

Assessing warehouse centralization and outsourcing in the healthcare sector: An Italian case study

Original

Assessing warehouse centralization and outsourcing in the healthcare sector: An Italian case study / Cagliano, A. C.; Grimaldi, S.; Rafele, C.. - ELETTRONICO. - Volume 2017:(2017), pp. 244-250. (Intervento presentato al convegno 22nd Summer School "Francesco Turco" - Industrial Systems Engineering 2017 tenutosi a Palermo (Italy) nel 13-15 September 2017).

Availability:

This version is available at: 11583/2703811 since: 2018-03-20T10:06:55Z

Publisher:

AIDI - Italian Association of Industrial Operations Professors

Published

DOI:

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

Assessing warehouse centralization and outsourcing in the healthcare sector: an Italian case study

Cagliano A.C.*, Grimaldi S.*, Rafele C.*

* Department of Management and Production Engineering, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 - Torino – Italy (anna.cagliano@polito.it, sabrina.grimaldi@polito.it, carlo.rafele@polito.it)

Abstract: In Western countries the ratio of the public spending on healthcare (HC) to the Gross Domestic Product is growing. In such a context the centralization of warehouses storing drugs, medical devices, and consumable products as well as the outsourcing of their management to qualified logistics providers are increasingly perceived as key drivers for the efficient provision of HC services. In fact, some projects have been carried out in Europe. However, most of the still few available literature contributions either analyze the supply network structure or preliminarily address the associated performance. A limited number of approaches assess the actual implications of HC warehouse centralization and outsourcing after its implementation. Also, there is a need for straightforward evaluation methods that can be easily applied by HC providers. This paper discusses the performance of a centralization and outsourcing initiative carried out by an Italian public hospital. Main logistics, HC, and economic indicators are identified based on a literature review and discussions with the hospital management and the logistics provider. After measuring and comparing the variable values over a twelve-year time span, the associated correlations are studied to provide a systematic interpretation of the outcomes able to uncover the benefits of the new organizational approach. In particular, a centralized material management, together with logistics improvements at the bed level, allowed optimizing the time spent on logistics activities at wards. Additionally, the inventory turnover ratio increased by 23%. Finally, the total logistics costs for the analyzed hospital were reduced by about 30%. By offering a simple assessment approach, this work might constitute a methodological starting point for evaluating the benefits of other similar logistics initiatives. As such, it can foster the development of ex-post assessment methodologies to tackle the advantages and drawbacks of warehouse centralization and outsourcing in HC.

Keywords: healthcare; warehouse management; centralization; outsourcing; performance

1. Introduction

In an age of shrinking economic resources and “spending review” programs efficiency plays a key role in any industry and in particular in the healthcare (HC) sector (Bendavid and Boeck, 2011). As a matter of fact, recent data show that the public spending on HC as a share of the Gross Domestic Product tends to grow in almost all the Western countries (OECD, 2017). The causes for this trend are to be found in some dynamics characterizing current socio-cultural settings, such as an increase in chronic diseases, the diffusion of technological innovations, a higher value given to health and wellness, and the lengthening of the aging period. In particular, it has been proved that the two cost items that have the greatest impact on the spending of HC systems are associated with staff and the purchase of goods and services, with a major contribution due to drugs and their management (Aronsson, Abrahamsson and Spens, 2011).

In this context logistics is one of the processes supporting HC services where there is still much room for efficiency as on average it accounts for 30-40% of hospital budgets (Scheller and Smeltzer, 2006; Landry and Beaulieu, 2013). Outsourcing has long been perceived as an effective way of focusing internal resources on core clinical activities in order to provide patients with higher service levels, while at the same time having logistics activities executed by skilled providers.

