# Using the Analytic Network Process (ANP) to assess the distribution of pharmaceuticals in hospitals – a comparative case study of a Danish and American hospital

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# Using the Analytic Network Process (ANP) to assess the distribution of pharmaceuticals in hospitals – a comparative case study of a Danish and American hospital

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## Abstract
Pharmaceuticals are a vital part of patient treatment and the timely delivery of pharmaceuticals to patients is therefore important. Hospitals are complex systems that provide a challenging environment for decision making. Implementing process changes and technologies to improve the pharmaceutical distribution process can therefore be a complex and challenging undertaking. A comparative case study was conducted benchmarking the pharmaceutical distribution process at a Danish and US hospital to identify best practices. Using the ANP method, taking tangible and intangible aspects into consideration, the most suitable solution for pharmaceutical distribution reflecting management preferences was identified.

**Keywords:** Hospital logistics, Pharmaceutical distribution, Analytic Network Process

### Introduction
Healthcare expenditure is growing year on year and hospitals face an increasing pressure to provide high quality care at lower costs. Pharmaceutical products have become more expensive and amount to almost 20% of health spending in OECD countries (OECD, 2015). Hospitals deal with high inventory levels and storage costs. Reducing pharmaceutical handling and logistics costs can therefore lead to major cost savings (Pinna et al., 2015).

Timely delivery of the correct pharmaceuticals to the right patients is vital for patient care. However, little empirical evidence exists on the opportunities for improving internal pharmaceutical logistics in a hospital (Romero and Lefebvre, 2015). Process design and various technological solutions can enhance the precision and timeliness in the delivery of pharmaceuticals, while at the same time reducing handling costs. Just in Time (JIT) can reduce inventory levels and handling costs in a hospital (Aptel and Pourjalali, 2001). Track and trace throughout a process can help eliminate waste by providing information that enables planning, coordination, and mistake prevention in processes. Barcodes and RFID can be used to track and trace pharmaceuticals (Anand and Wamba, 2013). Automated guided vehicles (AGVs) and pneumatic tube systems are examples of technologies that can be used for transportation and delivery of various types of goods in hospitals, e.g. (Granlund and Wiktorsson, 2013).

Hospitals are complex systems (Lillrank and Liukko, 2004), and implementing a new technology in a process has implications for procedures and organizational units across a hospital e.g. (Romero and Lefebvre, 2015). Moreover, the improvements achieved by implementing a particular technology in one organization might not be the same for another due to different conditions for operating and a different technological base (Chan et al., 2001). Recognizing the effects of changing a process and implementing new technologies is important in order to make an informed decision. A simulation model is a way to assess the effects over time of various scenarios and is useful for improving process flows and determining the need for resources, e.g. (Jun et al., 1999; Zhu et al., 2012). Thus, simulation models do not consider intangible aspects unless they affect the behavior of the process. An analytic approach to assessing process designs and technologies can capture the complexities and implications of a decision (Chan et al., 2001; Meredith and Suresh, 1986). The Analytic Network Process (ANP) and Analytic Hierarchy Process (AHP) are multi-criteria decision analysis methods that can rank solutions based on a set of parameters (Saaty, 2004). AHP and ANP allow for a quantitative comparison of solutions based on qualitative and quantitative criteria, whilst ensuring transparency of the decision process. Both methods have previously been applied in healthcare settings (Liberatore and Nydick, 2008) and to assess logistics processes (Meade and Sarkis, 1998) and technologies (Ordoobadi, 2012). The ANP method was chosen over the AHP method, as ANP accounts for interdependencies between parameters (Saaty, 2004). The following research question is addressed in this paper: *How can ANP be applied to assess process designs in healthcare logistics, exemplified by pharmaceutical distribution in hospitals?*

## Methodology

*Objectives and research design*

This study aims to provide a method for how ANP can be applied in a benchmarking effort to select a process and technology solution that best fits the preferences of decision makers in a hospital. The pharmaceutical distribution process is compared at a Danish and US hospital. As part of the benchmarking study, best practices were identified for the US hospital and the applicability for the Danish hospital was assessed.

