The Economic Value Added of Augmented Reality in the Packing Process

Tim Woltering
University of Applied Sciences Münster

Andre Sardoux Klasen
University of Applied Sciences Münster

Carsten Feldmann
University of Applied Sciences Münster

The use of augmented reality (AR) in outbound logistics is associated with potentially strong stimuli for cost savings and throughput time. Nevertheless, the benefits of AR compared to conventional methods require a holistic analysis for investment decision making. This paper answers the following research questions: How can the economic efficiency of AR in the packing process be quantified by utilizing a holistic model of value drivers? How can AR be technically implemented for packing processes in outbound logistics? What economic value added (EVA) results from the use of AR technology in a case company's packing process?

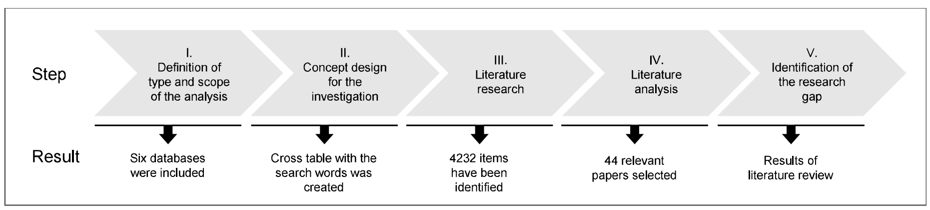
Keywords: augmented reality, AR, packing, packaging, economic value added, EVA, value contribution, cost analysis, cost drivers

INTRODUCTION

The packing process according to the Supply Chain Operations Reference (SCOR) model is defined as activities such as sorting/combining products, packing/kitting the products (pasting labels and barcodes, etc.), and delivering the products to the shipping area for loading (Supply Chain Council Inc., 2012). Increasing customer needs for individuality and quality are reflected both in the products and in the packing requirements. Manifold demands such as a large number of different components and frequent non-cubic shapes (e.g., in the mechanical engineering industry) create a complexity that is difficult for employees to master efficiently in terms of time, quality, and cost pressure (Mättig, Lorimer, Jost, & Kirks, 2016). Augmented reality (AR) is a group of technologies allowing for the situational visualization of information which has the potential to reduce complexity for the employee (Mättig et al., 2016). With AR, reality is interactively enriched or extended by the inclusion of additional information (Azuma et al., 2001). It is especially suitable for use in industrial environments because it enhances the visual perception of users by displaying additional computer-generated information in the field of vision (Alt, 2003; Schmidt, Wiedenmaier, Oehme, & Luczak, 2005). Examples include information about the pick location for warehouse operators and assembly instructions for employees at the production line (Alt, 2003; Mättig, Jost, & Kirks, 2018). Within the packing process, the use of AR manifold assistance can be imagined, e.g. for the instruction of an optimal packing scheme (Mättig et al., 2018), indications of areas requiring special protection, selection of packing materials or display of packing instructions. A packing system consists of the packaging material itself and is supplemented by the packing process: packing material (such as a covering or stuffing) is utilized to enclose or protect goods for shipping or storage (Lange, 2008). This article focuses on the process of packing goods in outbound logistics.

The objective of a supply chain is to maximize the overall value generated: i.e., the difference between what the value of the final product is to the customer and the costs of supply-chain activities for fulfilling the customer order (Chopra & Meindl, 2015). Therefore, the aim of this research project is to establish a model for calculating the economic value added (EVA) to determine the value contribution for investment decision making. The model was validated within a case company by means of an AR test installation. Before the validation, the EVA model was set up in the form of value-driver trees based on extensive desk research and expert interviews. Literature analysis was based on the approach of vom Brocke et al. (2009) (cf., Figure 1 and appendix).