A number of literature contributions discuss the benefits and limitations of the application of this strategy to HC organizations (Gobbi and Hsuan, 2010; Nicholson, Vakharia and Erenguc, 2004). Besides outsourcing, HC warehouse centralization has attracted significant considerations by both researchers and practitioners in the last decade, also based on the success such an approach has already gained in several sectors like for instance spare parts, food, and retail (Pedersen, Zachariassen and Arlbjørn, 2012; Schmitt et al., 2015). The inventory pooling consequent to warehouse centralization stimulates different organisations to use the same products, being them drugs, medical devices or consumables, and leads to a standardisation of the associated procurement and logistics procedures, with undeniable savings as a result of economies of scale and scope. However, despite several initiatives carried out by HC institutions, which often combines centralization with warehouse management outsourcing, literature on the topic is still scarce and only isolated studies address either the supply network structure or the potential performance that could be achieved. Few works investigate the implications of HC warehouse centralization and outsourcing after their implementation. An appropriate understanding of the actual advantages of these strategies might help their adoption. A further aspect that has to be taken into account is that HC providers are usually scarcely familiar with sophisticated assessment procedures and thus they

need straightforward methods to assess and analyse the consequences of management policies.

As an attempt to fill the identified research gaps, the present work deals with the performance of warehouse centralization and outsourcing in an Italian public hospital. The main indicators are identified based on a review of literature as well as the experience of the hospital executives and the logistics service provider (LSP) managing the warehouse. Then, the values assumed by such quantities in the first twelve years of operations of the central warehouse are analysed by studying their correlations. In this way a comprehensive interpretation of the outcomes of the new organizational approach is obtained.

The remainder of the paper is organized as follows. Section 2 introduces the issues of warehouse centralization and outsourcing by framing them in the existing literature. Section 3 presents the methodology and the case study, while Section 4 analyses the associated achieved performance. Finally, the implications and limitations of the study as well as future research directions are detailed in Section 5.

2. Healthcare logistics models: centralization and outsourcing

Nowadays in the HC sector there are three different organizational models for managing the physical and information flows associated with materials.

The first model is named “traditional” and despite being quite diffused, it is not always the most efficient and effective one (Battini, Persona and Rafele, 2008; Chandra, 2008). It requires a number of warehouses within each hospital whose job is interfacing with suppliers and providing floors with materials. Thus, product demand, bids, and master data are managed separately by each HC institution, with the proliferation of many different information flows although with the same goal.

The second model is an evolution of the first one and provides for the centralized management of procurement and warehouses, where a part of the activities can be outsourced and the remaining part is internally controlled by HC organizations (Rooney, 2011). Procurement centralization is of paramount importance in HC settings making use of expensive and highly technological products. It brings savings (Rego, Claro and Pinho de Sousa, 2013) and is able to rationalize and streamline the overall purchase process (Ferretti, Favalli and Zangrandi, 2014).

The third model is based on outsourcing. Material management and handling are entrusted to a LSP, while either a central purchasing department or the single HC institutions liaise with suppliers. Outsourcing enables organizations to resize the spectrum of their activities to focus on core competencies, with consequent benefits in terms of improved organizational flexibility and cost reduction (Nicholson, Vakharia and Erenguc, 2004). Often in case studies and literature (Vollan et al., 2017) different forms of integration between centralization and

outsourcing strategies are found. Among recent works, Azzi and others (2013) compare different organizational structures to support the decision of whether self-managing or outsourcing logistics operations in centralized HC networks. Essoussi and Ladet (2009) classify the new trends towards healthcare supply chain integration according to three logistic strategies: groups of purchasing organizations; partial/total centralization of medical supplies; outsourcing to third-party logistics providers.

Centralization and outsourcing strategies generate many advantages but also cause a greater managerial complexity due to the interdependencies between activities and functions to be transferred from one organization to another. Similarly to what happens with procurement centralization, even in the case of outsourcing coordination between the different parties involved should be ensured as well as the development of appropriate support tools within HC institutions. In particular, it is important to encourage both formal and informal communication among parties in order to monitor the evolution of relationships, to share knowledge, and develop trust. This is essential especially when not all the aspects of the relationship between suppliers and customers are formalized.

