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SUPPLY CHAIN MANAGEMENT PRACTICES IN THE GREEK HEALTHCARE SECTOR: IMPACT ON FINANCIAL PERFORMANCE AND ROLE OF ERP SYSTEMS

PhD Thesis

by

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Supply Chain Management Practices in the Greek Healthcare Sector:
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Summary

Competitive pressures and severe cuts in public healthcare spending force healthcare organizations worldwide to reconsider their business strategies and management practices. In this important industry sector, managers are seeking to lower costs while maintaining a high level of service quality - two goals that are perceived as contradictory by many healthcare professionals. Supply chain management (SCM) is regarded as having an important impact on reducing operating costs and improving cost performance. Therefore, it seems that researching and analyzing SCM in the healthcare industry is a promising and fruitful area of research that can have major practical consequences. Motivated by this background, a review of existing literature was performed, which highlighted the fact that the healthcare sector is clearly lagging behind compared to other industries regarding the deployment of SCM practices (SCMP) and identified areas that have not been adequately researched within the healthcare SCM context. Seeking to contribute towards filling this gap, the present thesis' objective was to research and offer insights on the adoption of SCMP in the supply chains of healthcare delivery settings. The methodology followed incorporated qualitative as well as quantitative research methods and was rolled out using a two-phased approach.

As part of the first phase two case studies were performed in major Greek public hospitals with the goals of (1) gaining insights on hospital SCM operations, (2) adapting SCM related practices suggested by literature and business studies to the healthcare context, (3) implementing these best practices and examine related barriers and facilitators of their adoption, and (4) measuring their impact on the hospitals' performance. The results of these case studies indicated that substantial operational performance improvements can be achieved through the application of SCM best practices in hospitals, suggesting that this line of research can significantly contribute towards reaching a major goal of healthcare executives, namely to deliver effective care at a lower cost.

Building upon these case study findings, the second phase followed a generalized approach entailing the conceptualization of a framework in order to investigate overall SCMP adoption in hospital supply chains and their impact.

For this purpose, the present thesis (1) drew on operations management and technology adoption literature, (2) identified applicable SCMP based on a holistic approach, (3) investigated the facilitating role of Enterprise Resource Planning (ERP) systems, (4) delineated the key factors influencing SCMP adoption in healthcare facilities, and (5) examined their impact on hospital cost performance. Using structural equation modeling, the research model was tested with survey data collected from 103 Greek public hospitals. The results of the study indicated that technological readiness, organizational readiness, perceived benefits and hospital size have significant influence on the extent of SCMP adoption in hospital supply chains. The evidenced positive link of SCMP adoption to hospital cost performance implies greater urgency for hospitals to fully exploit these practices.

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List of abbreviations

2SLS	Two Stage Least Squares
AGFI	Adjusted Goodness of Fit Index
ALOS	Average Length Of Stay
AMOS	Analysis of a MOment Structures
ASP	Application Service Provider
AVE	Average Variance Extracted
Avg	Average
B2B	Business To Business
BR	Business Partner Readiness
CEO	Chief Executive Officer
CFA	Confirmatory factor Analysis
CFI	Comparative Fit Index
CMI	Case Mix Index
CRM	Customer Relationship Management
CR	Construct Reliability
CSF	Critical Success Factor
DRG	Diagnosis Related Group
DM	Demand Management
DOI	Diffusion Of Innovations
EDI	Electronic Data Interchange
EOQ	Economic Order Quantity
ERA	Electronic Reverse Auction
ERP	Enterprise Resource Planning
eRFI	electronic Request For Information
eRFP	electronic Request For Proposal
eRFQ	electronic Request For Quotation
eRFT	electronic Request For Tender
eRFx	electronic Request For [x], x = (Q)uotation, (P)roposal, (T)ender or (I)nformation
GFI	Goodness of Fit Index
GHK	General Hospital KAT
GP	Government Policies
GPO	Group Purchasing Organization
HOT-fit	Human Organization and Technology fit