A case study was chosen as research design because it enables in-depth understanding of a phenomenon (Yin, 1994), in this case the pharmaceutical distribution process. Furthermore, case studies are suitable for building theory within the field of operations management (Meredith, 1998; Voss et al., 2002), making the research design suitable for this study. Two case studies of the pharmaceutical distribution process were carried out; one at a major public Danish hospital and another at a major nonprofit, top-ranking US hospital. The applicability of the US pharmaceutical distribution process design to a Danish hospital was investigated by comparing the process and organization of the two hospitals.

*Data collection*

The collected data was both qualitative and quantitative in nature. Data was collected through semi-structured interviews, structured interviews, and direct observations at the Danish and US hospital. Furthermore, quantitative data pertaining to management preferences for evaluated solutions was obtained for the Danish case study. Data for the

Danish case study was collected from February to August 2015 based on seven semi-structured and one structured interview, and process observations on four occasions. Data was collected for the US pharmaceutical distribution case study from September 2015 to January 2016 through process observations on three occasions and six semi-structured interviews. Interviewees were selected based on their knowledge of and involvement in the pharmaceutical distribution process, including key decision makers. Observations were recorded for each step of the pharmaceutical distribution process. The interviews lasted between ½-1½ hour and the observations lasted between ½-1 hour.

*Analysis*

A gap analysis was conducted as part of the benchmarking study (Camp, 1995). The pharmaceutical process was compared for the two hospitals and gaps between process steps were identified. Best practices identified in the gap analysis were subsequently evaluated for the Danish hospital using the ANP method. In the ANP method, logistics management at the Danish hospital subjectively assessed a set of decision criteria for each alternative. The decision criteria used for evaluating the alternatives are depicted in Figure 1. The software Super Decisions (www.superdecisions.com, 2016) was used to calculate the ANP ranking of solutions and identify the most desirable solution for the Danish hospital.

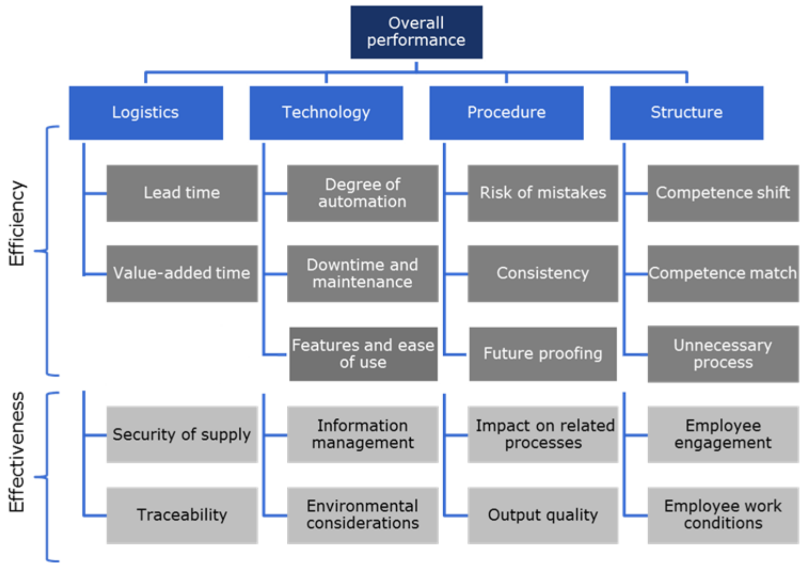


*Figure 1 - Decision criteria for assessing process designs in healthcare logistics*

The decision criteria in Figure 1 were identified in a previous case study of the bed logistics process in five Danish hospitals (Feibert and Jacobsen, 2015). The developed framework consists of 19 decision criteria for assessing technologies and process designs in healthcare logistics. The identification of decision criteria was based on two analyses: 1) challenges in the process, 2) reasons for implementing process changes and technologies. The identified decision criteria each relate to one of the following constructs: 1) Logistics, 2) Technology, 3) Procedure, and 4) Structure. Furthermore, the decision criteria are divided into efficiency and effectiveness to reflect both aspects of performance (Mentzer and Konrad, 1991; Neely et al., 2005). The decision criteria in Figure 1 and relations between the decision criteria were identified for the bed logistics case study and were validated for the pharmaceutical distribution cases.

