

# IMPROVING HOSPITAL LOGISTICS BY RETHINKING TECHNOLOGY ASSESSMENT

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## **ABSTRACT**

*In order to cope with the future challenges of the health care sector, there is an urging need for improving efficiency at hospitals. The study presents a framework enabling health care managers of improving the in-house logistics. The distinctiveness of the framework is the way in which it relates technology, logistics, structure and procedures to efficiency. Changing one factor e.g. technology, initiates an iterative loop focusing on change in the related factors in order to obtain the optimal efficiency. The search for an optimal efficient solution is the driving force of the framework, and will secure one iterative circle followed by another in an endless journey. The framework represents innovation as a broad solution where iteration between important factors secures an optimal solution. The study is performed as a case study with close relations to the staff at an emergency department at a Danish hospital. The framework is tested on the blood sample logistics between the emergency department and laboratory with the goal of enhancing the efficiency of the emergency department.*

*Keywords: Health care, logistics, technology assessment*

## **1. INTRODUCTION**

The developed countries will face a situation where the ratio of people needing care and the people providing health care will change dramatically (OECD 2007). Additionally modern healthcare is characterized by increasing demands for individualized high quality services, and rapid development of health care technologies, all resulting in increased pressure on in-house logistics. At the same time managing in-house logistics is becoming exceedingly complex as health institutions evolve into integrated health systems comprised of hospitals, outpatient clinics and surgery centers, nursing homes, and home health services (Curtright, Stolp-Smith 2000). Hence there is an increasing demand for utilizing the technological possibilities in order to optimize the logistical systems, and thereby maintaining the same health service level with less medical personnel.

Innovation and development of new technology in health care has mainly been related to the clinical area. Less emphasis has been on the use of technology to solve the emergent logistical challenges. Solving in-house logistical challenges has primarily been approached with a departmental (horizontal) view, and thereby lacking the holistic view of the entire in-house logistical system (vertical) leading to sub-optimization of the logistical system (Mayfield 2009, Shumaker 2007, Banerjee, Mbamalu & Hinchley 2008).

Implementation of new technology often results in modification of operational activities resulting in a change of procedures, as well as it often results in changes in the organizational structure. Consequently there is a need for developing a holistic framework that is capable of tying the different disciplines together and identifying the effect of implementation of a technological and logistical system at hospitals. Therefore establishing a framework that shows a clear and transparent link between logistics, technology, efficiency, procedure, and structure will be a new and innovative approach to dealing with implementation of technology in health care settings.

The paper will present a framework based on the presented considerations applied to a specific case, in order to test and validate the framework.

## **2. THEORETICAL BACKGROUND**

In order to understand how to think logistics and technology in health care, it is necessary to define the terms. Britannica Online Encyclopedia defines logistics as "...the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements." The definition of technology is "...the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment." Using these two definitions to achieve higher efficiency and service can then be looked as a change in the flow of goods, services, and related information by using products and services created by the application of scientific knowledge. If the use of Operations Management and LEAN thinking is brought into this context, it is the scope to create a systematic approach at improving the logistical systems by using new technological possibilities.

Literature concerning health care seems to be concentrated on sub optimized solutions, and the main focus is within three major areas. The first major area is concerned with new technological methods to improve patient treatment and diagnosing. This part of the literature is mainly focused on the new technological possibilities and inventions made, based on clinical results from various cases (Stein 2009, Nejat, Sun & Nies 2009, Spear 2005, Barbash, Glied 2010, Mendez et al. 2005, Berlinger 2006, Carlsson et al. 2010, Brennan, Mawson & Brownsell 2009, Okamura, Matarić & Christensen 2010). The second area of the literature focuses on telemedicine and the possibilities that this technology gives. Telemedicine is gaining increasing focus with journals entirely dedicated to this area e.g. *Journal of Telemedicine and Telecare*, *Telemedicine and e-Health*. The literature within telemedicine is primarily concerned with the possibility of treating and monitoring patients at home instead of at the hospital (Brennan, Mawson & Brownsell 2009, Lanseng, Andreassen 2007, Menachemi, Burke & Ayers 2004, Chau, Hu 2004), as well as the possibility of doctors being physically located at one hospital but using technology to do surgery and other treatment at another hospital (Mendez et

al. 2005, Berlinger 2006, Brennan, Mawson & Brownsell 2009, Okamura, Matarić & Christensen 2010, Chau, Hu 2004, Xiao et al. 2010, Gagnon et al. 2003). The third major area of technology literature in healthcare is within ICT (Information and Communication Technology). The primary focus is how to digitalize and control patient data (Lanseng, Andreassen 2007, Xiao et al. 2010, Neumann, Blouin 1999, Thompson, Dean 2009, Devaraj, Kohli 2000, Herriott 1999, Bogner 2010). Other areas with less focus in the technology literature are technology assessment (Neumann, Blouin 1999, Johnson et al. 2009, Thielst 2007), ethical issues concerning the use of robots in health care (Coeckelbergh 2010, Sharkey 2008), and the use of robots and other technologies used for rehabilitation of patients (Stein 2009, Nejat, Sun & Nies 2009, Okamura, Matarić & Christensen 2010, Matarić et al. 2007).