Centralization and outsourcing impact on the information and physical flows characterising macro-logistics. These flows start from the material demand generated by specific HC needs and involve pharmaceutical companies, depositary agents, and logistics providers. However, also the points of use within hospitals, such as wards and clinics, may benefit from the improvements brought by such strategies. As witnessed by literature, procurement and warehouse centralization together with outsourcing can be combined with applications of technological and organizational solutions affecting hospital micro-logistics (Bisbal and Berry, 2011). Initiatives like the computerization of information flows and full traceability of drugs allow to increase efficiency and decrease errors in the drug management process as far as the ultimate echelon, namely the patient bedside (Iannone et al., 2014). There are several national and international HC institutions that achieved remarkable results by introducing innovations such as outsourcing transportation and logistics, centralizing warehouse activities, and tracing therapies. In Italy, regions such as Toscana and Emilia Romagna (Lega, Marsilio and Villa, 2012) implemented strategies of centralized procurement and warehouse management by applying structured models characterized by different aggregation levels of the purchase process of goods and services. The mentioned Italian cases are part of a broader effort of logistics centralization and outsourcing, which is currently spreading in the national context through different application models, all having the goal of inducing substantial improvements in terms of quality and costs in the macro and micro HC logistics. In other countries, examples of centralization and outsourcing are constituted by the PASA Agency, OCG Buying Solutions, and the NHS supply chain in UK, CADES in Switzerland, CACIC and other national and regional initiatives in France, and CHC in Spain (Marsilio and Mele, 2010). While in the U.S.

most of hospitals have developed purchasing alliances (Burns and Lee, 2008).

Despite HC logistics centralization and outsourcing have become key topics in recent years, the related literature is still scarce (Wu, Rossetti and Tepper, 2015). Focusing on warehouse centralization, Lega, Marsilio and Villa (2013) put forward a framework for analysing the operational costs, financial, and organizational benefits of a regional network of HC institutions undertaking this strategy. Ferretti, Favalli and Zangrandi (2014) study the efficiency and cost-effectiveness of warehouse centralization for a hospital pharmacy. Cagliano, Grimaldi and Rafele (2016) develop an approach for assessing the similarities and differences in logistics management by a group of HC organizations wishing to centralise their warehouses. Identifying these characteristics leads to find out the management commonalities that can stimulate warehouse centralization as well as the criticalities that could hinder it.

Besides being very limited, the literature on the topic is frequently focused on the structure of centralised logistics networks. When performances are addressed, they are usually analysed before centralization and/or outsourcing initiatives are started, therefore just giving an overview of the potential benefits that might be achieved. In order to fill such a research gap, the present work discusses an approach to quantitatively evaluate the actual outcomes of warehouse centralisation and outsourcing strategies in HC.

3. Case presentation and methodology

3.1 Case presentation

The present research has been developed around the case of a large public hospital in Central Italy. It counts about 800 beds and a variety of specialties including cardiology, vascular surgery, plastic surgery, orthopaedics, obstetrics, and paediatrics among others. Until 2002 the hospital directly managed a number of small warehouses stocking products for different uses and outsourced material distribution to wards to a local LSP. The internal management of logistics was causing a number of criticalities such as the lack of a warehouse management system, with consequent manual procedures to monitor procurement and no availability of past data on inventory and material consumption. Such a situation was exacerbated by not appropriate vehicles and material handling systems, difficulties in managing personnel to make up for their sudden shortage, and the need to deal with new issues such as the management of plasma and blood products. In order to address these aspects, in 2003 the hospital started a project aimed at re-organizing physical and information flows which entrusted the logistics services related to drugs and other HC products to the above mentioned LSP. This project first focused on macro-logistics by centralising the hospital warehouses, outsourcing their management, and implementing a warehouse information system. In the subsequent years it was completed by also addressing micro-logistics. In this

field a patient traceability system relying on bracelets was adopted, together with a computerized system to support therapy prescription and administration as well as points of use material ordering to the central warehouse. Additionally, an information system assisting surgical blocks was introduced in 2011.