HPC	Health Procurement Committee
HW	Hardware
ICT	Information Communication Technology
IDT	Innovation Diffusion Theory
IFI	Incremental Fit Index
IM	Inventory Management
IS	Information System
IT	Information Technology
KPI	Key Performance Indicator
MOA	Motivation Opportunity and Ability model
MRO	Maintenance Repair and Operating supplies
MRP	Material Requirements Planning
NFI	Normed Fit Index
NNFI	Non-normed Fit Index
NHS	National Healthcare System
OECD	Office of Economic Cooperation and Development
OM	Operations Management
OR	Organizational Readiness
PB	Perceived Benefits
RBV	Resource Based View
RFID	Radio Frequency Identification
RMSEA	Root Mean Square Error of Approximation
RoC	Range of Coverage
R&D	Research and Development
SC	Supply Chain
SCM	Supply Chain Management
SCMP	Supply Chain Management Practices
SCMPAI	Supply Chain Management Practices Aggregate Index
SCOR	Supply Chain Operations Reference-model
SEM	Structural Equation Modeling
SRM	Supplier Relationship Management
SW	Software
TAM	Technology Acceptance Model

TLI	Tucker Lewis Index
TOE	Technology Organization Environment
TPB	Theory of Planned Behavior
TR	Technological Readiness
TRA	Theory of Reasoned Action
UK	United Kingdom
UN	United Nations
USA	United States of America
UTAUT	Unified Theory of Acceptance and Use of Technology
VED	Vital Essential Desired
VEN	Vital Essential Non-Essential
VMI	Vendor Managed Inventory

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1 Introduction

1.1 Motivation

Healthcare spending is globally on the rise as technological advances and an aging population are driving up costs. Recent reports project spending increases ranging from 2.4 % to 7.5 % between 2015 and 2020 in the world's major regions as shown in Figure 1. Therefore it seems plausible that governments and health systems throughout the world continue to implement cost-containment measures aimed at improving operational efficiency. In this environment, healthcare organizations are realizing more and more that they can create substantial cost-reducing opportunities across their organizations by managing their supply chains efficiently (Chen, 2013).

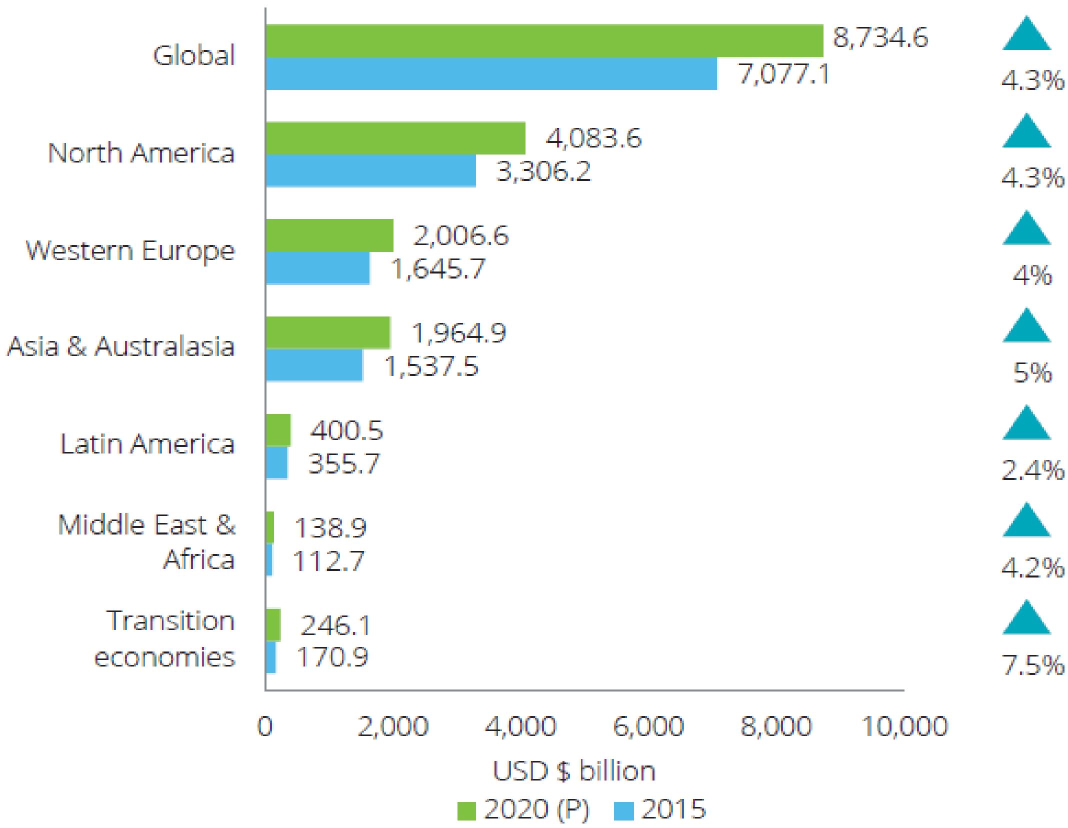

Figure 1: Healthcare spending 2015-2020 (World Industry Outlook, 2016)

In a broader context, Supply Chain Management (SCM) systems are gaining an increasing importance due to globalization and strong competitive pressures. They represent a paradigm shift in conducting business in the modern era, where collaboration rather than antagonism seems more important and rewarding among the firms operating in a networking environment. However, for the global healthcare industry, which comprises various sectors such as pharmaceutical, medical equipment and supplies, and healthcare services, the management of its supply chain is as complex and important as the industry's size and velocity. Furthermore, the healthcare sector worldwide is affected by major changes arising from legislative and regulatory obstacles as well as globalization and increasing operating costs.