Exploring the literature focusing on logistics in the health care sector four major areas has had great attention. LEAN in health care has had a lot of attention within the last couple of years (Banerjee, Mbamalu & Hinchley 2008, Spear 2005, King, Ben-Tovim & Bassham 2006, Dickson et al. 2009). The literature has been divided into case study works or more theoretical founded publications (Souza 2009). Secondly the use of RFID and other logistical tracking devices has been used in health care. The focus has been on how to improve logistics by having tracking devices to control the logistics very closely, with the aim of improving patient safety (Pan, Pokharel 2007, Florentino et al. 2008, Awami, Swatman & Calabretto 2009). A third area with great interest is the flow of patients (Vermeulen et al. 2009, Vissers, Beech 2005) and structure of departments (Oddoye et al. 2009, Espinosa, Case & Kosnik 2004, Norrish, Rundall 2001, Villa, Barbieri & Lega 2009). This literature is concerned with how to make a better patient flow at hospitals. The last main area focuses on the supply chain of hospitals with emphasis on external logistics and the purchasing function at hospitals (Pan, Pokharel 2007, Jarrett 2006, Poulin 2003, Sinha, Kohnke 2009, King 2004, Birk 2008, Dooley 2009, Lapierre, Ruiz 2007, Vries, Huijsman 2011).

The aim of this project will therefore be to focus on a broad and holistic view of the flows in a health care area and analyze how a combined technological and logistical solution can improve the efficiency. The project includes a framework that relates efficiency to technology, logistics, structure and procedures. Using a structured framework in this sense will secure that flow costs are systematically lowered which is one of the criteria for “innovative care-process change” according to Paulus, Davis & Steele (2008). As the search for better efficiency is a continuous process the framework will represent a never ending journey. This never ending journey is related to continuous improvement and innovation as it can be difficult to separate these two terms from each other as defined by Chapman & Corso (2005) “...as both the small-step continual improvement activities are necessary, as well as the more dramatic, on-going technological-, organizational- and market-based changes normally considered under the term innovation”.

### **3. RESEARCH QUESTION**

In order to address the problems and challenges the health care sector is facing, the following research question has been formulated, “How can technology improve the logistics and service in the health care sector?” Four sub-questions are constructed to support the research question. The two first sub-questions relate technology to logistics.

1. Which relations exist between technology, logistic, efficiency, procedure, and structure?

2. How can a model be created containing technology, logistic, efficiency, procedure, and structure?

The last two sub-questions relates to practice.

3. How can a hospital use this model?
4. How can new technology concepts be included in the different existing logistical flows?

#### **4. METHODOLOGY**

Based on the research question and sub-questions the study has been performed as a case study (Morgan, Morgan 2009, Voss, Tsikriktsis & Frohlich 2002), with close relations to the staff at the Emergency Department and the laboratory at a Danish hospital. Case research is good for exploring certain phenomenon within “some real life context” (Yin 1991). This makes case research suitable in regard to this study due to the focus on building and testing a conceptual framework.

The study consists of two main processes; creating the framework and testing the framework. The two phases are closely combined because the framework will be adjusted according to the experience gained from the testing. This makes the present study follow an iterative process where the theoretical development of the framework is supplied with case study.

The creation of the framework started with a deductive process establishing the theoretical foundation using literature survey followed by an inductive process using semi-structured interviews (Winter, Munn-Giddings 2001) and on-site observations (Maaloe 2002). The literature survey focused on the literature concerning health care, logistics, and technology. The interviews were conducted with staff members from both the emergency department and the laboratory. The aim of the development process was to create the framework so that it was capable of analyzing the logistical systems followed by an analysis and evaluation of the effect of implementation of different technological possibilities.

The second part of the study was an empirical exemplification; analyzing the blood sample logistics from the emergency department to the laboratory and result back to the emergency department. The hospital had a great interest in using this case and it was an obvious case for the research project. The hospital is in a situation with increased pressure on the emergency department. This is a result of the Danish Health Care Reform (Andersen, Jensen 2010), which have resulted in the intake of patients at the emergency department increasing 15 % from 1<sup>st</sup> of January 2011, without the department getting any additional funding to cope with this increase in patients. This constitutes a need for making the emergency department more efficient. One approach is to diagnose the patients faster, in which blood testing plays a crucial part. Making the blood sample logistics more efficient will enable the emergency department to be more efficient. Having the hospitals interest in analyzing the system makes it easier to get access to data and employees.

All the interviews were conducted in a semi-structured and informal manner, with the emphasis on the interviewees telling their “story”. The questions posed to the interviewees were in relation to quality and traceability issues, and what are the criteria for a successful logistical system in relation to their tasks and working routines. Prior to

doing the interviews it was emphasized by fellow health care researchers, that personnel at public hospitals often have a negative attitude towards the way things are currently running as well as to doing changes. This paradox was kept in mind during the interviews as well as when the interviews were being “decoded”.