*Validity and reliability*

Different types of data sources were utilized to triangulate the findings and ensure reliability and internal validity. E.g. interviews were conducted with several interviewees from the same department and from different parts of the supply chain. Furthermore, the decision criteria from the previous study were validated through the interviews and respondent validation further strengthened internal validity.

The external validity of the study was ensured through case study sampling. The Danish hospital was chosen because it is the same hospital as from the previous study (Feibert and Jacobsen, 2015). The US hospital was chosen because it is a top ranking hospital and could potentially provide best practices for the Danish hospital. The hospital sampling allowed for the decision criteria to be generalized to other hospital logistics processes such as the pharmaceutical distribution process and to other contexts such as a US hospital.

## Literature review

Literature on how to improve internal logistics of pharmaceuticals is limited (Romero and Lefebvre, 2015). Al-Shaqha and Zairi investigated the reengineering of pharmaceutical processes and found that decentralizing pharmacists to the clinical departments provides more patient-focused care (Al-Shaqha and Zairi, 2000). Pinna and colleagues found that a unit dose pharmaceutical distribution system entails a more simple process with reductions in stock levels and easier stock management (Pinna et al., 2015). Chen and colleagues found that the implementation of TQM tools in a pharmaceutical logistics organization led to cost reductions, increased sales and low employee turnover (Chen et al., 2004).

Technologies can play a vital role in reengineering processes (Hammer and Champy, 1993; Hammer, 1990). One of the technologies that have caught much attention in logistics literature, including hospital logistics, is radio frequency identification (RFID), e.g. (Chircu et al., 2014; Romero and Lefebvre, 2015; Wamba and Ngai, 2015; Wamba et al., 2013). Wamba and colleagues identified three applications of RFID technology in healthcare: asset management, patient management and staff management (Wamba et al., 2013). Chircu and colleagues investigated a pharmaceutical supply chain end-to-end and identified the different benefits of RFID for each actor in the supply chain. The benefits identified include time and money savings, safety of medication, easier control and transport of medication, reductions in delivery errors, compliance on temperature, better documentation, reductions in manual data entry costs, easier information transfer, and user-friendly track and trace of drugs (Chircu et al., 2014). RFID is often compared to the more established barcode technology for track and trace purposes. E.g. Romero and Lefebvre identified some benefits of using RFID, barcodes and the two technologies in conjunction. RFID provided the most benefits, e.g. efficiency and accuracy, inventory visibility and reduced inventory costs, increased patient security and shorter cycle times (Romero and Lefebvre, 2015). Çakici and colleagues compared inventory costs when using RFID and barcodes and found that cost savings are significantly larger using RFID than barcodes, especially when combined with business process reengineering. However, RFID technology is more costly to install and is not without errors (Çakici et al., 2011; Romero and Lefebvre, 2015).

Poor inventory management can lead to high inventory costs and stock-outs. Inventory control approaches such as JIT, stockless and vendor managed inventory (VMI) can improve the efficiency and effectiveness of materials handling. Kim and Schniederjans found that JIT and stockless systems can reduce inventory costs and improve service quality (Kim and Schniederjans, 1993). However, JIT solutions require close proximity between wholesaler and clinic, which is not always possible. A case study of a pharmaceutical supply chain in Malaysia therefore found that VMI was a more suitable solution that could reduce the amount of high-cost urgent orders and improve stock availability (Mustaffa and Potter, 2009).