Therefore, in many healthcare delivery settings, such as hospitals, executives endeavor to lower costs of incoming supplies and to keep the quality standards at the same time. Consequently, efficient logistics are increasingly recognized as more important, even critical, to the performance of the healthcare sector. Making this added value more explicit by performance metrics as well as the conditions under which this added value emerges is without doubt one of the main challenges research on supply chain management in a healthcare context is facing. Therefore, it seems that researching SCM in the healthcare industry is a promising area of research with major implications.

1.2 Objective

The main objective of the thesis is to offer insights on the adoption of SCMP (Supply Chain Management Practices) in healthcare delivery settings, to encourage hospital executives to view SCM as a strategic asset and an integral part of their organization, and to contribute towards reaching a major goal of healthcare executives, namely to deliver effective care at a lower cost. In order to meet this goal, the present thesis aspires to (1) highlight the value and essentiality of SCM related research in the healthcare sector, (2) build upon previous research and established theoretical lenses in order to develop a conceptual framework that investigates SCMP adoption in healthcare, (3) approach SCMP adoption in a holistic way by integrating a business performance lens, ultimately driving improvements in operational cost performance, (4) provide powerful insights on technological and organizational aspects of the adoption and assimilation of hospitals' SCMP, (5) empirically validate the proposed framework in the Greek healthcare sector, and (6) provide healthcare executives with practically relevant lessons.

1.3 Methodology

Initially, the foundation for the thesis is laid by reviewing related literature and identifying research areas with practical relevance within the outlined context. Secondly, case study based, qualitative research is performed in order to gain insights on the application of selected SCMP and evaluate their impact on hospital performance. Thirdly, building upon the literature review and the results of the case studies, a research framework is developed in terms of conceptualizing SCMP adoption and its business impact. Hypotheses and relevant measurement instruments are developed and tested using survey data from 103 Greek public hospitals. The results of the quantitative research are analyzed using SEM (Structural Equation Modeling) and various methods are used to lessen methodological concerns and increase the methodological rigor of the thesis.

The precise methodologies followed for the case studies as well as for the quantitative analysis of the data are described in detail in the relevant sections. The combination of both qualitative and quantitative research methods is expected to increase the depth and breadth of understanding of the investigated aspects and offset weaknesses inherent to using each approach by itself, further increasing the robustness of the empirical findings.

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1.4 Contribution

The present thesis contributes significantly to the body of SCM research by: (1) expanding our knowledge frontier on innovation adoption theory, (2) introducing a shift from single technology orientation to a holistic approach in order to investigate supply chain management practices (SCMP) adoption, (3) examining the extent of SCMP adoption rather than simply treating adoption as a dichotomous (yes/no) variable, contrary to the vast majority of prior research studies, (4) demonstrating results that indicate the transferability of SCMP successfully applied in other business sector to the healthcare sector, (5) investigating the critical role of ERP systems in this context and (6) highlighting the key factors impacting adoption of SCMP in hospitals providing practical guidance to hospital executives on how to increase their breadth of adoption.

Furthermore, it empirically proves a statistically significant association between the aggregated adoption of SCMP and hospital cost performance, which is unique and highly relevant for both SCM theory and practice. Scholars often argue that SCM has “bottom line” impact, but the case for such relationships is based largely on assertion rather than demonstration (Shi and Yu, 2013). Aiming to fill this gap, the thesis develops a holistic framework that investigates the determinants of SCMP adoption and uses performance metrics to empirically demonstrate their impact on organizational-level performance, thus bringing attention to this less explored area of study and reinforcing the role of SCM as a strategic asset. The findings of the thesis are important because hospital managers, like managers of other organizations, need to show the value derived from the application of SCMP and the underlying technology investments. They imply that the issue of rising supply costs in hospitals, which comprise a large percentage of the total cost of care, can be counteracted by implementing a full array of SCMP in their supply chains.