3.2 Methodology

With the aim of assessing the performance trends of the warehouse centralization and outsourcing project during its first twelve years, a phased approach is adopted.

First of all, current logistics and supply chain management (SCM) processes are investigated in order to develop a complete knowledge of the operational and managerial conditions underpinning the case at issue. Such an analysis is carried out through direct observations of activities and semi-structured interviews with the hospital logistics executives, representatives from the main wards, the LSP and the employees working in the centralised warehouse. Process mapping and flow chart techniques are then applied to organize and systematise the gathered information.

The knowledge thus acquired allows to move to the second step of the approach, namely the identification of the relevant key performance indicators (KPIs). According to a literature review about logistics and SCM in manufacturing and HC sectors and the experience of the working team, which is composed by the authors and the same professionals mentioned before, multiple performance dimensions are taken into account to get a comprehensive perspective on the issue. In particular, to capture how the demand for HC services influences logistics activities and as a consequence the associated expenses, logistics, healthcare, and economic KPIs are considered (Lega, Marsilio and Villa, 2012). Logistics KPIs are in turn classified into those related to the warehouse and those concerning wards. Their detailed description is provided in Section 4.

After collecting the values of each KPI before warehouse centralization and outsourcing and over the next twelve years, the results are compared and contrasted. Since just thirteen numerical observations are available, forming a too limited sample size to enable statistical analyses, correlations between couples of selected KPIs are studied by computing how the values of their ratios change overtime.

Finally, the outcomes of the analysis are discussed and validated by the working team.

4. Case analysis

The following paragraphs discuss the main phases of the application of the methodology described in Section 3.2.

4.1 Performance indicator definition

Several brainstorming sessions are conducted together with the working team to review mainstream literature about supply chains (SCs) in HC and manufacturing industries and to cross-check it with the experience and the performance indicators already measured by the hospital and the LSP. Based on this process fifteen KPIs to assess the performance of the case warehouse are identified and classified into the four categories defined in Section 3.2 according to their nature (Table 1). It is important to highlight that such a warehouse manages both stock and direct delivery products. Stocked products

are stored in the warehouse and delivered to points of use (e.g. wards, laboratories) upon request. They include frequently used stock keeping units (SKUs) such as most of drugs and less specific medical devices. Direct delivery products are ordered by the warehouse from suppliers based on point of use requests and immediately delivered to their ultimate consignees upon receiving. Thus they are not stored in the warehouse, which constitutes a transit point for them. Not frequently used or high value SKUs such as some types of medical devices belong to this product category (Scheller and Smeltzer, 2006).

Table 1: Selected key performance indicators

KPI type	KPI name	Source
Logistics - Warehouse	N° handled SKUs (stock, direct delivery)	Brewer, Button and Hensher, 2008
	N° outgoing items	De Koster, Le-Duc and Roodbergen, 2007; Scheller and Smeltzer, 2006
	Economic value outgoing items	
	N° handled packs	Working team
	Economic value warehouse inventory	Gu, Goetschalckx and McGinnis, 2010
	Warehouse inventory turnover ratio	
	N° material requests (ordinary, urgent)	Working team
Logistics - Ward	N° order lines (ordinary, urgent)	Faber, De Koster and Smidts, 2013
	Economic value ward inventory (drugs, diagnostic material, medical devices, dialysis material)	Silver, Pyke and Peterson, 1998
Healthcare	Weekly time spent on logistics activities	Working team
	N° stays (ordinary, day hospital, day surgery)	Working team
Economic	Days of stay (ordinary, day hospital, day surgery)	Working team
	N° beds (ordinary, day hospital)	Working team
	Warehouse management cost (before outsourcing)	De Koster, Le-Duc and Roodbergen, 2007
	LSP revenue (ordinary/urgent service, computerized prescription and administration, hospitalization services. Includes VAT)	Working team

4.2 Performance indicators assessment

A collection of past values of the selected KPIs is performed by accessing the information management systems of both the case hospital and the LSP. Data are gathered over the time period 2002-2014, where 2002 represents the situation before warehouse centralization and outsourcing and the years 2003-2014 are the first twelve years of implementation of the centralised logistics management approach.

