventory Management, Operational Performance, Business Process, Business Intelligence, Key Performance Indicator, Measurement Framework.

1 Introduction

Over the past decade, the Enterprise Systems (ESs) industry has proven to be an enormous growth market [7], [22]. The broad adoption of ESs by the business world is considered the most important development in the corporate use of information technology during the 1990s [4], [7], [22]. As a consequence, the ES market has become a billion dollars' market for quite some time already [18], [30]. Annual growth rates up till thirty percent as observed in the last decade illustrate the rapid growth and significant size of the current ES market. Enterprise Resource Planning (ERP) applications are an example of an ES. ERP packages usually aim to integrate the key business processes, a goal that is typically achieved based on suitable information technologies [2], [10], [34]. Consistent, in time information provision to all members

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of the organization can be considered as the key enabling characteristic of ERP systems next to the intensive automation of administrative activities. Modern ERP systems tend to include Business Intelligence (BI) functionality as well. To do so, data as available in their databases is usually collected in big data warehouses, then analysed, and finally visualized to enable improved business decision-making.

The expectations of ERP are generally quite high: the vendors claim significant improvements in efficiency and effectiveness with their ERP packages [15]. For example, organising the internal logistics using ERP software is supposed to improve processes and to create better performance [4][1]. However, to what extent the performance is improved often remains unclear since only a limited number of researchers focused on expressing the benefits gained with ERP in numbers [14], [18]. In addition, only little references have been found that discuss the correct set of metrics to use for extracting useful management information from ERP. Most authors only mention single metrics or a small set of metrics that can be measured to manage inventories [6], [13], [19], [20], [21], [31]. Due to the wide variation of metrics that can be used, it is often difficult to select appropriate ones [1].

Concluding we observe that existing literature does not seem to provide a coherent view on different performance metrics, and an ERP or BI-tool through which this insight can be gained is also missing. For reasons to be explained below, we decided to focus the research for this paper on the design of a framework that can be used to structurally measure the performance of IM. The focus on IM can be considered as just one possible choice of all sub-domains in supply chain management.

The structure of the rest of this paper is as follows. The next section provides context information on ERP and inventory logistics. Section 3 presents the results of our analysis of the IM business process. Section 4 describes the process of selecting an appropriate measurement technique, and section 5 introduces the designed framework. The results of our testing and validation work are provided in section 6, while section 7 offers our conclusions.

2 Enterprise Resource Planning and Inventory Logistics

Many different definitions of ERP systems can be found including this one: 'Enterprise resource planning systems are configurable information systems packages that integrate information and information-based processes within and across functional areas in an organization' [22]. It is often promised that one ERP package can replace dozens of legacy systems. Fig. 1 illustrates the difference between traditional software solutions and the modern ERP solution. Because of its relevance, we explicitly projected the location of BI software tools in the latter.

IM is part of a much broader field of logistics, called Supply Chain Management (SCM). 'Inventory' and 'stock' are often used to relate to the same thing [35]. IM can

[1] Improved business processes are expected to yield higher returns and better competitive advantage. Within this view, business processes are sometimes termed 'intangibles', i.e., 'non-monetary assets without physical substance that are controlled by the enterprise as a result of past events and from which future economic benefits are expected' [37].

be defined as the 'management of materials in motion and at rest' [3]. IM serves two main goals [26]: first of all, good IM is responsible for the availability of goods. Secondly, the inventory should be managed against low costs. These two goals form a dilemma: keeping large stocks of each item results into a high service level, but at the price of high costs. The reasons for us to select the sub-domain IM can be summarized as follows. First of all, the biggest costs hidden in business are usually found in the inventory [11]. Consequently the biggest potential benefits can thus be gained here. Secondly, stocks form a source for risks [6], [32]: for example, stock may catch fire, can be stolen, damaged etc. If stock levels are lowered, the related risks are reduced too. A third reason to focus on inventory (management) is that inventory costs are relatively easy to identify and reduce [15].