1.5 Structure

The structure of the thesis can be broken down into three parts as depicted in figure 2. In the second chapter, existing literature is presented and the theoretical background of the thesis is outlined. Chapter 3 presents the case studies performed as part of the qualitative part of the research. The next sections encompass the quantitative research part, describing the adopted research framework (chapter 4) and the methodology followed including the data analysis with the study’s results (chapter 5). Chapter 6 highlights the contributions to theory as well as the managerial implications, followed by a discussion of the limitations and opportunities for future research (chapter 7).

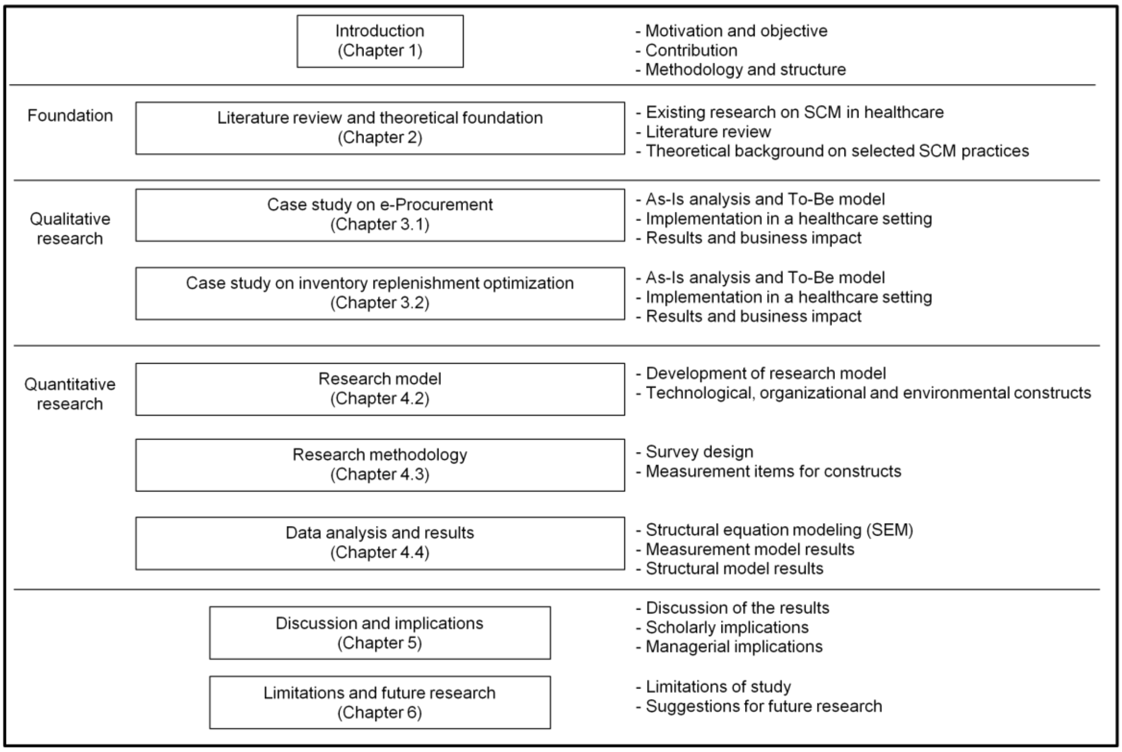


Figure 2: Structure of the thesis

2 Literature review and theoretical foundation

To provide the theoretical foundation for the present thesis, this section initially investigates the role of supply chain management in general as well as for the healthcare sector in particular. Since the relative importance of SCM is on the rise, as witnessed by current global trends which are moving it to the forefront of business strategy, company executives realize its role in defining how a business can and should operate (Hugos, 2018). The supply chain can be defined as a way to envision all steps needed from beginning to end in order to deliver products or services to the customer (Meijboom et al., 2011). Expanding on this definition, the term "Supply Chain Management", which was introduced in 1982, can be described as "the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies" (Council of SCM Professionals, 2013). Other definitions suggest that SCM involves management of the flows of products, information and funds upstream and downstream in the supply chain (Sila et al., 2006).

2.1 Prior SCM related research in healthcare

The supply chain literature has focused mainly on the improvement of material flows to best match supply and demand, although it is equally important for a competitive firm to manage and control information and fund flows within the supply chain (Fayezi and Zomorrodi, 2016; Al Saa'da et al., 2013; Medows, 2011). Chopra and Meindl emphasize on the management of these flows for the purpose of maximizing profitability (Chopra and Meindl, 2001). Essentially, SCM can be seen as an attempt to address the challenges of the current businesses environment by integrating organizations, their suppliers and their customers into a seamless unit (Nel and Badenhorst-Weiss, 2010).