The goal of the interviews was to establish a perspective on how different health care employee groups consider technology implementations, and the main concerns in regard to their field of work. Both nurses and doctors were interviewed in the emergency department followed by on-site observations in the emergency department. This gave an insight to the requirements at a department with a particular stressful environment. Interviews were also conducted with doctors and biomedical laboratory technicians working in the laboratory at the hospital. This gave an insight to the concerns of personnel where the clinical quality is of utmost importance. Lastly administrative personnel within the department of Internal Service and Logistics were interviewed, who mainly has an efficiency and economic perspective on the logistics.

Further interviews with laboratory personnel and on-site observations have been conducted at a similar laboratory at another Danish hospital. This hospital has experiences from implementing new technology in a comparable logistical system, using the case as a further evaluation and validation of the constructed framework. The total amount of interviewed employees was 20 people.

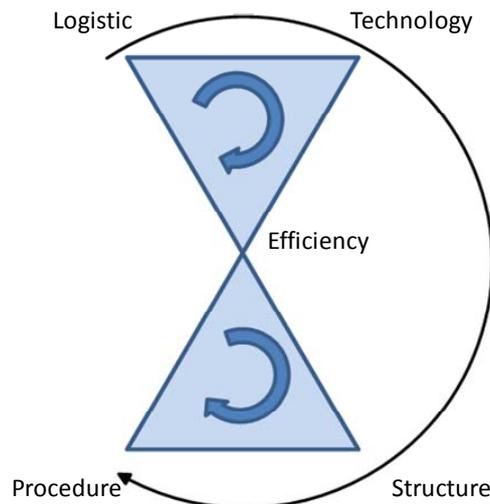
The basis of the analysis conducted using the framework was based on different static analyses. A functional analysis using IDEF<sub>0</sub> (Ang, Gay Robert & Khoo 1999), value stream analysis, competence shifts were highlighted using process map (Bicheno, Holweg 2008), 5S analysis to eliminating waste and possibilities for standardization (Russell, Taylor 2009), finished off with Poka Yoke (Bicheno, Holweg 2008) for error prevention and traceability. This was followed by a dynamic analysis using simulation. The simulation is excellent in testing real life logistical problems in a controlled manner, and is therefore a good way of evaluating different logistical systems, as well as pointing to problems within the analyzed system (Karlsson 2009). These analyses ensure that a full picture of the current system of the potential improvement is gained. All additional data used have been extracted from databases at the hospital.

#### **4.1 THE CASE**

The case represents the situation where a blood test is taken at an emergency department, transported to a laboratory, tested and finally the result is send back to the emergency department. Two Danish hospitals have been involved as cases. The primary case is a Danish hospital having the responsibility for the health services of approximately 425.000 inhabitants. The secondary case is a Danish hospital with the responsibility for the health services of approximately 300.000 inhabitants.

#### **4.2 FRAMEWORK**

The framework consists of two triangles merged together, see figure 1. Each triangle represents a separate iteration. The first triangle represents logistics, technology and efficiency. The three areas affect each other in an iterative manner. The second triangle represents structure, procedures and efficiency, also here the three areas affects each other. By merging the two triangles a relationship between logistics, technology, organizations and procedures is obtained with efficiency as a resulting parameter.



**Figure 1. The framework**

The logistic in our framework is mainly controlled by, 1) the distance between start and end point, 2) the quantity moved between the points, 3) the frequency the quantity has to be moved and 4) the speed the quantity is moving.

The technology is mainly controlled by 1) the method or principle used and 2) the medium or tool transferring the technology.

The structure represents the relation between the following, 1) the division, 2) the hierarchy, 3) the organization and 4) present competences.

The procedure expresses the approach for doing certain actions and processes and is expressed by 1) what is the process, 2) who does it and 3) the sequence of the processes. The procedures can both represent physical actions and the information flow related to another flow e.g. a patient flow. The procedure will be inspired by the LEAN philosophy.

Changes in efficiency can be measured and evaluated in many different ways, all depending on the logistical system. Criteria and parameters can for instance be lead time, number of handover situations, length of stay (LOS), resource utilization etc.

Health care is a constantly changing environment with constantly changing demands. Therefore the framework needs to be constructed in order to cope with this ever changing environment.

#### **4.3 APPLYING THE FRAMEWORK**

By applying the framework to the case the following procedure was used;

1. The system is chosen and bounded.
2. The system is described and the overall processes defined.
3. Quality demands and specification requirements are defined.
4. Technological possibilities for each of the overall processes are explored through study of the literature, searching the internet, and through brainstorm with employees.
5. The system at the hospital of analysis is thoroughly described using e.g. IDEF<sub>0</sub>.

6. The processes, where responsibility is shifted from one department to another, are thoroughly analyzed.
7. A flow chart is created showing the linkage to the overall processes.
8. The structure and related procedures are analyzed and described.
9. Using the flow chart combined with VSM, 5S, and Poka Yoke.
10. The analysis gives a basis for recommendation for improvements.