FIGURE 1
PROCESS OF LITERATURE ANALYSIS



A total of 44 publications were selected on the basis of the criteria currency, relevance, authority, accuracy, and purpose. The present studies are characterized by a wide heterogeneity in terms of the applied analyses, the empirical data base, and the presentation of the results, so the findings are not strictly comparable. The practice-oriented research focuses primarily on decentralized order picking, assembly, maintenance and repair (Kohn & Harborth, 2018; Ong, Yuan, & Nee, 2008; Schmidt et al., 2005; Schwerdtfeger & Klinker, 2008; Webel et al., 2011). A large number of articles examine the topic mainly from a theoretical perspective of potential applications in a production logistics environment (Hammerschmid, 2017; Kückelhaus, 2015; Lang, Dastagir Kota, Weigert, & Behrendt, 2019; Michel, 2018). The packing process is not addressed sufficiently (Mättig et al., 2016; Stoltz et al., 2017). In the literature, no comprehensive and coherent statements are offered about the direction and impact of value drivers on costs. None of the articles identified present a model for investment decision making and evaluation of the advantages. Mättig et al. prove the efficiency of AR in the packing process under laboratory conditions (Mättig et al., 2016), but with neither reference to a natural working environment nor with consideration of the actual economic value contribution.

Thus, an EVA-based analysis of AR in packing processes is needed to understand and prioritize the value drivers for a calculation scheme for investment decision making. To ensure value orientation, the profitability analysis was based on the concept of EVA, which is widely accepted as a financial metric for measuring value (Young & O'byrne, 2000). EVA is a measure of economic (not accounting) profit and is defined as the difference between net operating profits after taxes (NOPAT) and capital charge, which depends upon total invested capital and a weighted average cost of capital (WACC) (Ehrbar, 1998; Young & O'byrne, 2000). Against this background, the following research questions are addressed:

***RQ_1:** How can the economic efficiency of AR in the packing process be quantified by utilizing a holistic model of value drivers?*

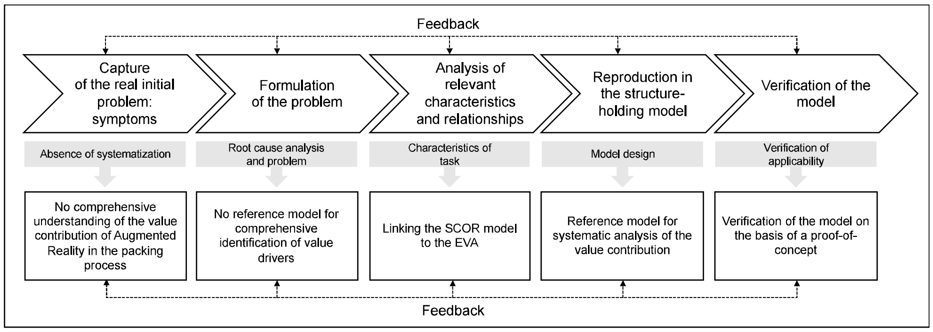
***RQ_2:** How can AR be technically implemented for packing processes in outbound logistics?*

***RQ_3:** What economic profit results from the use of AR technology in the case company's packing process?*

METHODOLOGY

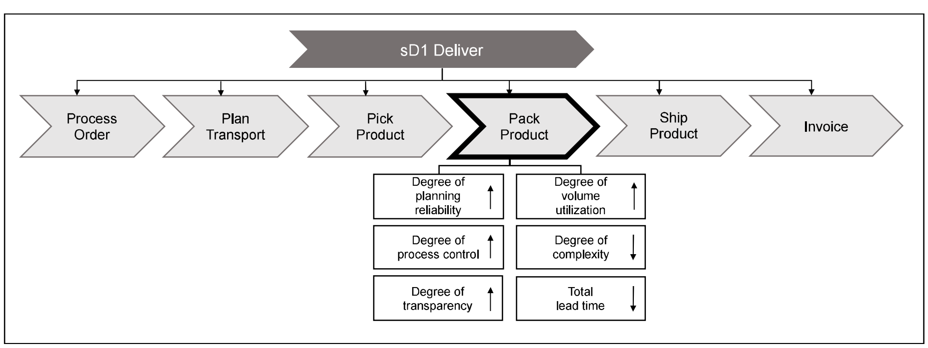
First, an overall procedure model was created, which is based on the modeling process according to Adam (1996) as presented in Figure 2.