The healthcare supply chain in particular can be defined as a "network of entities that plan, source, fund, and distribute products and manage associated information and finances from manufacturers through intermediate warehouses and resellers to dispensing and health service delivery points" (Dalberg, 2008). It is composed of three major players at various stages, namely, producers, purchasers and healthcare providers. Producers include pharmaceutical companies, medical-surgical products companies, device manufacturers, and manufacturers of capital equipment and information systems. Purchasers include grouped purchasing organizations (GPOs), pharmaceutical wholesalers, distributors, and product representatives from manufacturers. Providers include hospitals, systems of hospitals, integrated delivery networks (IDNs), and alternate site facilities (Toba et al., 2008). The healthcare supply chain is essentially acting as an ecosystem that integrates all aspects of a supply chain, including medicines, human resources, technology, policies, distribution systems, warehousing and service delivery (UN CoLSC, 2014). An ecosystem whose management is proportionally as complex and important as the size and velocity of the healthcare industry (Beeny, 2014) and which can broaden geographic access to high quality products and services when operating with efficiency, adaptability and financial integrity (UN CoLSC, 2014).

With over $4.5 trillion in expenditure, the global Healthcare industry is one of the world's largest and fastest growing industries, comprising various sectors: medical equipment and supplies, pharmaceutical, healthcare services, biotechnology and alternative medicine sectors (Beeny, 2014). It is facing an increasingly complex regulatory and legislative environment as well as a variety of economic and business challenges (UPS Survey, 2013), such as the policy level that may restrict product selection possibilities, the service delivery point that may face frequent stock outs due to poor forecasting, unavailability of transport and a variety of other issues (UN CoLSC, 2014). These risks combined with new growth opportunities are driving healthcare businesses to overcome the inefficiencies of the past. Given the personal and professional impact of timely, cost efficient and most importantly effective treatments, today's global healthcare industry is forced to manage its supply chain more effectively. To be effectively managed, supply chain resources, such as suppliers, partners and customers need to be linked. The supply chain is transforming from a controlled entity within the four walls of a warehouse into a network of resources, scattered across facilities and entities in different cities and countries (Beeny, 2014).

Failing to manage the supply chain effectively has been shown to have significant negative impacts on organizations (Kanyoma et al., 2013). It has been argued that especially for the healthcare industry inefficient supply chain management (SCM) processes cause significant cost increases (De Vries and Huijsman, 2011), as activities related to the purchase, distribution, and management of supplies account for about one third of the operating costs of healthcare facilities (Kumar et al., 2008). These findings are supported by industry surveys, which show that healthcare providers are using almost a third of their annual operating funds to support their supply chain as depicted in figure 3.