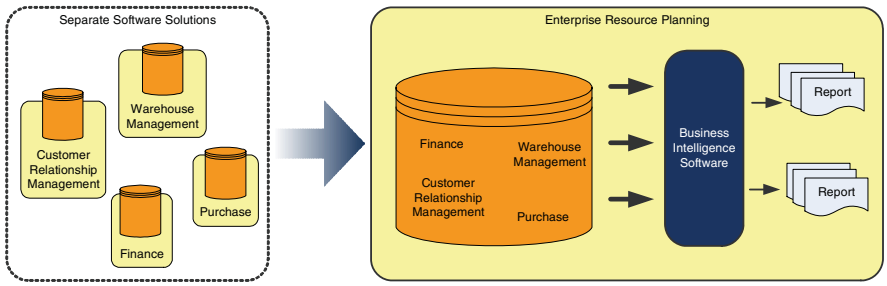

Fig. 1. Enterprise software stages: from non-integrated legacy solutions (*left*) towards contemporary ERP systems (*right*)

3 Analyzing the Inventory Business Process

In order to get a precise picture of what a typical inventory business process entails, literature was reviewed and interviews were conducted with thee experts [12]. Finally, five main process steps were considered to be key processes in IM:

- *Forecasting*. Forecasting forms the first process step and is necessary to anticipate on future demand in order to maintain a continuous production or service level. Forecasting forms the input to scheduling and planning [3].
- *Purchase*. There are various theories about how purchases should be performed. Here a purchase is viewed as a good being ordered.
- *Goods receipt*. When new goods arrive at the stock's location, several checks take place. Firstly, the price and quantity are compared to the purchase-order to see whether the delivered quantity and price match. For some materials, the quality is also checked before adding the goods to the stock.
- *Storage*. When all checks for received goods are passed, the goods are finally added to the stock.
- *Goods issue*. Finally goods have to be issued. In a warehouse, 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.

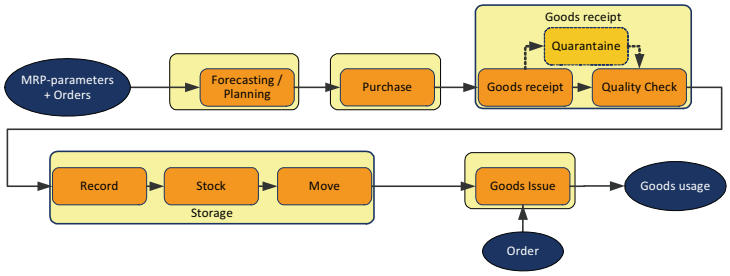

Fig. 2. The 5 main inventory business process steps identified

It should be clear that ERP software systems support these process steps by providing facilities to store data and information related to the concrete activities performed.

Based on this conceptualisation of the inventory business process, an analysis was executed to identify activities that contain possibilities for improving performance: (1) improved MRP (planning of manufacturing process), (2) better supplier-contracts registration, (3) (automatic) restriction of approved suppliers, (4) advanced (and real-time) budget control, (5) improved 'three-way-match' between purchase order, packing note and invoice, (6) better supplier reliability monitoring, (7) improved inventory turnover visibility, (8) enhanced dead stock visibility, (9) less waste through better information on expiration dates, (10) better handling of rush orders, and (11) less faults through single registration of master data.

In Fig. 3, the 11 activities are visualized by mapping them on the inventory business process steps they relate to. We observe here that the 11 potential benefits have been validated by two experts who work in the field of logistics [12].

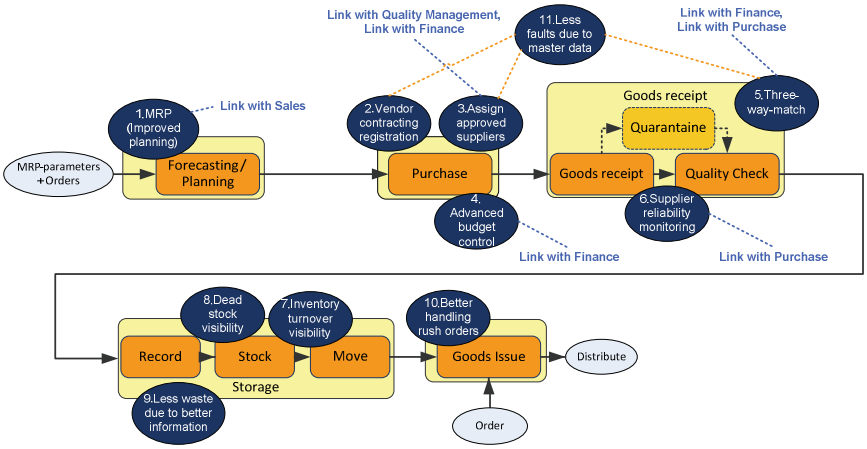

Fig. 3. The 11 activities with potential performance improvement of the inventory process