Böhme and colleagues conducted a benchmarking study on improving the reliability of medical supply value streams. Identified best practices included visual management, pharmaceutical dispensing machines, barcoding of consumables, and automatically adjusted stock levels (Böhme et al., 2016). Benchmarking is a way to systematically search for industry best practices that can lead to superior performance (Camp, 1989a). Benchmarking consists of a metric component and practice component (Camp, 1989b; Voss et al., 1997); however, a benchmarking study does not necessarily include both (Hanman, 1997; Mayle et al., 2002). One of the steps in a ten step benchmarking process defined by Camp is performing a gap analysis. The most common gap analysis is analyzing the financial gap. A more process oriented gap analysis utilizes tools such as flow charts to identify differences in processes and subsequently differences in performance. Based on a gap analysis, best practices can be identified for the investigated processes in order to achieve or exceed performance levels of the superior process (Camp, 1995).

One of the dilemmas in benchmarking is displaying multiple measures when comparing processes (Chan et al., 2001; Meredith and Suresh, 1986). Analytic methods such as AHP can be used to justify technologies (Chan et al., 2001; Meredith and Suresh, 1986) and to prioritize key benchmarking activities (Camp, 1995). The methods are largely quantitative but can include intangible benefits to better capture the complexities in a system (Chan et al., 2001; Meredith and Suresh, 1986).

**Hospital comparison and identification of process gaps**

The Danish hospital is a 700 bed public hospital in the capital region of Denmark. Pharmaceuticals are received in the docking area from a regional warehouse and transported in carts to an area where boxes containing pharmaceuticals are re-arranged according to the recipient. The boxes are then distributed on carts to the receiving clinical departments where the pharmaceutical items are stored. It is not possible to track the items anywhere in the process, and received pharmaceuticals are not checked with the order until they are unpacked and stored in the clinical departments. When the pharmaceuticals are administered to the patients, barcodes are used to ensure the right drug for the right patient.

The US hospital is a 1,250 bed non-profit hospital ranked as one of the best hospitals in the US. Pharmaceuticals are received in a docking area and transported to the inpatient pharmacy manually or by AGVs. Received items are then checked with orders and transported to the storage area. Throughout the day, pharmaceutical products are picked and delivered manually or through pneumatic tube systems to the clinical departments. In the clinical departments, items are stored in dispensing stations before being administered to patients. At each handover in the process, items are scanned using barcodes, enabling track and trace of items throughout the process and ensuring that the correct items are handed over.

The main gap between the Danish and US process is that items can be tracked throughout the US process using barcodes. Track and trace in the US process allows for better monitoring of the process. At any point in time, the location of all items is known due to the barcoding system. Conversely, in the Danish process, items are unaccounted for until they are received in the clinical departments. The only documentation that occurs is the registration of number of carts and boxes received in the docking area.

Furthermore, the US process is more automated as AGVs and pneumatic tube systems are used for some transports. However, most items are still transported to the clinical departments manually.

Another significant difference is the placement of inventories in the process. At the US hospital, there is a central inventory serving the decentralized inventories in each clinical department. Most pharmaceuticals are reordered based on a reorder point in the central pharmacy. In the Danish hospital, inventories are only found in the clinical departments where a third party provider manages the inventories.

The comparison of the Danish and US processes identifies some process design gaps, suggesting a more advanced pharmaceutical distribution process in the US. The following three aspects of the US process design were evaluated for the Danish hospital:

- AGV
- Pneumatic tube
- Track and trace

Track and trace would be an inherent part of the AGV and pneumatic tube solutions but can also be viewed as a solution in itself. The three solutions are applicable to the Danish hospital because they are already part of the future plan for the hospital or have been tested for possible future use. Firstly, AGVs are already planned as part of the future Danish hospital, which is undergoing a significant expansion. Secondly, a pneumatic tube system already exists between the emergency department and the lab, albeit on a small scale. Finally, an RFID solution has been tested for pharmaceuticals and other items, but the project was stopped for political reasons. Furthermore, an RFID solution would address the lack of control in the pharmaceutical distribution process. The three solutions are therefore viable for the Danish hospital.