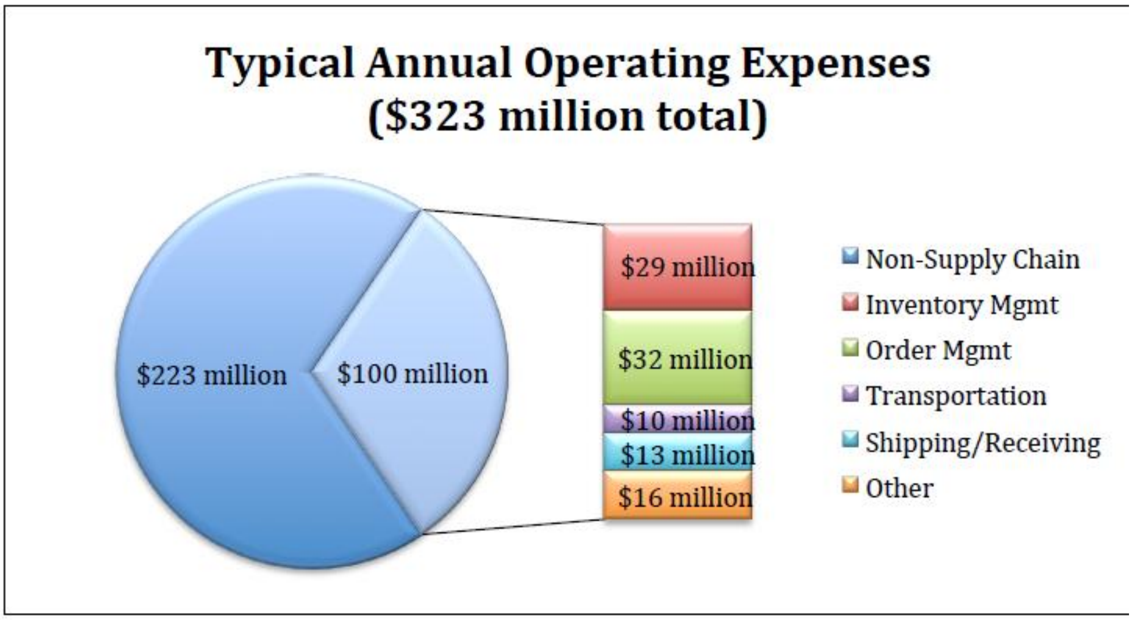


Figure 3: Typical annual operating expenses of a large health care provider (Nachtmann and Pohl, 2009)

The management of the supply chain in the healthcare industry in particular, possesses an additional dimension of complexity, as companies have to do a highly accurate job, considering that potential dysfunctions might have negative consequences on peoples wellbeing and even people's lives (Mustaffa and Potter, 2009). Thus, companies in the healthcare sector need to make continuous efforts to improve their supply chain performance, especially since experts have estimated that SCM practices of the healthcare industry are 10 to 15 years behind other industries such as retail and manufacturing (Chen et al., 2013). According to a survey among healthcare executives, investing in new technologies was identified as the top strategy to improve competitiveness and increase efficiency (UPS Survey, 2013). As the significance of information and communication technologies (ICT) in improving healthcare supply chains has been proved, many healthcare organizations initiated related projects (De Vries and Huijsman, 2011). Even in developed countries such as the US, the healthcare industry is suffering from inconsistent and inaccurate product information, which negatively impacts the rest of the supply chain including the quality of care delivery for patients (Pleasant, 2009). Room for improvement through the use of ICT also exists for UK's national healthcare provider NHS, as it is characterized by lack of common commercial and procurement data standards, which means that the analysis of expenditure and demand requirements across organizations is very costly in terms of time and resources (Hodson-Gibbons, 2009; Kritchanchai, 2012).

Regarding the Greek healthcare sector, the implementation of supply chain concepts is at an early stage, reflecting into poorly functioning supply chains and leading to redundancy of efforts, higher costs, stock outs, wastage and, as a result, lower level of healthcare services (Fragkiadakis et al., 2014). The participants in the healthcare supply chain, whether manufacturers, wholesalers, distributors or healthcare providers appear to be acting isolated with low levels of coordination amongst them. Similar to studies performed on the healthcare sector of developing countries, such as Thailand (Kritchanchai, 2012), it is evident that SCM in the Greek healthcare sector is characterized by inefficient processes, inconsistent and inaccurate data information, lack of data standardization, lack of systems integration and low transparency.

The importance of the healthcare sector and the significance of SCM in the healthcare context, combined with the fact that the majority of prior supply chain studies focus on the manufacturing environment, establishes the need to study hospital supply chain integration and performance to extend the body of SCM research (Chen et al., 2013). Especially with information technology now reshaping the day-to-day business processes, research needs to provide helpful insights and assist the healthcare industry in leveraging technology advances to create a more efficient and effective supply chain, to reduce unnecessary costs and to improve patient safety (Pleasant, 2009).

A primary task, as well as a challenge, in SCM practice is the integration of the business functions and activities throughout the supply chain, especially regarding the synchronous information access and process integration between the company and its suppliers. As such, information technology (IT) has become the backbone for companies to achieve integration with their supply chain partners and the topic of supply chain integration has drawn growing attention from researchers (Chen et al., 2013).

Recently, in the field of healthcare the concept of SCM has gained momentum as a tool for increasing productivity and improving quality, although the adoption of integrated and standardized approaches is still far from common. In particular, public healthcare organizations have been involved in a series of innovative projects that address two key SC processes with economic significance: purchasing and logistics. However, this momentum has not been matched by an increase in the research that investigates and quantifies the benefits and drawbacks of such initiatives (Lega et al., 2013). The literature on SCM has historically focused on the manufacturing and retail industries. According to Chen et al., hospital supply chains are unique and different from the typical industrial supply chains in the following five aspects: mission critical to the health of the public, dealing with many high value materials that require special handling, lack of specific universal product number classification systems and data standards, supply selections driven by physician preferences rather than sales forecasts and cost considerations, information and knowledge intensive SCM due to rapid technology and medical innovations. This results into more complex and knowledge-intensive SC practices compared to the traditional industry (Chen et al., 2013).