FIGURE 2
OVERALL MODELING PROCESS



In a second step, a structural model was established to comprehensively identify the value drivers in the packing process. To identify the operational costs and asset impacts associated with implementing AR, a successive approach is applied. First, cost drivers are identified per process activity. A cost driver is any factor which causes a change in the cost of an activity, reflecting any linkages or interrelationships that affect it (Porter, 1998). Business process models have been proven to represent knowledge and can be utilized as a basis for aggregating different types of information (Lindemann, Jahnke, Moi, & Koch, 2012). Prior to identifying cause-effect relationships, all relevant supply-chain processes have been investigated and modeled in the overall research project. In this paper, however, only the influences on the sub-process "material packing" within the SCOR process sD1 are presented (see Figure 3). After modeling the process, the direction of influence is determined per cost driver (increase versus decrease of the reference parameter) using scenario analysis (Fischer, Möller, & Schultze, 2015). The cause-effect relationships identified between value drivers and costs were initially established based on desk research and then validated in a second step by ten expert interviews in the German manufacturing industry. The interviews were carried out as semi-structured guided interviews with interview partners from different companies. The answers were transcribed, and a qualitative content analysis was performed afterwards following the approach of Mayring (2002).

FIGURE 3
SUBPROCESS sD1 Deliver

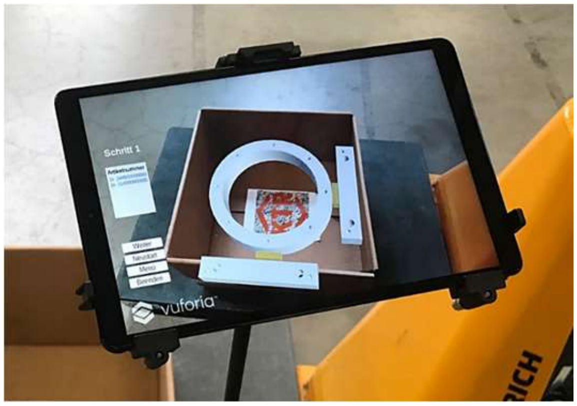


When discussing the cost drivers with the interviewed experts, the process activities depicted in Figure 3 were accredited with the major cost impacts in an AR scenario. A higher degree of volume utilization of the package (such as a covering carton box, container) is achieved by providing information regarding the geometry and quantity (packing pattern), weight, and points of the packages which require special protection. The aforementioned information also optimizes the consumption of packaging materials. These are the box size (transport costs) and packing material, such as fillers (material costs). AR situationally visualizes relevant information by displaying additional computer-generated information in the field of vision, thereby reducing complexity for the employee. This could potentially lead to shorter throughput times in the packing process, mainly driven by a higher level of transparency, process control, and planning reliability. Overall, the experts assume that packing costs decrease when AR is used.

In a third step, the structural model encompassing the value-driver trees needed to be linked to the EVA as the target figure for economic profit. As for supply-chain management (SCM), the highest objective of the EVA concept–maximizing the value added respectively business success–should be achieved by means of value drivers. An investment in AR technologies is to be assessed based on the same approach. The supply-chain value drivers are identified according to the EVA concept and then further systematically decomposed per SCM target area: costs (target: low operational costs), assets (target: low investments in assets), and sales volume (target: high turnover). These objectives contribute to increasing EVA: Higher sales volume and lower operational costs result in higher profits. Reduced working capital results in lower capital costs. Costs are broken down according to SCM processes–source, make, deliver, return–as described in the SCOR model (Supply Chain Council Inc., 2012). The means of achieving higher sales revenue in SCM is high customer satisfaction facilitated by a high logistics service level, determined by delivery reliability and lead time (Chopra & Meindl, 2015; Schnetzler, Sennheiser, & Schönsleben, 2007). The approach of Feldmann/Pumpe was employed to evaluate the economic efficiency of the model based on the EVA (Feldmann & Pumpe, 2017).

In the last step, an AR prototype was developed by using the software engine Unity from Unity Technologies and the Vuforia plugin from PTC Inc. The validation of the assumed cause-effect relationships took place at the case company, a German manufacturing engineering company, to calculate the influence on the EVA. With regards to the AR hardware, a head-mounted device ("AR glasses") would have been desirable under the selection criteria of mobility and flexibility. Against the background of employee acceptance, AR glasses were rejected and a solution based on a tablet PC was established instead (see Figure 4). For the test scenario, the pack pattern was established manually. The pattern was then integrated into the prototype. As a tracking solution, a marker in the form of a DIN A4 sheet at the bottom of the box was chosen to ensure the correct positioning of the 3D objects. Other tracking approaches are conceivable such as tracking the box as a marker or AR without marker. An interface to other IT systems was not developed. In the AR camera view, the warehouse operator can observe the goods to be packaged and the optimum positioning in the cardboard box. Both the goods to be boxed and packing materials are displayed step by step as 3D objects in the optimal position. The objects are placed with consideration of space saving, transport safety, and packing time.