4 Performance Management Techniques

Measuring reliable and adequate performance is critical for, among others, achieving the goals set by top-management [6] and for evaluating certain changes made to the business. In order to design a measurement tool, a suitable measurement technique has to be selected first. A literature study was done to search for existing methods that might be suitable. In total six important techniques were identified, namely (1) *Key Performance Indicators* (KPIs) [27], [28]; (2) *Balanced Score Card* (BSC) [17]; (3) *Return on Investment* (ROI) [8], [16], [33]; (4) *Net Present Value* (NPV) [25]; (5) *Critical Success Factors* (CSFs) [24], [28], [33]; (6) *Supply Chain Operations Reference-model* (SCOR) [29]. Looking at these techniques, the Balanced Score Card (BSC) is a well-known method. It is occasionally used to create a BI tool for monitoring different aspects of Inventory Management (IM). However, we did not found a clear prescription in literature how to determine the type of metrics to be included. The disadvantage of ROI and NPV is their purely financial nature, which is too limited to measure performance [19]. Because CSFs are mainly qualitative, they are also considered as less applicable in this case. The SCOR framework provides some (too) general ideas about what to measure across the complete supply chain, and is for this reason not particularly suitable for IM. Furthermore, some attempts have been made to structure performance measurement in terms of different categories [23] or levels [8], but again, these approaches are not well applicable in the context of IM [12]. Therefore, at the end, Key Performance Indicators (KPIs) have been selected as performance metric to be used, most importantly due to their ability to provide 'quantifiable measures based on several criteria' [12].

KPIs are quantifiable metrics that are usually defined and measured over a period of time or during a specific time interval. In an attempt to make the set of KPIs as complete as possible, several sources and experts were consulted (as prescribed by the idea of data triangulation [5]). First, KPIs relevant to IM were collected from various sources of literature including [6], [9], [13], [19], [20], [21], [29]. In total around one hundred KPIs relevant for IM were listed. From this long-list of KPIs, the most suitable KPIs have next been selected as basis for the creation of the performance measurement framework. This selection was done based on a mapping of the KPIs to the different process steps as shown in Fig. 2, on literature, and on expert-judgments [12]. The finally selected KPIs are described in the next section.

5 Designing the Performance Management Framework

Based on the business process steps taking place at IM as introduced in section 3 and the KPIs referred to in section 4, an overall framework for optimising IM is designed. The resulting Inventory Performance Measurement Framework is visualized in Fig. 4. The framework provides a structured way of measuring the performance of IM: It can be viewed top-down or bottom up. At the top of it the main goal is represented: optimal management of inventory, which concerns a trade-off between a high service level and a low price. Going one level lower, specific KPIs are shown. These KPIs are linked to the specific business process step they are related to (and are shown at the bottom of the framework). At the very bottom, the KPIs relevant to the overall IM

process are listed. The (dark) oval blocks on the left and right represent inputs and outputs. The MRP input concerns Material Requirements Planning that, contrary to Manufacturing Resources Planning mentioned above, incorporates human and machinery capacities. The distribution of goods at the output side can be to different places, i.e., to both internal and external destinations. The blocks on top represent goals that need to be achieved by good IM. The blocks in the middle represent the main processes: within each main process one or more sub-processes take place.