The healthcare sector is a very complex and vast environment. As a consequence, in order for research to be effective, it needs to be multidisciplinary (Vries and Huijsman, 2011) and focused on the critical issues concerning the performance of the healthcare organizations and the provision of quality services. The healthcare sector in its broader context does not only include clinics and hospitals but wholesale distributors, pharmaceuticals manufacturers, medical supplies' enterprises, pharmacies, government regulatory agencies, private health insurance companies, technology providers and information technology vendors. Logistics, purchasing and supply chain management considerations apply and are important for the whole industry, which is interconnected and mutually dependent. For example, Ritchie et al (2010) focus on the concept of reverse logistics and especially the recycling of pharmaceutical stock for later re-use, discussing supply chain management practices in the National Health Service. They argue that by developing effective reverse logistics processes in the NHS, there have been significant financial and operational advantages. The evaluation and improvement of the recycling and disposal of pharmaceutical products in the Manchester Royal Infirmary (MRI) is the objective of another study (Kumar et al., 2008). According to this study, in many healthcare systems, executives focus not on lowering the total delivered cost, but on efforts to lower the acquisition price of supplies, which is only a part of the total cost. To achieve cost reductions, hospitals need to review their processes and the associated costs eliminating non value-added activities.

Meijboom, et al. (2011) identified four major problem categories in the healthcare organizations: communication, patient safety, waiting times, and integration. The findings are based on literature concerning country comparisons of patient experiences. The authors argue that the most important problems and the weakest links occur between providers; therefore supply chain management can be used effectively to minimize problems. A number of issues, such as the availability of medical records of individual patients and information on provider performance, need to be considered and improved. Poor data quality was also found to be the case in healthcare environments in other studies (e.g. Bhakoo and Chan, 2011). Thus, information technology in combination with cross-functional and cross-organizational integration in a supply chain perspective can be very effective on patient care (Meijboom, et al., 2011). However, the implementation of effective SCMP is not always straightforward. Lack of top management support and performance measurement systems, conflicting incentives in an organization, limited education on the performance and the function of a supply chain, inconsistent relationships with group purchasing organizations have been identified, among others, as serious barriers in implementing effective supply chain management systems (McKone-Sweet et al., 2006).

Cost reduction, however, is a goal which cannot be easily achieved due to the nature of the healthcare industry. Despite governmental pressures to cut costs, this is not easily achieved due to the behavior of purchasing managers in selecting suppliers, and preferring quality products or services over low prices (Lambert, et al., 2006). It is interesting to see whether this finding holds true for both the private and the public healthcare sectors. As far as procurement practices are concerned, as an example, it has been suggested that there are significant differences between the public and the private sector (Lian and Laing, 2005). Public sector organizations almost exclusively rely on transactional-based approaches. The restrictions imposed by public policy on procurement practices results in sub-optimal outcomes (Lian and Laing, 2005). The global nature of suppliers is also a key issue when considering to implement a healthcare supply chain (Bhakoo and Chan, 2011). Collaboration and trust between partners are required for a successful SCM system implementation.

Another key issue for effective supply chain management is the inventory management (Chen, 2013). Hospitals need to maintain an efficient inventory of drugs and medical supplies in order to meet emergency demand, but this policy, although necessary, may raise costs. A hospital-supplier integration through information technology is expected to lower inventory costs while at the same time allowing hospitals to be able to meet patients' requirements. Technology issues in addition to management and business issues, is also regarded important by other researchers in the context of supply chains (Lillrank, et al., 2011). Last but not least, shortcomings of the healthcare supply chain have severe impact on human health. Drug shortages due to supply chain problems as an example are constantly increasing, leading to additional costs for hospitals worldwide and creating opportunities for counterfeiters threatening patient safety. Even in the US, which is not facing developing world challenges, drug shortages have tripled in the last decade (McKinsey & Company, 2013).

Based on the review of related literature outlined above, it becomes evident that various supply chain theories and practices have not been adequately researched in the healthcare environment. One major reason being the late recognition of the value of supply chain management for the healthcare sector and accordingly the late adoption of modern supply chain practices as compared to other sectors such as the consumer goods industry, where supply chain management has been prevalent for decades. As healthcare is a vastly growing business segment worldwide and a key aspect to quality of life, and since it has been proven that strong supply chain management is essential to effective delivery of healthcare in the public as well as the private sector, this section highlights the limited research related to this area and proposes a research agenda encompassing the following areas.