Despite a more advanced pharmaceutical distribution process in the US, the process still poses some issues. E.g. errors occur even with the use of barcodes to track the pharmaceutical products. This issue is mainly due to human errors when overriding the system, leading to another issue of stock counting accuracy. Most of the stock is automatically reordered when the stock level reaches a reorder point. The stock count is based on barcode registrations but must be manually counted every two weeks to ensure that the stock count matches the system records. As the manager of the pharmacy points out, this task would not be necessary if RFID were used instead, see also e.g. (Çakici et al., 2011).

**Results from the ANP analysis to evaluate pharmaceutical distribution solutions**

Three solutions were assessed for the pharmaceutical distribution process at the Danish hospital. These scenarios were inspired by the gap analysis of the Danish and US processes and include the following: 1) AGV, 2) pneumatic tube, and 3) track and trace.

*(1) AGV.* In the AGV solution, AGVs transport pharmaceuticals around the hospital. Unless the pharmaceutical products are delivered, sorted according to clinical department on carts manageable by AGVs and tagged with an RFID, some manual handling will have to take place to load the AGVs. Upon arrival in the departments, staff will have to receive the load or the AGV will place the load in a designated area. Narcotics pose an additional issue as they cannot be transported unaccompanied. At the US hospital, this issue was addressed by having an employee follow the AGV. The US hospital experienced fewer injuries after having implemented AGVs because of less heavy lifting and pushing of carts. Another benefit of AGVs was that they could be used

for transporting several different types of materials throughout the hospital at any hours of the day.

*(2) Pneumatic tube.* A pneumatic tube system can transport canisters through a network of tubes using compressed air. A main pharmaceutical inventory would hold most of the inventory and smaller inventories would be held in the clinical departments. This would lead to an overall smaller inventory as the buffer inventories currently held in each clinical department would be reduced to a smaller buffer in the central inventory. Larger orders to the clinical departments might still be transported manually to the reduced decentral inventories, but the majority of non acute medicine would be transported via pneumatic tubes. One of the advantages of pneumatic tubes is the reduced risk of theft during transport compared to the exposed transport with AGVs.

*(3) Track and trace.* The track and trace solution could be implemented as a separate solution or in conjunction with the AGV or pneumatic tube solutions. RFID or barcodes can be used to track and trace items through a supply chain. This would ensure knowledge about the location of a particular item at any point in time and ensure better process control.

The ANP method was applied to the decision criteria in Figure 1 to provide a quantitative assessment ranking the three alternatives for the pharmaceutical distribution process at the Danish case study hospital. The results of the ANP analysis for the Danish hospital are seen in Table 1. The “Raw data” column contains output from the ANP analysis, the “Normals” column contains normalized output data, and the “Ideals” column contains data with the ideal solution receiving the value 1. The results showed that the most desirable alternative for the Danish hospital is a pure track and trace solution.

*Table 1 - synthesized priorities for solutions*

| Scenario | Raw data | Normals | Ideals | Rank |
|---|---|---|---|---|
| AGV | 0.18 | 0.24 | 0.58 | 3 |
| Pneumatic tube | 0.25 | 0.33 | 0.79 | 2 |
| Track & trace | 0.32 | 0.42 | 1.00 | 1 |

## Discussion

The study found that the decision criteria in Figure 1 can be used in combination with the ANP method to assess process solutions and technologies in a healthcare logistics context. Applying the ANP method to the decision criteria provides a more data driven and transparent decision process, taking intangible aspects and the preferences of decision makers into account. Furthermore, the study provides an example of how ANP can be used as part of a benchmarking effort in selecting a best practice solution that best fits the preferences at a particular hospital. Each of the assessed scenarios had initially been presented and discussed with the logistics manager at the Danish hospital. The interviews indicated a preference for the track and trace solution, which was validated by the ANP analysis.

A framework with relevant decision parameters to which an analytic method such as ANP can be applied is a prerequisite that is often not in existence (Chan et al., 2001). This study found that the framework of decision criteria can be used to assess logistical processes in hospitals. Furthermore, the decision criteria and their inter-relations were validated in the study and can be generalized from the bed logistics process in a Danish hospital to the pharmaceutical distribution process in a Danish and US hospital setting.