FIGURE 4
PROTOTYPE IN ACTION



A total of four groups were formed, each of which performed a case number of n=10. Two of these groups were composed of inexperienced employees in the packing process (Experimental Design 1), the other two groups with experienced employees (Experimental Design 2). Two scenarios for the test setup were prepared. Scenario 1 was set up without AR support (control group), Scenario 2 with AR support (experimental group, see Table 1). This resulted in a control group and experimental group four both scenarios. The experiment was carried out in the logistics center of the case company. The materials for the packing task were made available to the test persons at a packing area, which consisted of a workbench, a lift truck and a rack filled with cardboard boxes and packing materials. For scenarios 1 and 2, a total of eight goods of different geometries and weights had to be packed. In Scenario 1, a suitable cardboard box first had to be selected out of a selection of different sizes. The test groups were advised to pack as space-saving as possible and to assure the safety of the goods. For the safety of the goods, the test subjects could use as much packing material as needed. In Scenario 2, the tablet was mounted on a tripod, and the tablet's camera was aligned with an AR marker mounted in the box. With the help of the touch display, the employee was guided through the packing process by visualizing the process stepwise. Looking at the tablet's display, the 3D objects virtually overlaid the box (see Figure 4).

The throughput time per cycle was measured with a stopwatch. The arithmetic mean values of the time measurement were tested for significance using a t-test and a significance level of $\alpha=5\%$. Quality and box-volume utilization were evaluated by comparison with an optimum packing scheme determined beforehand. A quality deficit was defined by the aspect of inadequate transport safety. The results are presented in Table 1 and show a significant difference (Scenario 1: $p=0.21\%$; Scenario 2: $p=3.63\%$) in terms of throughput time, volume utilization, and quality for both groups, inexperienced and experienced, in test Scenario 2. The reduction of variance is also noticeable. Especially inexperienced employees were able to increase their volume utilization and quality due to the assistance of the AR system. Against the background of the frequent employment of semi-skilled temporary workers with a high fluctuation in this process area, this is a relevant finding for practitioners.

TABLE 1
RESULTS OF THE EXPERIMENT: VOLUME UTILIZATION

	Scenario 1		**Scenario 2**	
Group	**1** Inexperienced; without AR	**2** Inexperienced; with AR	**3** Experienced; without AR	**4** Experienced; with AR
Experience level	low	low	high	high
AR support	no	yes	no	yes
Experimental design	1		2	
Volume utilization	50%	100%	70%	100%
Mean (minutes)	4.06	3.13	3.16	2.57
p value	0.21%		3.63%	
Variance	0.53	0.22	0.84	0.05
Quality	40%	100%	60%	100%

A significant reduction could also be demonstrated in the throughput time. The non-representative results indicate that AR technology enables newly hired and temporary employees to become productive more quickly, and it also requires a lower level of experience knowledge. This would accommodate trends in logistics such as high fluctuation or a high proportion of temporary workers. The experiment confirms the hypotheses presented in the model. The results were used to calculate the actual value contribution of the case company, based on the EVA. Table 2 shows the cost effect triggered by the described causes. The savings of process costs were calculated based on the measured cycle times in the test setup. For this purpose, the percentage reduction of the throughput time was interpolated to all packing processes.

TABLE 2
COST DRIVERS

Cost drivers (in €)	**2019**	**2020**	**2021**	**2022**
Process costs	-	- 59,847.60	- 119,695,21	- 179,542,81
Packing material	- 18,857.36	- 18,857.36	- 18,857.36	- 18,857.36
Packing aids	- 46,957.05	- 46,957.05	- 46,957.05	- 46,957.05
Write-offs	29,880.00	38,173.00	38,466.00	36,879.00
Maintenance	3,000.00	3,000.00	3,000.00	3,000.00
Balance	**- 32,934.41**	**- 84,489.01**	**- 144,043.61**	**- 205,478.22**

Table 3 shows the change in assets in the balance sheet. Due to the existing high-performance level of the case company's packing processes and barriers in the data collection of the sales drivers, these were excluded from the calculation. With regard to the calculation of an optimal packing scheme, the assumption of an automated software solution was made such as PUZZLE. Both the license costs for the software to determine the optimal packing scheme and the development costs for the app presented were considered as asset drivers. However, due to the faster processing time and higher packing quality, positive effects on sales are assumed. Taking into account the cost and asset effects discussed, an AR-induced value contribution of €175,508 (discounted from 2018) could be demonstrated for the case company (see Table 4).