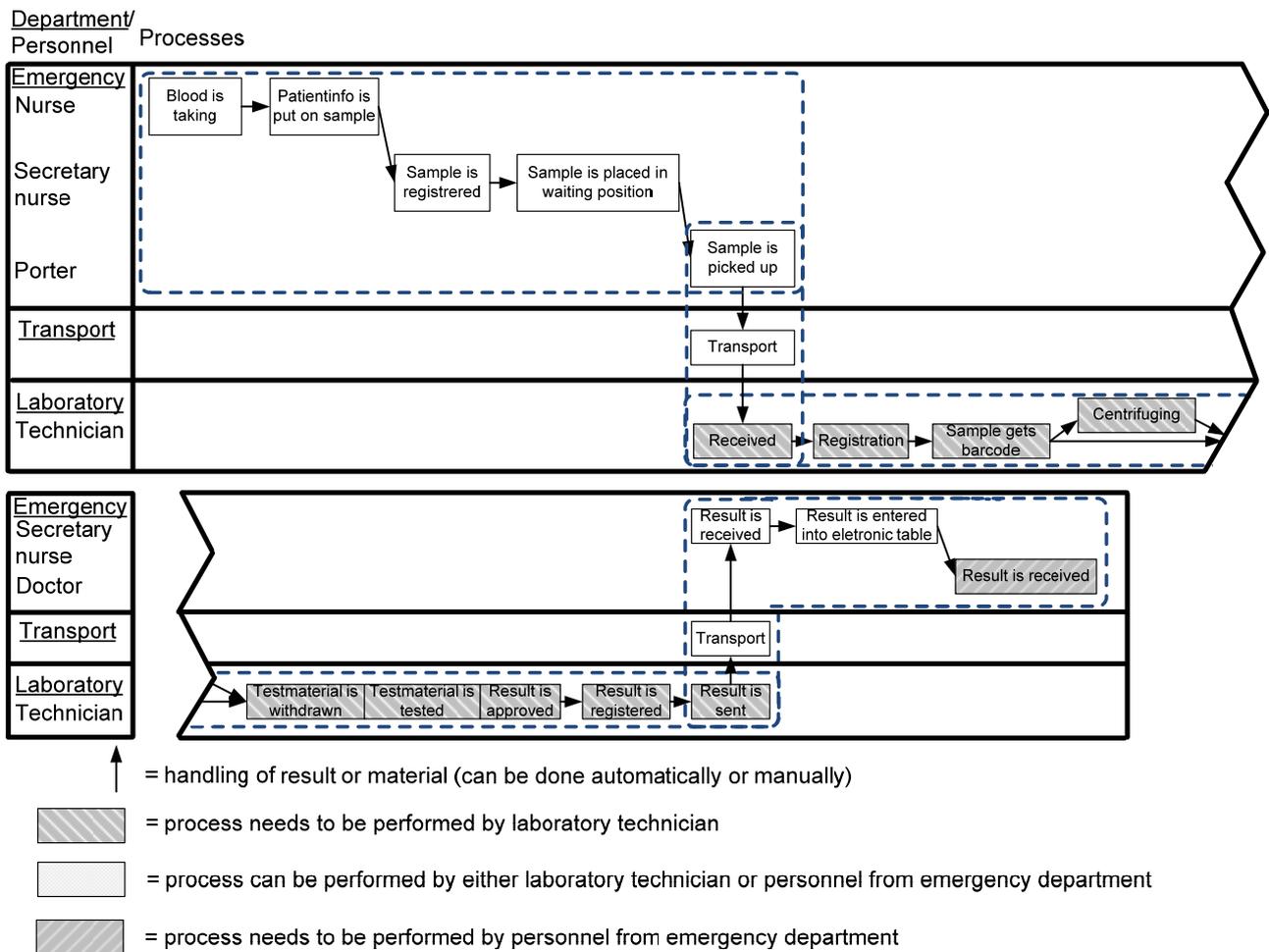
Using the specific case of blood testing, the logistical system can on an overall level be divided into four major processes, and the different technological possibilities within each of the processes;

- Taking the blood sample
  - Manually
  - Automatic
- Transporting the blood sample to the laboratory
  - Manual transport
  - AGV
  - Pneumatic tube system
  - De-central laboratories
- Testing the blood sample
  - Manually
  - Automatic
- Transporting the result of the test back to the emergency department.
  - Physical
    - Manually, AGV, pneumatic tube
  - Electronic
    - Computer, fax, telephone

The important quality criteria for the system were defined as;

- Violence to the blood sample during transportation
- Time between blood taking and blood analysis
- Influence of temperature
- Traceability
- Number of handover situations

The analysis and description of the current system developed into a flowchart presented in figure 2.



**Figure 2. Flow chart of the analyzed case**

Figure 2 shows the flow chart for the analyzed case. The flow chart shows where and by whom the processes are done. The flow chart is divided into two parts in order to make the figure manageable.

## 5. RESULTS

Using the quality criteria and the analysis of the system, considerations in regard to the overall level and recommendations for each of the major processes can be presented.

Overall level:

- A lot of non-value adding time in the transportation
- The feedback of the result was functioning very unsatisfying
- An unnecessary high number of competence shift where a handover situations takes place
- Some processes were being conducted unnecessarily

Blood taking process:

- The nurses should register the blood samples instead of the secretary. This can be done by having a barcode equivalent to the patient on the blood samples that the nurses can scan after the blood samples are taken.