In order to better understand the KPI trends and to facilitate their analysis with the working team, the gathered numerical values are displayed by means of histograms. As an example, Figure 1 provides the values of the KPI Total number of days of stay.

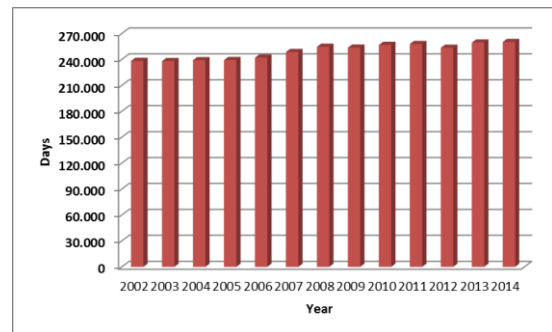


Figure 1: Total number of days of stay

The KPI values are then compared with each other to capture their possible mutual influences in determining the global performance of the warehouse. Here the

purpose is obtaining meaningful results although the limited number of available observations, which is quite a common situation when assessing the initial performance of new organizational models. This limitation is overcome by computing ratios between couples of KPIs in order to correlate their values. Also this step was inspired by the literature review carried out in the performance indicators definition phase as well as by the experience of the working group members. To be more precise, twenty-seven ratios studying the connections between the main logistics indicators and the other KPIs in Table 1 are investigated. The logistics KPIs taken into account are inventory levels, both in the warehouse and at the points of use, number of material requests, number of order lines, and number of handled SKUs and packs. Again the values assumed by the identified ratios over the analysed time span are displayed by histograms. Table 2 reports some examples of ratios, while Figure 2 shows the histogram of the ratio of the total number of order lines to the total number of days of stay in each year.

Table 2: Some examples of ratios

Ratio
Economic value outgoing items/ Economic value warehouse inventory (Inventory turnover ratio)
Economic value drug ward inventory /Total economic value ward inventory
LSP revenue for ordinary service/N° ordinary material requests
Total LSP revenue (ordinary and urgent service)/Total N° order lines (ordinary and urgent)
N° urgent order lines/N° urgent material requests
N° handled packs/ Total N° order lines
N° handled direct delivery SKUs /Total N° handled SKUs (stock and direct delivery)
Total N° order lines/Total days of stay

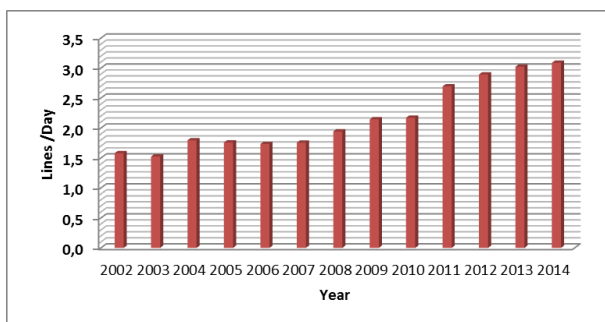


Figure 2: Total N° order lines / Total days of stay

4.3 Outcome analysis

This section discusses the results of the KPI analysis performed together with the working team.

The KPIs belonging to the healthcare class allow to get a deep understanding of those changes in the HC services

that generated material demand variations overtime with ultimate impacts on the logistics and economic variables. The growing demand for HC services in the time period under investigation has led to an increase in the total number of days of stay of about 9% (Figure 1). The enhanced number of ordinary hospitalizations increased the number of the associated material requests of about 37%. However, the number of urgent requests was cut by half due to a progressive confidence by operators in the new material procurement system and thus orders more compliant with the actual needs. In this way, the increase in the total number of requests, both ordinary and urgent ones, was of just 33%. Such a trend is also confirmed by the reduction of 37% of the number of urgent order lines.