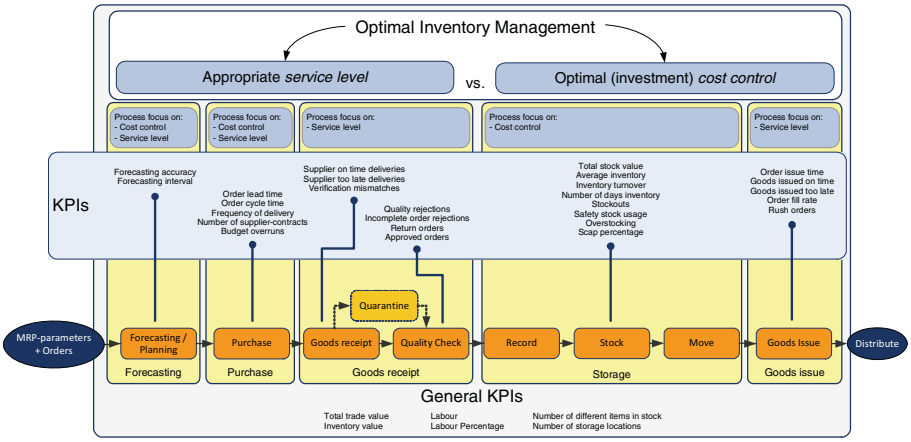

Fig. 4. The designed Inventory Performance Measurement Framework showing the tension between providing a high, appropriate service level versus optimal cost control in terms of KPIs for the different sub-processes in IM and the overall IM process

We next shortly discuss the other dimension of the framework concerning the various stages (steps). (1) Problems with forecasting can lead to too much stock (yielding unnecessary higher costs) or to too little stock (negatively affecting the service level). Delivery times should be incorporated in the forecast to cope with latency of delivery. (2) 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. (3) At the goods receipt process step, all metrics concern the service level. Whether goods are being delivered on time and in good quality are the main drivers. Monitoring of supplier performance is indirectly done by checking (in)correct delivery times as well as the number of approved/returned orders. (4) The metrics related to storage are mostly concerned with costs. Only the number of days of inventory and the number of stock outs are metrics influencing the service level. The metrics at this process should together indicate whether the amount of stock kept, is efficient. (5) In the final process step, the goods issuing part, the focus is on offering a good service towards the client. 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. 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. For many more details, we refer to [12].

6 Testing the Measurement Framework

The framework was designed based on a combination of literature research, interviews, and logic reasoning. Accordingly, a first attempt was made to test the design, in order to judge its usability and validity in practise. Validation of the framework was done in two ways. First, experts were consulted to reflect on the final design: four experts with experience in the field of logistics/inventory management and ERP have been asked to reflect on the framework in order to provide one additional validation check towards the design. The results are as follows. In the first place, all KPIs in the model are considered to be useful (although there have been some discussion on two KPIs that might measure the same thing). Next, the list of 33 KPIs was considered to be very long. In an ERP environment this may not be a problem (because once an SQL query is available, it can be used again and again), but in a less integrated environment the calculation of many KPIs may become difficult. For this reason, a TOP-10 was constructed. The TOP-10 list of most important KPIs (together with the IM sub-process they belong to) is as follows: (1) Forecasting accuracy (Forecasting); (2) Forecasting interval (Forecasting); (3) Order lead time (Purchase); (4) Vendor on time deliveries (Goods receipt); (5) Vendor too late deliveries (Goods receipt); (6) Verification of mismatches (Goods receipt); (7) Quality rejections (Quality check); (8) Return orders (Quality check); (9) Order fill rate (Goods issue); (10) Rush orders (Goods issue). These top-ten KPIs combined can be very useful and might serve as a good starting point for IM performance management evaluation, e.g., to detect possible ‘quick-wins’.

Furthermore, the framework was applied in two case studies performed in the health care sector. The reasons for choosing this domain are obvious: currently, the Dutch government demands hospitals to work effectively and efficiently, meaning that they have to be competitive against predefined fares and other hospitals. For this reason, budgets are under pressure and hospitals are seeking for means to reduce costs. This also holds for IM in hospitals. The case studies were conducted at two different hospitals. One hospital used ERP software (i.e. SAP SRM, SAP MM and SAP FI/CO) to support purchase, logistics and finance respectively. The other hospital does not use ERP, but Vila software for purchase and logistics and SAP FI/CO software at finance. Both hospitals are medium-sized and classified as non-academic. The operation excellence strategy dominates at both hospitals: their aim is to offer excellent care against the lowest costs. Both a qualitative and a quantitative comparison have been performed.