The best practices identified by Böhme and colleagues for the medical supply process include visual management, pharmaceutical dispensing machines, barcoding, and automatic reordering of inventories (Böhme et al., 2016). All of these practices were identified at the US hospital. Based on discussions with the Danish logistics manager, barcoding and subsequently the more sophisticated RFID technology were chosen as potential scenarios. Furthermore, pneumatic tube systems and AGVs were identified as significant potential improvement initiatives, which had also been identified in healthcare logistics literature, e.g. (Granlund and Wiktorsson, 2013; Jørgensen et al., 2013; Landry and Philippe, 2004).

Both RFID and barcodes would enable track and trace of the pharmaceutical items in the distribution process. RFID would provide more benefits than a barcode solution, but an RFID solution is also a more costly solution (Romero and Lefebvre, 2015). Current trends and potential benefits are proponents of RFID technology. However, the issue of financing is one of the inhibitors of RFID adoption (Wamba et al., 2013). The Danish hospital is a public hospital and subject to strict financial budgets that rarely allow for investments in logistical opportunities. Given that the Danish hospital already has the software needed to use barcodes and the solution being the least expensive option, barcodes might be the most plausible option. Another decision factor to consider is the impact and influence of the rest of the supply chain. E.g. the rest of the supply chain using barcodes is another proponent of the barcode solution (Romero and Lefebvre, 2015). Hence, there is a network effect that must be considered. E.g. to reap the full benefits of introducing RFID into the supply chain would mean that RFID would also have to be implemented by actors upstream in the supply chain. Similarly, the pneumatic tube solution might require a change in the format of the delivered pharmaceuticals, e.g. to unit dose packaging (Pinna et al., 2015), not only to that hospital but all hospitals supplied by the same wholesaler.

Implementing a track and trace solution provides the much needed information of the whereabouts of pharmaceutical items throughout the logistics process at the Danish hospital. Pharmaceutical supply chains are subject to stringent regulations due to the potential adverse effects on health (Shah, 2004). The diligent use of barcodes in the US hospital ensures transparency in the supply chain and control of the process (Chircu et al., 2014).

This paper contributes to the limited literature on benchmarking within healthcare logistics and provides an example of how the ANP method can be used in a benchmarking effort to rank potential process and technology solutions. Furthermore, the case study provides insights on process gaps and best practices in the pharmaceutical distribution process between a public Danish hospital and a high ranking US hospital.

## Conclusion

This study successfully applied ANP for evaluating pharmaceutical distribution solutions based on a set of decision criteria specific to a healthcare logistics context. A method for assessing technologies and process designs in healthcare logistics processes has been proposed. The applied method incorporates both quantitative measures and qualitative decision criteria capturing the complexities of a healthcare setting. Best practices were identified for the US hospital and validated as viable solutions for the Danish hospital. Based on the ANP method, the most preferable solution for the Danish case study hospital was determined. Applying the study's demonstrated approach yields a data driven decision process for a more informed decision.

## Limitations and future research

The decision criteria to which the ANP method was applied have been validated for a bed logistics process and a pharmaceutical distribution process and in a Danish and US setting. The findings of this study were only tested for two Western hospitals. To improve the validity of findings, the framework should be applied to other hospital logistics processes and other settings. Furthermore, a sensitivity analysis should be conducted to assess the effects on the results from changing the importance of the parameters in the framework. Finally, more empirical research is needed on how to benchmark healthcare logistics processes, both on the metric and best practice side.

## References


Al-Shaqha, W.M.S. and Zairi, M. (2000), "Re-engineering pharmaceutical care: towards a patient-focused care approach", *International journal of health care quality assurance*, Vol. 13, No. 5, pp. 208–217.

Anand, A. and Wamba, S.F. (2013), "Business value of RFID-enabled healthcare transformation projects", *Business Process Management Journal*, Vol. 19, No. 1, pp. 111–145.