TABLE 3
ASSET DRIVER

Asset driver (in €)	2019	2020	2021	2022
Redesign of workplaces	3,000.00	-	-	-
Software Development	100,000.00	40,000.00 €	-	-
Licenses	40,000.00	-	-	-
Tablets	2,640.00	880.00	880.00	880.00 €
Balance	**145,640.00**	**40,880.00**	**880.00 €**	**880.00 €**

TABLE 4
EVA CALCULATION

EVA Calculation (in €)	2018	2019	2020	2021	2022
NOPAT	21,330.067	21,363.001	21,414.556	21,474.110	21,535.545
NOA	194,187.537	194,360.472	194,252.179	194,211.886	194,213.473
WACC	5.60%	5.60%	5.60%	5.60%	5.60%
EVA	**10,455.565**	**10,478.815**	**10,536.434**	**10,598.245**	**10,659.590**
EVA changes	-	23.250	57.619	61.811	61.345
Discounted	-	22.017	51.669	52.489	49.332
Sum					**175,508**

CONCLUSION AND FUTURE RESEARCH

This paper aims to establish a model to identify the contribution of an investment in AR in the packing process to increase company value. Transparency regarding the cause-effect relations should help to assess an investment in AR technology. The model presented is a systematically structured framework of value drivers and resulting effects on costs. Taking a dynamic EVA perspective, an exemplary in-depth decomposition was provided for the packing process, as this area has been widely neglected in current research. The model supports investment decisions for practitioners, i.e., by comparing the employment of AR versus a conventional scenario without AR. Utilizing the concept of EVA for calculating the economic efficiency, it provides a consistent framework for analyzing the effects of AR oriented to value creation (RQ_1: How can the economic efficiency of AR in the packing process be quantified by utilizing a holistic model of value drivers?). Moreover, the same framework can be utilized to optimize the investment across the life cycle by integrating the value drivers into operational controlling and periodically measuring the economic value added. The implementation of the prototype at the case company has successfully proven the technical suitability of AR in the packaging process (RQ_2: How can AR be technically implemented for packing processes in outbound logistics?). Within the course of the field experiment at the case company, a positive value contribution could be demonstrated (RQ_3: What economic profit results from the use of AR technology in the case company's packing process?).

However, some limitations of the methodology should be mentioned. The results of the expert interviews are not representative and can be related only to the manufacturing sector. Furthermore, of the 20,000 different materials within the case company’s portfolio and the resulting potential combination, only one combination was selected for the experiment, which limits the transfer of the findings to the whole portfolio. The monetary assessment must be considered on a case-by-case basis, as the WACC level, process cost rates, packing material costs, and other applicable model conditions cannot be generalized. Prior to applying the model, a decision needs to be made regarding a specific AR technology. The model has to be interpreted in view of the specific context of the company and product portfolio analyzed. The findings of the case company indicate the best suitability for a low mix/high volume portfolio of materials to be packed. The strengths of influences between value drivers and costs depend on the company's context as well. This leads to the fact that transferability to other companies is given only to a very limited extent.

For future research, applications of the methodology must be carried out for further iterations and improvements. Further case studies are desirable which focus on a specific AR technology or industry and which use the presented framework for systematic analysis. In addition, other target areas can be integrated into the model, such as ecological aspects.

REFERENCES

Adam, D. (1996). *Planung und Entscheidung-Modelle-Ziele-Methoden-Mit Fallstudien und Lösungen.* Wiesbaden: Gabler.

Alt, T. (2003). *Augmented Reality in der Produktion.* München: Herbert Utz Verlag.

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, 21(6), 34–47.

Chopra, S., & Meindl, P. (2015). *Supply-chain management* (6th ed.). Boston: Pearson.

Ehrbar, A. (1998). *EVA: The Real Key to Creating Wealth.* New York: Wiley.

Feldmann, C., & Pumpe, A. (2017). A holistic decision framework for 3D printing investments in global supply chains. *Transportation Research Procedia*, 25, 677–694.

Fischer, T. M., Möller, K., & Schultze, W. (2015). *Controlling: Grundlagen, Instrumente und Entwicklungsperspektiven.* Stuttgart: Schäffer-Poeschel.