Transportation of the blood sample:

- Locating the laboratory and the emergency department close to each other would be the optimal, but an extremely expensive and not realistic solution. The best technological solution is therefore a pneumatic tube system, which has its beginning at the emergency department and end at the laboratory.
  - The pneumatic tube system works at other hospitals.
  - The quality of the blood samples is maintained.
  - This system will decrease the transportation time by up to 40 minutes.
  - The investment will be saved within two years. The system cost app. € 67.000 to install. Two transporting porter positions each with a salary of app. € 27.000 per year will be saved.

Analysis of the blood sample at the laboratory:

- The analysis is highly automated but attention to the hand-over situations receiving the blood samples should be taken.

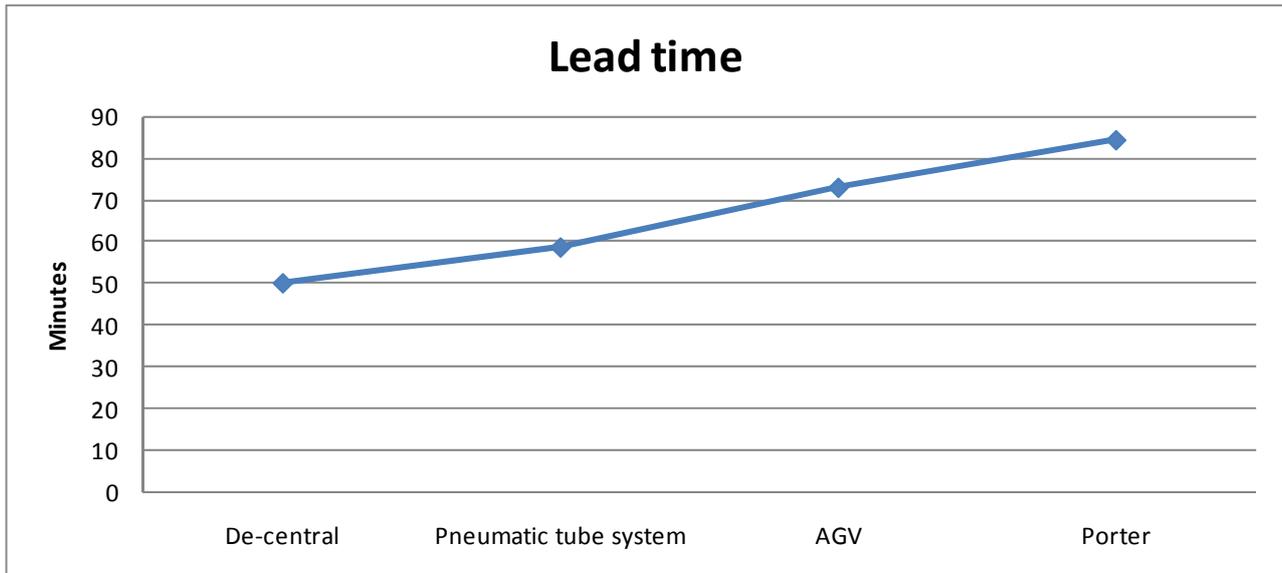
Transportation of result back to emergency department:

- When the result is received in the emergency department, the personnel responsible for the patient should be notified immediately, instead of having to look for the answer themselves. One solution would be by giving the doctors some form of PDA or notifying them via their telephone. The device should then be linked to the system in the emergency department controlling the patients, so the doctor will be notified when the result is available for his/her patient, as well as being notified if it is a critical result. Another solution could be big screens in the emergency department that show some kind of alarm when a result is ready.

Besides these recommendations, it is extremely important that the implementations are done so that focus is on the handover in between department. This is especially important due to the risk of sub-optimizing the system. If the different processes are optimized but the linkage between the processes is neglected, this will result in the problem of not getting the optimal out of the system.

### **5.1 RECOMMENDATIONS**

Using the results founded in the analysis of the system combined with the results from the simulation the biggest improvement to the system would be achieved by changing the transportation process into a pneumatic tube system. Implementing the pneumatic tube system resulted in a number of changes and considerations to the current setup.



**Figure 3. Lead time using different transportation technologies (Burasci, Demelas 2011, Nandrup-Bus 2011)**

- The change in efficiency:
  - The simulation shows that the lead time of the blood samples will be reduced from app. 74 min. to app. 51 min as shown on figure 3. This change will have a big impact on the flow of patients in the emergency department.
  - The amount of handover situations will also be decreased from 5 to 3. This minimizes the risks for errors.
  - The length of stay (LOS) of the patients will be able to be reduced with the same amount as the lead time app. 23 min.
- Technology change:
  - The technology will be changed from a purely manual approach into using a pneumatic tube system. It will be a more reliable system with low maintenance costs
- Logistics:
  - The implementation will change the value stream of the system eliminating unnecessary activities.
  - The tests will arrive at the lab more smoothly avoiding the risk of having queues.
- Structure of the system:
  - On a short term the change will result in two positions being cut back, because there will not be a need for the blood sample porters after the implementation.
  - On long term the system will probably have some effect on the personnel in the emergency department, because the system will be more effective and therefore there might be need for fewer personnel.
- Procedure:
  - Instead of the secretary the nurses will have the responsibility of registering the blood samples before sending them. The nurses will also have the responsibility of informing the laboratory that the blood samples have been sent and arrive shortly after at the laboratory. The notification will probably be done by pressing a button.