By looking at the connections among different indicators, the values assumed by the ratio “Total N° order lines/Total days of stay” (Figure 2) show a doubling of the order lines processed during a single hospitalization day in the reference period. Three major reasons can be invoked. First, an increased complexity of treated pathologies required many and heterogeneous products. Second, the hospital efforts to rationalize the length of stay resulted in less days of stay per patient for a same clinical pathology. Finally, as the operators trusted the centralised material management system, less inventory was kept at points of use, generating more frequent material requests and a greater number of order lines.

Although the augmented HC demand and the significant increase in the number of outgoing items (+67%), the outsourcing of warehouse activities, together with improvements at bed level, allowed a re-engineering and an optimization of logistics processes. In turn, the time weekly spent on material management at points of use drastically went down (-71%) (Figure 3) with a consequent positive impact on human resource costs, especially those connected with clinical personnel, such as nurses, who is also responsible to carry out logistics tasks.

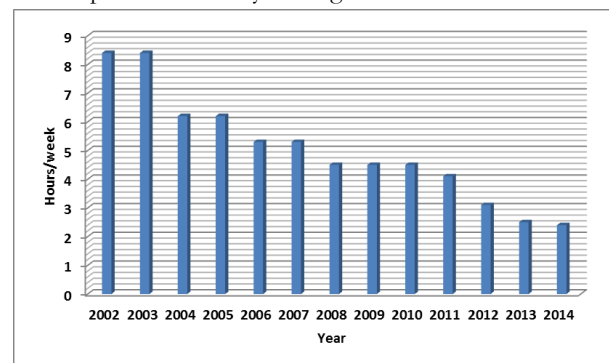


Figure 3: Weekly time spent on logistics activities

The analysis of those indicators assessing inventory performance shows the efficiency gained through centralization and outsourcing. As a matter of fact, the economies of scale given by inventory pooling and entrusting the management of the warehouse to a specialized LSP brought to a reduction of about 8% in the inventory economic value and a 23% increase in the turnover ratio. It is interesting to point out that these results were achieved in the face of a greater complexity of clinical needs and an increased number of stock managed

SKUs (+70%) during the reference period. The latter trend was due to a number of factors, among them the less frequent adoption of highly specific products by single wards and difficulties in managing stocks of direct delivery SKUs at points of use.

On the contrary, the ward inventories increased particularly in the first part of the analysed period with a peak in 2007 as a consequence of moving the hospital to a new facility. Such trend is motivated by two reasons. First, the need to keep in each ward a minimum quantity of all the used SKUs, regardless their stock or direct delivery management mode. Second, the increase of approximately 25% of the total number of handled SKU because of product diversification. However, the logistics efficiency induced by warehouse outsourcing made possible to limit the growth of the economic value of ward inventories to just 19% although a greater HC service demand and an increase in the number of drugs (+53%) and diagnostic products (+58%).

All these outcomes affect the economic performance. KPIs unveil a lower impact of logistics activities on hospital costs compared with when they were performed in-house. As a matter of fact, the outsourcing operation led to a 28% cost saving in warehouse and ward logistics activities. Such a result can be improved by applying information and communication technologies supporting traceability, especially in drug prescription and administration, with the aim of intercepting adverse events. During the investigated time span the average cost of a single material request has decreased by 36%, or by 16% if the costs for electronic-based prescription and administration are included. Instead, the cost of each processed order line was cut by half. Additionally, the macro-logistics innovations and the computerization of the material management process introduced over the years produced a reduction in the LSP revenue (which is a cost for the HC institution) by approximately 30% compared with the initial contract value. This profit margin has recently made it possible to finalize the computerization of logistics operations at wards.