Qualitative comparison: using interviews with purchasers and logistics managers the processes taking place at each hospital were mapped and compared to each other using pattern matching [36]. Several differences between the hospitals have been observed. (1) At forecasting: in the ERP case, the forecasting process was fully automated via an internal web-application (as a part of SAP SRM), whilst in the non-ERP

case, a lot of work had to be done manually, a labour-intensive job requiring more personnel and, as a consequence, more money. (2) At goods receipt: in the hospital 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, faults are occasionally made and have to be repaired (at high costs). (3) At goods issue: at the hospital with ERP 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

Quantitative comparison: to start, relevant data about each KPI have been collected. Unfortunately, not all KPIs could be measured exactly. In those cases, the KPIs were assessed by experts who work in the corresponding inventory department. Data collection was difficult but in the end it was managed for all KPIs, except for the ones from the storage process. Using these metrics, an attempt has been made to evaluate the eleven potential ERP benefits identified earlier. The data were however insufficient to draw valid conclusions. Only slight differences were found. The data pointed out that possibly three of the eleven potential benefits are actually achieved, namely, (1) improved MRP (improved forecasting/planning), (2) automatic restricting of approved suppliers, and (3) improved three-way-match (between purchase order, packing note and invoice). An important remark should be made at this point: due to the limited amount of data this is only an indication and more research is required to further validate the framework and test the potential benefits. In general it was found that in the hospital with ERP, far less people were concerned with inventory management. For this reason, the ERP-hospital has to operate in any case more efficiently (even if relevant KPIs are not measured at all).

7 Conclusions

The aim of this research has been to develop a framework for measuring inventory management performance. As a result, a generic framework for doing so has become available. The framework incorporates a set of metrics to evaluate performances based on which a coherent view on IM in all kinds of organizations can be induced. In more detail, we conclude that the new framework has the following advantages:

- Based on the business process approach applied, a coherent set of metrics is designed and structured into one overall model. The model is structured because it clearly describes what to measure and how to measure that.
- Due to the span of the framework, different actors involved are represented. This characteristic makes sure that the focus is not just on a single subprocess, input, or output, but that, instead, the interests of all stakeholders are taken into account.
- Contrary to what is found in most literature, the framework provides a business process view on inventory management (and corresponding relevant metrics). In this way, the model helps organisations to gain insight in the operational performance of inventory processes.

From the case studies performed, it may be concluded that the framework provides a practical tool for making standardised comparisons between inventory (management) situations. The induced framework matches with practice and it turned out that all metrics proposed are valuable and relevant. Despite of the limited testing of the framework, the obtained measurements suggest that certain performance benefits can be expected in case integrated ERP software is in use.

In general however, more research is needed to fully validate the framework and to discover under which conditions and to what extent performance benefits are consistently present. In case a simple performance management approach is preferred, the ten KPIs of the TOP-10 list can be used to identify the quick-wins. Finally we observe here that, by using similar measurement frameworks (to be developed analogous to our analysis and design), comparable performance improvements are expected to be possible in other ERP domains.

References

1. Beamon, B.M.: Measuring supply chain performance. International Journal of Operations & Production Management 19(3), 275–292 (1999)
2. Beheshti, H.M.: What managers should know about ERP/ERP II. Management Research News 29(4), 184–193 (2006)
3. Coyle, J.J., Bardi, E.J., Langley Jr., C.J.: The Management of Business Logistics: A Supply Chain Perspective, 7th edn. South-Western, Ohio (2003)
4. Davenport, T.H.: Putting the enterprise into the enterprise system. Harvard Business Review 76(4), 121–131 (1998)
5. Denzin, N.K.: Sociological Methods: A Sourcebook. McGraw Hill, New York (1978)
6. Fawcett, S.E., Ellram, L.M., Ogden, J.A.: Supply Chain Management: From Vision to Implemention. Pearson Education, Inc., New Jersey (2007)
7. Gable, G.G.: Panel Discussion. In: 9th Australasian Conference on Information Systems, Sydney, NSW (1998)
8. Goor, A.R.v., Weijers, S.J.: Poly Logistiek Zakboekje. PBNA, Arnhem (1998)
9. Gunasekaran, A., Patel, C., Tirtiroglu, E.: Performance measures and metrics in a supply chain environment. International Journal of Operations & Production Management 21(1/2), 71–87 (2001)
10. Gupta, A.: Enterprise resource planning: the emerging organizational value systems. Industrial Management & Data Systems 100(3), 114–118 (2000)
11. Harrington, L.: Untapped savings abound. Industry Week, 53–58 (July 15, 1996)
12. van Heck, G.F.N.: Inventory Management: Performance Measurement - Designing a Framework to Assess Inventory Management's Performance. MSc Thesis. Delft University of Technology (2009)
13. Hendricks, K.B., Singhal, V.R., Stratman, J.K.: The impact of enterprise systems on corporate performance: A study of ERP, SCM and CRM system implementations. Journal of Operations Management 25, 65–82 (2007)
14. Hunton, J.E., Lippincott, B., Reck, J.L.: Enterprise resource planning systems: comparing firm performance of adopters and nonadopters. International Journal of Accounting Information Systems 4(3), 165–184 (2003)
15. Johnson, M.E., Pyke, D.F.: Supply Chain Management. In: Harris, C., Gass, S. (eds.) Encyclopedia of MS/OR (2001)