- At the laboratory the personnel needs to be aware that samples from the emergency department will arrive continuously compared to every half hour currently.

## 6. DISCUSSION

The overall aim of the study was to examine how efficiency can be improved by technology and logistics. In order to fulfill this aim, four different sub-questions were presented. Two of the questions focused on the theoretical part of creating the framework and the second two were related to the usage of such a framework.

The theoretical part of the study focused on developing a framework capable of doing an analysis of a logistical system at a hospital and show relations between technology, logistic, efficiency, procedure, and structure. This has been done to a certain extent. The framework was based on a literature survey that is general for all logistical systems at hospitals. The purpose of the framework was to secure solutions based on a broader basis and in this way avoid sub optimization. Additionally the framework should secure a continuous process. The framework was then tested, refined, and validated using a single case study. This constitutes some concerns about the applicability of the framework in relation to other logistical systems.

In terms of the second part of the study the framework were tested on a specific case at a hospital. The framework fitted nicely with the specific case, the logistical system was fully analyzed and recommendations as to where the biggest improvement will be reached were presented. In this sense the study showed how to apply the framework, and how new technology can be included in the existing logistical flow. Further the effects achieved from the implementation were examined, and the management at the hospital has decided to implement the pneumatic tube system at the hospital.

## 7. CONCLUSION

The contribution of this study is a descriptive analysis within innovation research (Crossan, Apaydin 2010, Boer, Gertsen 2003). There are two innovative aspects of the research. Firstly the approach of developing a framework for analyzing logistical systems and exploring how this system can be improved by implementing new technology, and how the systems should be change in terms of procedure and structure to get the full potential out of the implementation. Secondly the way the framework has been constructed secures the possibility to continuously evaluate a logistical system, pointing out what technological implementations have the largest beneficial effect.

Crossan and Apaydin (2010) use the definition of radical innovation as “fundamental changes and a clear departure from existing practices in the organization” whereas incremental innovation is seen as a “variation in existing routines and practices”. In this context the framework is considered as a an approach to do incremental innovation to the logistical system, due to the approach in which the framework not only focuses on the technology, logistics, and efficiency but also what impact this will have concerning structure and procedure.

## REFERENCE

Andersen, P.T. & Jensen, J. 2010, "Healthcare reform in Denmark", *Scandinavian journal of public health*, vol. 38, no. 3, pp. 246-252.

- Ang, C., Gay Robert, K.L. & Khoo, L.P. 1999, "IDEF\*: a comprehensive modelling methodology for the development of manufacturing enterprise systems", *International Journal of Production Research*, vol. 37, no. 17, pp. 3839-3858.
- Awami, S., Swatman, P.M.C. & Calabretto, J. 2009, "Implementing medication management software effectively within a hospital environment: Gaining benefits from metaphorical design", *Lecture Notes in Business Information Processing*, vol. 20 LNBIP, pp. 346-354.
- Banerjee, A., Mbamalu, D. & Hinchley, G. 2008, "The impact of process re-engineering on patient throughput in emergency departments in the UK", *International Journal of Emergency Medicine*, vol. 1, no. 3, pp. 189-192.
- Barbash, G.I. & Glied, S.A. 2010, "New Technology and Health Care Costs - The Case of Robot-Assisted Surgery", *New England Journal of Medicine*, vol. 363, no. 8.
- Berlinger, N.T. 2006, "Robotic surgery - Squeezing into tight places", *NEW ENGLAND JOURNAL OF MEDICINE*, vol. 354, no. 20, pp. 2099-2101.
- Bicheno, J. & Holweg, M. 2008, *The Lean toolbox: The essential guide to Lean transformation*, 4th edn, Picsie Books, Buckingham.
- Birk, S. 2008, "Improved efficiency through automation", *Materials management in health care*, vol. 17, no. 10.
- Boer, H. & Gertsen, F. 2003, "From continuous improvement to continuous innovation: A (retro)(per)spective", *International Journal of Technology Management*, vol. 26, no. 8, pp. 805-827.
- Bogner, M.S. 2010, "Reducing error in safety critical health care delivery", *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 5962 LNCS, pp. 107-114.
- Brennan, D.M., Mawson, S. & Brownsell, S. 2009, "Telerehabilitation: Enabling the Remote Delivery of Healthcare, Rehabilitation, and Self Management", *Studies in health technology and informatics*, vol. 145, pp. 231-248.
- Burasci, C. & Demelas, R. 2011, *Medical Analysis: The effects of the technological improvements on the functioning of an emergency department*, M. Sc., Technical University of Denmark, Kgs. Lyngby.
- Carlsson, S., Nilsson, A.E., Schumacher, M.C., Jonsson, M.N., Volz, D.S., Steineck, G. & Wiklund, P.N. 2010, "Surgery-related Complications in 1253 Robot-assisted and 485 Open Retropubic Radical Prostatectomies at the Karolinska University Hospital, Sweden", *Urology*, vol. 75, no. 5, pp. 1092-1097.
- Chapman & Corso 2005, "From continuous improvement to collaborative innovation: the next challenge in supply chain management", *Production Planning and Control*, vol. 16, no. 4, pp. 339-344.
- Chau, P.Y.K. & Hu, P.J. 2004, "Technology implementation for telemedicine programs", *Communications of the ACM*, vol. 47, no. 2, pp. 87-92.
- Coeckelbergh, M. 2010, "Health Care, Capabilities, and AI Assistive Technologies", *Ethical Theory and Moral Practice*, vol. 13, no. 2, pp. 181-190.
- Crossan, M.M. & Apaydin, M. 2010, "A Multi-Dimensional Framework of Organizational Innovation: A Systematic Review of the Literature", *Journal of Management Studies*, vol. 47, no. 6, pp. 1154-1191.