Hammerschmid, S. (2017). Chances for Virtual and Augmented Reality Along the Value Chain. *European Conference on Software Process*, pp. 352–359.

Kohn, V., & Harborth, D. (2018). Augmented Reality–A Game Changing Technology for Manufacturing Processes? *26th European Conference on Information Systems*, pp. 1–18.

Kückelhaus, M. (2015). Eleven reasons to consider augmented reality in logistics. *Logistics & Transport Focus*, pp. 14–17.

Lang, S., Dastagir Kota, M.S.S., Weigert, D., & Behrendt, F. (2019). Mixed reality in production and logistics: Discussing the application potentials of Microsoft HoloLensTM. *Procedia Computer Science*, 149, 118–129.

Lange, V. (2008). Verpackungs- und Verladetechnik. In D. Arnold, H. Isermann, A. Kuhn, H. Tempelmeier, & K. Furmans (Eds.), *Handbuch Logistik* (pp. 613–726). Berlin, Heidelberg: Springer Berlin Heidelberg.

Lindemann, C., Jahnke, U., Moi, M., & Koch, R. (2012). Analyzing product lifecycle costs for a better understanding of cost drivers in additive manufacturing. *23th Annual International Solid Freeform 2012*, pp. 177–188.

Mättig, B., Jost, J., & Kirks, T. (2018). Erweiterte Horizonte–Ein technischer Blick in die Zukunft der Arbeit. In *Zukunft der Arbeit–Eine praxisnahe Betrachtung* (pp. 63–72). Springer Vieweg, Berlin, Heidelberg.

Mättig, B., Lorimer, I., Jost, J., & Kirks, T. (2016). Untersuchung des Einsatzes von Augmented Reality im Verpackungsprozess unter Berücksichtigung spezifischer Anforderungen an die Informationsdarstellung sowie die ergonomische Einbindung des Menschen in den Prozess. *Logistics Journal: Proceedings*, (10).

Mayring, P. (2002). *Einführung in die qualitative Sozialforschung.* Weinheim: Beltz Verlag.

Michel, R. (2018). Insight into smart glasses. *Modern Materials Handling*, pp. 44–50.

Ong, S. K., Yuan, M. L., & Nee, A. Y.C. (2008). Augmented reality applications in manufacturing: a survey. *International journal of production research*, 46(10), 2707–2742.

Porter, M. E. (1998). The Competitive Advantage of Nations. *The Free Press, New York.*

Porter, M. E. (2000). *Location, completion and economic development. Economic Development Quarterly*, pp. 23–34.

Schmidt, L., Wiedenmaier, S., Oehme, O., & Luczak, H. (2005). Benutzerzentrierte Gestaltung von Augmented Reality in der Produktion. In C. Stary (Ed.), *Mensch & Computer 2005. Kunst und Wissenschaft - Grenzüberschreitung der interaktiven ART* (pp. 51–60). München: Oldenbourg.
Schnetzler, M. J., Sennheiser, A., & Schönsleben, P. (2007). A decomposition-based approach for the development of a supply chain strategy. *International Journal of Production Economics*, 105, 21–42.
Schwerdtfeger, B., & Klinker, G. (2008). Supporting order picking with augmented reality. *IEEE 2008 – 2008 7th IEEE/ACM International Symposium*, pp. 91–94.
Stoltz, M-H., Giannikas, V., McFarlane, D., Strachan, J., Um, J., & Srinivasan, R. (2017). Augmented reality in warehouse operations: opportunities and barriers. *IFAC-PapersOnLine*, 50(1), 12979–12984.
Supply Chain Council Inc. (2012). *Supply chain operations reference model (SCOR)* (11th ed.).
vom Brocke, J., Simons, A., Niehaves, B., Niehaves, B., Reimer, K., Plattfaut, R., & Cleven, A. (2009). *Reconstructing the giant: On the importance of rigour in documenting the literature search process*.
Webel, S., Bockholt, U., Engelke, T., Peveri, M., Olbrich, M., & Preusche, C. (2011). Augmented Reality Training for Assembly and Maintenance Skills. *BIO Web of Conferences*, 1, 1–4.
Young, S. D., & O'byrne, S. F. (2000). *EVA and value-based management*. McGraw-Hill Professional Publishing.