5. Discussion and conclusions

Centralisation of logistics activities, like procurement and warehousing, combined with their outsourcing is one of the most promising and discussed strategies nowadays (Wu, Rossetti and Tepper, 2015). The present work illustrates by means of a case study an approach to ex-post assess the associated operational and economics effects. This is one of the first attempts to understand the actual performance of such policies after their implementation and not only before it (Ferretti, Favalli and Zangrandi, 2014; Lega, Marsilio and Villa, 2013). Additionally, it does not focus on just few elements but takes a broad perspective by considering all the main aspects that are affected by the new logistics paradigm. Moreover, the investigation of the relationships among different performance dimensions helps developing a comprehensive picture of how centralisation and outsourcing can improve the behaviour and the outcomes of HC organizations. The suggested KPIs constitute a

scorecard that guides the choice of specific evaluation perspectives. Also, the proposed analysis methodology is quite straightforward, because it relies on simple mathematical and graphical tools, but at the same time quantitatively measures performance. This is a strength of the approach because HC institutions are often poorly familiar with complicated managerial and decision-making methods while at the same time they need objective frameworks to first select strategies and then assess their effectiveness. Finally, the discussed case study provides an extensive demonstration of the benefits of warehouse centralization and outsourcing in HC and witnesses that they can only be achieved with a continuous improvement effort over time by acting on both macro and micro-logistics. Moreover, the outcomes underline that a solid and technologically updated LSP, together with the constant commitment of the hospital management and the cooperation of HC professionals, allows to introduce innovations in logistics management by relying on private investments otherwise unaffordable by hospitals whose core business is treating patients and not managing warehouses.

The present work poses both theoretical and practical implications. From an academic point of view, it contributes to expand the relatively recent research stream about centralised logistics management in HC by assessing the effects of the combination of this strategy with outsourcing. As such, it might constitute a methodological starting point to develop more articulated ex-post assessment models addressing the associated strengths and weaknesses. For instance the developed approach might be integrated by statistical and simulation tools. Also, it might be adapted to also measure the benefits introduced by different types of organizational innovations. This contribution provides practitioners with knowledge about the real benefits of centralization and outsourcing. Thus, it can assist HC organizations in the process of choosing the best strategies fitting their needs. Then, it can support institutions in the later evaluation of the outcomes of their implementation.

However, some limitations can be recognized in this work. First, the proposed approach requires a strong involvement by the assessed institutions, which might lack in case of scarce awareness about the need for constantly monitoring the results of set strategies. Second, the quality and the quantity of the available numerical data strongly influence the reliability of the analysis. The case study was facilitated by the systematic collection of performance data the LSP has been carrying out for some years.

Future research directions will concern validating the approach by applying it to other national and international HC warehouse centralization initiatives in order to refine it. Also, its integration with statistical and simulation methods aimed at capturing the cause and effect relationships between different performance indicators will be explored.