- Curtright, J.W. & Stolp-Smith, S. 2000, "Strategic performance management: Development of a performance measurement system at the Mayo...", *Journal of Healthcare Management*, vol. 45, no. 1, pp. 58.
- Devaraj, S. & Kohli, R. 2000, "Information technology payoff in the health-care industry: a longitudinal study", *Journal of Management Information Systems*, vol. 16, no. 4, pp. 41-67.
- Dickson, E.W., Anguelov, Z., Vetterick, D., Eller, A. & Singh, S. 2009, "Use of lean in the emergency department: a case series of 4 hospitals", *Annals of emergency medicine*, vol. 54, no. 4, pp. 504-510.
- Dooley, L. 2009, "Make logistics the focus of your supply chain plan", *Materials management in health care*, vol. 18, no. 5, pp. 26.
- Espinosa, J.A., Case, R. & Kosnik, L.K. 2004, "Emergency department structure and operations", *Emergency medicine clinics of North America*, vol. 22, no. 1, pp. 73-85.
- Florentino, G.H.P., Paz de Araujo, C.,A., Bezerra, H.U., Junior, H.B.A., Xavier, M.A., de Souza, V.,S.V., de M Valentim, R.,A.A., Morais, A.H.F., Guerreiro, A.M.G. & Brandao, G.B. 2008, "Hospital automation system RFID-based: technology embedded in smart devices (cards, tags and bracelets)", *Conference proceedings*, vol. 2008, pp. 1455-1458.
- Gagnon, M., Godin, G., Gagné, C., Fortin, J., Lamothe, L., Reinharz, D. & Cloutier, A. 2003, "An adaptation of the theory of interpersonal behaviour to the study of telemedicine adoption by physicians", *International journal of medical informatics*, vol. 71, no. 2-3, pp. 103-115.
- Herriott, S. 1999, "Reducing delays and waiting times with open-office scheduling", *Family practice management*, vol. 6, no. 4, pp. 38.
- Jarrett, P.G. 2006, "An analysis of international health care logistics: The benefits and implications of implementing just-in-time systems in the health care industry", *Leadership in Health Services*, vol. 19, no. 1, pp. 1-10.
- Johnson, A.P., Sikich, N.J., Evans, G., Evans, W., Giacomini, M., Glendining, M., Krahn, M., Levin, L., Oh, P. & Perera, C. 2009, "Health technology assessment: A comprehensive framework for evidence-based recommendations in Ontario", *International Journal of Technology Assessment in Health Care*, vol. 25, no. 2, pp. 141-150.
- Karlsson, C. 2009, *Researching Operations Management*, Routledge, New York, N. Y.
- King, D.L., Ben-Tovim, D. & Bassham, J. 2006, "Redesigning emergency department patient flows: Application of Lean Thinking to health care", *Emergency Medicine Australasia*, vol. 18, no. 4, pp. 391-397.
- King, J. 2004, "HEALTH CARE'S Major Illness", *Computerworld*, vol. 38, no. 19, pp. 31.
- Lanseng, E.J. & Andreassen, T.W. 2007, "Electronic healthcare: a study of people's readiness and attitude toward performing self-diagnosis", *International Journal of Service Industry Management*, vol. 18, no. 4, pp. 394-417.
- Lapierre, S.D.S. & Ruiz, A.B.A. 2007, "Scheduling logistic activities to improve hospital supply systems", *Computers and Operations Research*, vol. 34, no. 3, pp. 624-641.
- Maaloe, E. 2002, *Casestudier af og om mennesker*, 2nd edn, Akademisk Forlag, Viborg.
- Matarić, M.,J., Eriksson, J., Feil-Seifer, D. & Winstein, C.J. 2007, "Socially assistive robotics for post-stroke rehabilitation", *Journal of NeuroEngineering and Rehabilitation*, vol. 4, no. 1.