Aptel, O. and Pourjalali, H. (2001), "Improving activities and decreasing costs of logistics in hospitals - A comparison of U.S. and French hospitals", *The International Journal of Accounting*, Vol. 36, No. 1, pp. 65–90.

Böhme, T., Williams, S.J., Childerhouse, P., Deakins, E. and Towill, D. (2016), "Causes, effects and mitigation of unreliable healthcare supplies", *Production Planning & Control*, Vol. 27 No. 4, pp. 249–262.

Çakici, Ö.E., Groenevelt, H. and Seidmann, A. (2011), "Using RFID for the management of pharmaceutical inventory - system optimization and shrinkage control", *Decision Support Systems*, Vol. 51, No. 4, pp. 842–852.

Camp, R.C. (1989a), *Benchmarking: the search for industry best practices that lead to superior performance*, Quality Press, Milwaukee, WI.

Camp, R.C. (1989b), "Learning from the best leads to superior performance", *Journal of business strategy*, Vol. 13 No. 3, pp. 3–6.

Camp, R.C. (1995), *Business process benchmarking: finding and implementing best practices*, ASQC Quality Press.

Chan, F.T.S., Chan, M.H., Lau, H. and Ip, R.W.L. (2001), "Investment appraisal techniques for advanced manufacturing technology (AMT): a literature review", *Integrated Manufacturing Systems*, Vol. 12, No. 1, pp. 35–47.

Chen, H.-K., Chen, H.-Y., Wu, H.-H. and Lin, W.-T. (2004), "TQM Implementation in a Healthcare and Pharmaceutical Logistics Organization: The Case of Zuellig Pharma in Taiwan", *Total Quality Management & Business Excellence*, Vol. 15, No. 9-10, pp. 1171–1178.

Chircu, A., Sultanow, E. and Saraswat, S.P. (2014), "Healthcare RFID In Germany: An Integrated Pharmaceutical Supply Chain Perspective", *Journal of Applied Business Research*, Vol. 30, No. 3, pp. 737–752.

Feibert, D.C. and Jacobsen, P. (2015), "Relations between decision indicators for implementing technology in healthcare logistics – a bed logistics case study", *22nd International Annual EurOMA Conference - Operations Management for Sustainable Competitiveness.*, Neuchâtel, p. 10.

Granlund, A. and Wiktorsson, M. (2013), "Automation in Healthcare Internal Logistics: a Case Study on Practice and Potential", *International Journal of Innovation and Technology Management*, Vol. 10, No. 3, pp. 1–20.

Hammer, M. (1990), "Reengineering Work: Don't Automate, Obliterate", *Harvard Business Review*, Vol. 68, No. 4, pp. 104–112.

Hammer, M. and Champy, J. (1993), *Reengineering the Corporation: A manifesto for business revolution*, HarperCollins Publishers, New York, 1st ed.

Hanman, S. (1997), "Benchmarking your firm's performance with best practice", *The International Journal of Logistics Management*, Vol. 8, No. 2, pp. 1–18.

Jun, J.B., Jacobson, S.H. and Swisher, J.R. (1999), "Application of discrete-event simulation in health care clinics: A survey", *Journal of the Operational Research Society*, Vol. 50, pp. 109–123.

Jørgensen, P., Jacobsen, P. and Poulsen, J.H. (2013), "Identifying the potential of changes to blood sample logistics using simulation", *Scandinavian Journal of Clinical Laboratory Investigation*, Vol. 73, No. 4, pp. 279–285.