16. Jones, B.: Balanced Scorecard Tower: a framework for comparing IT investment against business benefits. MSc Thesis, Delft University of Technology (2009)
17. Kaplan, R.S., Norton, D.P.: The Balanced Scorecard – Measures that Drive Performance. Harvard Business Review 71 (1992)
18. Klaus, H., Rosemann, M., Gable, G.G.: What is ERP? Information Systems Frontiers 2(2), 141–162 (2000)
19. Kleijnen, J.P.C., Smits, M.T.: Performance metrics in supply chain management. Journal of the Operational Research Society 54(5), 507–551 (2003)
20. Klundert, J.: Supply Chain Management en Technologie. Mateum/Universtiteit Maastricht, Venlo (2003)
21. Krauth, E., Moonen, H., Popova, V., Schut, M.C.: Performance Measurement in Control and Logistics Service Providing. In: Proceedings of the Seventh International Conference on Enterprise Information Systems (ICEIS), Miami, USA, May 25-28 (2005)
22. Kumar, K., van Hillegersberg, J.: ERP Experiences and Evolution. Communications of the ACM 43(4), 22–26 (2000)
23. Neely, A., Gregory, M., Platts, K.: Performance measurement system design. International Journal of Operations & Production Management 15(4), 80–116 (1995)
24. Pairat, R., Jungthirapanich, C.: A chronological review of ERP research: an analysis of ERP inception, evolution, and direction. In: Engineering Management Conference Proceedings, Canada (2005)
25. Png, I., Lehman, D.: Managerial economics. Blackwell Publising, Malden (2007)
26. Reid, R., Sanders, N.R.: Operations Management: an integrated approach, 3rd edn. John Wiley & Sons, New York (2007)
27. Rockart, J.F.: Chief executives define their own data needs. Harvard Business Review (2), 81–93 (1979)
28. Rockart, J.F.: A Primer on Critical Success Factors. In: Bullen, C.V. (ed.) The Rise of Managerial Computing: The Best of the Center for Information Systems Research. Dow Jones-Irwin, Homewood (1986)
29. SCC, Overview of the SCOR Model V8.0. Supply Chain Council, Inc. (2006)
30. Umble, E.J., Haft, R.R., Umble, M.M.: Enterprise resource planning: implementation procedures and critical success factors. European Journal of Operational Research 146(2), 241–257 (2003)
31. Veldman, M.A., Leijdekkers, B.A.: Appendix D, Key Performance Indicators (Retail Business model). KPMG internal documentary (2009)
32. Visser, H.M., Goor, A.R.v.: Werken met Logistiek. Wolters-Noordhoff, Groningen (2004)
33. de Waal, A.A.: Quest for Balance - The human element in performance management systems, ch. I. John Wiley & Sons Ltd., Chichester (2002)
34. Wier, B., Hunton, J.E., HassabElnaby, H.R.: Enterprise Resource Planning & Non-Financial Performance Incentives: The Joint Impact on Corporate Performance. International Journal of Accounting Information Systems 8(3), 165–190 (2007)
35. Wild, T.: Best Practice in Inventory Management, 2nd edn. Butterworth-Heinemann (imprint of Elsevier), Oxford (2002)
36. Yin, R.K.: Case Study Research: Design and Methods, 2nd edn. Sage Publishing, Beverly Hills (1994)
37. IASC (International Accounting Standards Committee), International Accounting Standards 38, Intangible Assets, Londra, IASC (1998)