- Mayfield, S.R. 2009, "Hospitals get 'Lean' in pursuit of excellence", *AHA News*, vol. 45, no. 9, pp. 4.
- Menachemi, N., Burke, D.E. & Ayers, D.J. 2004, "Factors Affecting the Adoption of Telemedicine—A Multiple Adopter Perspective", *Journal of medical systems*, vol. 28, no. 6, pp. 617-632.
- Mendez, I., Hill, R., Clarke, D., Kolyvas, G. & Walling, S. 2005, "Robotic long-distance telementoring in neurosurgery", *Neurosurgery*, vol. 56, no. 3, pp. 434-440.
- Morgan, D. & Morgan, R. 2009, *Single-Case Research Methods for the behavioral and health sciences*, 1st edn, SAGE, Thousand Oaks.
- Nandrup-Bus, T. 2011, *Optimering af Blodprøvetagning*, B. Sc., Technical University of Denmark, Kgs. Lyngby.
- Nejat, G., Sun, Y. & Nies, M. 2009, "Assistive Robots in Health Care Settings", *Home Health Care Management & Practice*, vol. 21, no. 3, pp. 177-187.
- Neumann, C.L. & Blouin, A.S. 1999, "Achieving success: Assessing the role of and building a business case for technology in healthcare", *Frontiers of health services management*, vol. 15, no. 3.
- Norrish, B.R. & Rundall, T.G. 2001, "Hospital Restructuring and the Work of Registered Nurses", *The Milbank quarterly*, vol. 79, no. 1, pp. 55-79.
- Oddoye, J.P., Jones, D.F., Tamiz, M. & Schmidt, P. 2009, "Combining simulation and goal programming for healthcare planning in a medical assessment unit", *European Journal of Operational Research*, vol. 193, no. 1, pp. 250-261.
- OECD 2007, 01-03-2007-last update, [www.oecd.org/topicstatsportal/](http://www.oecd.org/topicstatsportal/) [2010, 13/01].
- Okamura, A.M., Matarić, M.J. & Christensen, H.I. 2010, "Medical and Health-Care Robotics", *IEEE Robotics&Automation Magazine*, vol. 17, no. 3, pp. 26-37.
- Pan, Z.X.(. & Pokharel, S. 2007, "Logistics in hospitals: a case study of some Singapore hospitals", *Leadership in Health Services*, vol. 20, no. 3, pp. 195-207.
- Paulus, R.A., Davis, K. & Steele, G.D. 2008, "Continuous Innovation In Health Care: Implications Of The Geisinger Experience", *Health Aff (Millwood)*, vol. 27, no. 5, pp. 1235-1245.
- Poulin, É. 2003, "Benchmarking the hospital logistics process", *CMA Management*, vol. 77, no. 1, pp. 20-23.
- Russell, R. & Taylor, B.W. 2009, *Operations management: Creating value along the supply chain*, 6th edn, John Wiley & Sons, Hoboken, N. J.
- Sharkey, N. 2008, "The Ethical Frontiers of Robotics", *Science*, vol. 322, no. 5909, pp. 20177061.
- Shumaker, P. 2007, "What Lean Thinking can do", *H&HN: Hospitals & Health Networks*, vol. 81, no. 1, pp. 8.
- Sinha, K. & Kohnke, E. 2009, "Health care supply chain design: toward linking the development and delivery of care globally", *Decision Sciences*, vol. 40, no. 2, pp. 197-212.
- Souza, L.B.d. 2009, "Trends and approaches in lean healthcare", *Leadership in Health Services*, vol. 22, no. 2, pp. 121-139.

- Spear, S.J. 2005, "Fixing health care from the inside, today", *Harvard business review.*, vol. 83, no. 9, pp. 78-91, 158.
- Stein, J. 2009, "Adopting new technologies in stroke rehabilitation: the influence of the US health care system", *European Journal of Physical and Rehabilitation Medicine*, vol. 45, no. 2, pp. 255-258.
- Thielst, C.B. 2007, "Effective Management of Technology Implementation", *Journal of Healthcare Management*, vol. 52, no. 4, pp. 216.
- Thompson, S.M. & Dean, M.D. 2009, "Advancing information technology in health care", *Communications of the ACM*, vol. 52, no. 6, pp. 118-121.
- Vermeulen, I.B., Bohte, S.M., Elkhuisen, S.G., Lameris, H., Bakker, P.J.M. & Poutré, H.L. 2009, "Adaptive resource allocation for efficient patient scheduling", *Artificial Intelligence in Medicine*, vol. 46, no. 1, pp. 67-80.
- Villa, S., Barbieri, M. & Lega, F. 2009, "Restructuring patient flow logistics around patient care needs: implications and practicalities from three critical cases", *Health care management science*, vol. 12, no. 2, pp. 155-165.
- Vissers, J. & Beech, R. 2005, *Health Operations Management: Patient Flow Logistics in Health care*, Routledge, London.
- Voss, C., Tsikriktsis, N. & Frohlich, M. 2002, *Case research in operations management*, MCB UP Ltd.
- Vries, J.d. & Huijsman, R. 2011, "Supply chain management in health services: an overview", *Supply Chain Management: An International Journal*, vol. 16, no. 3, pp. 159-165.
- Winter, R. & Munn-Giddings, C. 2001, *A Handbook for action research in Health and social care*, 1st edn, Routledge, New York.
- Xiao, L., Hu, B., Croitoru, M., Lewis, P. & Dasmahapatra, S. 2010, "A knowledgeable security model for distributed health information systems", *Computers & Security*, vol. 29, no. 3, pp. 331-349.
- Yin, R.K. 1991, *Applications of case study research*, 8th edn, Sage Publications, Newbury Park, CA.