References

- Aronsson, H., Abrahamsson, M., and Spens, K. (2011). Developing lean and agile health care supply chains. *Supply Chain Management: An International Journal*, 16 (3), 176-183.
- Azzi, A., Persona, A., Sgarbossa, F., and Bonin, M. (2013). Drug inventory management and distribution: Outsourcing logistics to third-party providers. *Strategic Outsourcing: An International Journal*, 6(1), 48-64.
- Battini, D., Persona, A., and Rafele, C. (2008). The hospital efficiency management: just in time and kanban technique. *International Journal of Healthcare Technology and Management*, 9(4), 373-391.
- Bendavid, Y. and Boeck, H. (2011). Using RFID to Improve Hospital Supply Chain Management for High Value and Consignment Items. *Procedia Computer Science*, 5, 849-856.
- Brewer, A.M., Button, K.J., and Hensher, D.A. (2008). *Handbook of Logistics and Supply-Chain Management*, 3rd Edition. Pergamon, Amsterdam, New York.
- Burns, L.R. and Lee, J.A. (2008). Hospital purchasing alliances: utilization, services, and performance. *Health Care Management Review*, 33 (3), 203-215.
- Cagliano, A. C., Grimaldi, S., and Rafele, C. (2016). Paving the Way for Warehouse Centralization in Healthcare: A Preliminary Assessment Approach. *American Journal of Applied Sciences*, 13 (5), 490-500.
- Chandra, C. (2008). The case for healthcare supply chain management: insights from problem-solving approaches. *International Journal of Procurement Management*, 1 (3), 261-279.
- De Koster, R., Le-Duc, T., and Roodbergen, K.J. (2007). Design and control of warehouse order picking: A literature review. *European Journal of Operational Research*, 182 (2), 481-501.
- Faber, N., De Koster, M.B.M., and Smidts, A. (2013). Organizing Warehouse Management. *International Journal of Operations & Production Management*, 33 (9), 1230-1256.
- Ferretti, M., Favalli, F., and Zangrandi, A. (2014). Impact of a logistic improvement in an hospital pharmacy: Effects on the economics of a healthcare organization. *International Journal of Engineering, Science and Technology*, 6 (3), 85-95.
- Gobbi, C. and Hsuan, J. (2010). Collaborative purchasing in healthcare system. *Proceedings of the Seventeenth International Annual EurOMA Conference: Managing Operations in Service Economies*. Porto, Portugal, 7-9 June.
- Gu, J., Goetschalckx, M., and McGinnis, L.F. (2010). Research on warehouse design and performance evaluation: A comprehensive review. *European Journal of Operational Research*, 203 (3), 539-549.
- Iannone, R., Lambiase, A., Miranda, S., Riemma, S., and Sarno, D. (2014). Pulling Drugs Along the Supply Chain: Centralization of Hospitals' Inventory. *International Journal of Engineering Business Management*, 6 (21), 1-11.
- Landry, S. and Beaulieu, M. (2013). The Challenges of Hospital Supply Chain Management, from Central Stores to Nursing Units. In Denton, B.T. (ed.), *Handbook of Healthcare Operations Management*. Springer, Ann Arbor.
- Lega, F., Marsilio, M., and Villa, S. (2013). An evaluation framework for measuring supply chain performance in the public healthcare sector: Evidence from the Italian NHS. *Production Planning & Control*, 24 (10-11), 931-947.
- Marsilio, M. and Mele, S. (2010). La centralizzazione degli acquisti in sanità: esperienze internazionali a confronto. *Mecosan*, 2 (75), 3-23.
- Nicholson, L., Vakharia, A.J., and Erenguc, S.S. (2004). Outsourcing Inventory Management Decisions in Healthcare: Models and Application. *European Journal of Operational Research*, 154 (1), 271-290.
- OECD (2017). Health expenditure and financing dataset. http://stats.oecd.org/Index.aspx?DatasetCode=HEALTH_STAT (Accessed February 10, 2017).
- Pedersen, S.G., Zachariassen, F., and Arlbjorn, J.S. (2012). Centralisation vs decentralization of warehousing. *Journal of Small Business and Enterprise Development*, 19 (2), 352-369.
- Rego, N., Claro, J., and Pinho de Sousa, J. (2013). A hybrid approach for integrated healthcare cooperative purchasing and supply chain configuration. *Health Care Management Science*, 17(4), 303–320.
- Rooney, C. (2011). The value of group purchasing organizations in the United States. *World Hospitals and Health Services: The Official Journal of the International Hospital Federation*, 47(1), 24-26.
- Scheller, E.S. and Smeltzer, L.R. (2006). *Strategic Management of the Health Care Supply Chain*, 1st ed. Wiley, San Francisco (CA).
- Schmitt, A.J., Sun, S.A., Snyder, L.V., and Shen, Z.J.M. (2015). Centralization versus decentralization: Risk pooling, risk diversification and supply chain disruptions. *Omega*, 52, 201-212.
- Silver, E.A., Pyke, D.F., and Peterson, R. (1998). *Inventory Management and Production Planning and Scheduling*, 3rd Edition. John Wiley and Sons, New York.
- Vollan, J., Fügener, A., Schoenfelder, J., and O.Brunner, J. (2017). Material logistics in hospitals: A literature review. *Omega*, 69, 82–101
- Wu, D., Rossetti, M.D., and Tepper, J.E. (2015). Possibility of inventory pooling in China's public hospital and appraisal about its performance. *Applied Mathematical Modelling*, 39 (23-24), 7277-7290.