Kim, G.C. and Schniederjans, M.J. (1993), "Empirical comparison of just-in-time and stockless materiel

management systems in the health care industry", *Hospital Materiel Management Quarterly*, Vol. 14, No. 4, pp. 65–74.
Landry, S. and Philippe, R. (2004), "How Logistics Can Service Healthcare", *Supply Chain Forum: An International Journal*, Vol. 5, No. 2, pp. 24–30.
Liberatore, M.J. and Nydick, R.L. (2008), "The analytic hierarchy process in medical and health care decision making: A literature review", *European Journal of Operational Research*, Vol. 189, No. 1, pp. 194–207.
Lillrank, P. and Liukko, M. (2004), "Standard, routine and non-routine processes in health care.", *International journal of health care quality assurance*, Vol. 17, No. 1, pp. 39–46.
Mayle, D.T., Hinton, C.M., Francis, G.A.J. and Holloway, J.A. (2002), "What really goes on in the name of benchmarking?", in Neely, A. (Ed.),*Business performance management*, Cambridge University Press, Cambridge, MA, pp. 211–224.
Meade, L. and Sarkis, J. (1998), "Strategic Analysis of Logistics and Supply Chain Management systems using the analytical network process", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 34, No. 3, pp. 201–215.
Mentzer, J.T. and Konrad, B.P. (1991), "An efficiency/effectiveness approach to logistics performance analysis", *Journal of Business Logistics*, Vol. 12, No. 1, pp. 33–61.
Meredith, J. (1998), "Building operations management theory through case and field research", *Journal of Operations Management*, Vol. 16 No. 4, pp. 441–454.
Meredith, J.R. and Suresh, N.C. (1986), "Justification techniques for advanced manufacturing technologies", *International Journal of Production Research*, Vol. 24, No. 5, pp. 1043–1057.
Mustaffa, N.H. and Potter, A. (2009), "Healthcare supply chain management in Malaysia: a case study", *Supply Chain Management: An International Journal*, Vol. 14, No. 3, pp. 234–243.
Neely, A., Gregory, M. and Platts, K. (2005), "Performance measurement system design: A literature review and research agenda", *International Journal of Operations & Production Management*, Vol. 25, No. 12, pp. 1228–1263.
OECD. (2015), *Health at a Glance 2015 - OECD Indicators*, doi:http://dx.doi.org/10.1787/health_glance-2015-en.
Ordoobadi, S.M. (2012), "Application of ANP methodology in evaluation of advanced technologies", *Journal of Manufacturing Technology Management*, Vol. 23, No. 2, pp. 229–252.
Pinna, R., Carrus, P.P. and Marras, F. (2015), "The drug logistics process: an innovative experience", *The TQM Journal*, Vol. 27, No. 2, pp. 214–230.
Romero, A. and Lefebvre, E. (2015), "Combining barcodes and RFID in a hybrid solution to improve hospital pharmacy logistics processes", *International Journal of Information Technology and Management*, Vol. 14, No. 2/3, pp. 97–123.
Shah, N. (2004), "Pharmaceutical supply chains: Key issues and strategies for optimisation", *Computers and Chemical Engineering*, Vol. 28, No. 6, pp. 929–941.
Saaty, T.L. (2004), "Decision making — the Analytic Hierarchy and Network Processes (AHP/ANP)", *Journal of Systems Science and Systems Engineering*, Vol. 13, No. 1, pp. 1–35.
Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations & Production Management*, Vol. 22, No. 2, pp. 195–219.
Voss, C.A., Åhlström, P. and Blackmon, K. (1997), "Benchmarking and operational performance: some empirical results", *International Journal of Operations & Production Management*, Vol. 17, No. 10, pp. 1046–1058.
Wamba, S.F., Anand, A. and Carter, L. (2013), "A literature review of RFID-enabled healthcare applications and issues", *International Journal of Information Management*, Elsevier Ltd, Vol. 33, No. 5, pp. 875–891.
Wamba, S.F. and Ngai, E.W.T. (2015), "Importance of issues related to RFID-enabled healthcare transformation projects: results from a Delphi study", *Production Planning & Control*, Vol. 26, No. 1, pp. 19–33.
www.superdecisions.com. (2016), "Super Decision website", available at: http://www.superdecisions.com/ (accessed 19 June 2016).
Yin, R.K. (1994), *Case study research - design and methods*, Sage.
Zhu, Z., Hen, B.H. and Teow, K.L. (2012), "Estimating ICU bed capacity using discrete event simulation", *International Journal of Health Care Quality Assurance*, Vol. 25, No. 2, pp. 134–144.