1) Identification of SCMP that are relevant to the healthcare context and their impact on hospital financial performance

   Researchers and practitioners have provided evidence on the positive link between application of SCMP and improved operational performance in many different industries, with several studies reporting significant inventory cost reductions as a result of their adoption (Kalchschmidt, 2012; Småros, 2007; Morita and Flynn, 1997). Therefore, it seems plausible to expect that this also holds true in the healthcare sector. The relevant and applicable SCMP should be identified and their adoption characteristics and their impact on financial performance should be investigated.

2) Examination of the Critical Success Factors (CSFs) for the implementation and execution of Supply Chain Management in Healthcare

   There have been numerous academic publications on the CSFs regarding the SCM field in general. A recent comprehensive study conducted on those publications by Syazwan and Abu Bakar (2014) identified four major CSFs: collaborative partnership, information technology, top management support and human resources. The relevance, reliability and importance of these CSFs in regards to optimum supply management in the healthcare sector needs to be researched, barriers need to be identified and best practices need to be recommended .

3) Identification of appropriate Supply Chain Performance metrics and standards in Healthcare

Various studies and reports have pointed out the significant benefits of SCM in the healthcare sector, such as the potential cost savings, the better healthcare access and the improved patient safety (McKinsey & Company, 2013). Efforts to develop performance measurement methods, such as using the balanced scorecard approach, have been made from healthcare institutions and agencies in order to be able to identify whether these benefits are achieved and to what extent (Ontario Ministry of Finance, 2006). However, no widely adopted ways of measuring the efficiency and effectiveness of healthcare SCM in a transparent way have evolved. Thus, there is a need to research and define metrics and standards for assessing and improving healthcare SCM performance as well as for benchmarking and comparison purposes across healthcare institutions.

4) Identification and categorization of risk factors of SCM in Healthcare and development of appropriate response strategies

   Methodologies for identifying, categorizing and managing risks related to the supply chain need to be tailored to the healthcare sector. Health Supply Chain Managers need to be given the necessary tools in order for them to be able to manage the risks associated with SCM. Especially since disruptions in the health supply chain don't only reflect in higher healthcare costs, but can have serious impacts on people's lives. Adequate research needs to address risks to patient safety that can be impacted by SCM systems and policies in place, such as risks of medication errors and counterfeit drugs (McKinsey & Company, 2012). Furthermore it needs to categorize and prioritize those risks and examine the most effective prevention and response strategies.

5) Identification of roles most appropriate for the public and private sectors as part of the SCM in healthcare

   Health care supply chains, especially in developed countries, rely heavily on the private sector for functions such as supply, distribution and provision of key auxiliary services, even if the healthcare system itself is largely controlled by the public sector. There are various roles to play related to SCM in healthcare, such as product registration and quality oversight, market regulation, procurement, health services networks, financing, physical distribution and others (MIT-Zaragoza International Logistics

Program, 2008). Research effort is needed in order to investigate which of those areas are most appropriate for the public or for the private sector to play a role. As there have been indications that significant differences exist between the public and private sectors in healthcare regarding specific supply chain management aspects, the research areas could distinguish their findings between those two sectors in order to verify this assumption.

Based on these findings and after discussing their practical relevance with subject matter experts from the Greek healthcare sector, the focus of the present thesis was targeted towards researching SCMP applied in the supply chains of healthcare settings. This seems to be an area where the undertaken research effort is expected to have significant implications on managerial practices and impact the bottom line of Greek hospitals in a period where financial means are sparse due to the unprecedented financial crisis that the country is experiencing.

2.2 Literature on SCM practices adoption

Researchers and practitioners have provided evidence on the positive link between application of SCMP and improved operational performance in many different industries, with several studies reporting significant inventory cost reductions as a result of the adoption of these practices in the supply chain (Kalchschmidt, 2012; Småros, 2007; Morita and Flynn, 1997). Demand planning and forecasting, data segmentation, inventory replenishment and optimization are some of the practices that have been reported to positively impact an organization’s competitive advantage (Blanchard, 2010; Wild, 2007). The same holds true for the healthcare sector, where hospital supply chain performance has been seen as an enabler for improving operational efficiency and reducing costs (Baltacioglu et al., 2007). As part of the thesis, supply chain related practices in the healthcare sector were initially researched, focusing on studies exploring practices that lead to performance improvements (Callender and Grasman, 2010; Wild, 2007). Although SCMP can be both technology and process driven, with the emerge of new innovative technologies even process related practices are increasingly linked to technology applications, making this distinction harder and less relevant (Aberdeen Group, 2008) Previous research on SCMP either focuses directly on specific technologies such as ERP, EDI, RFID and e-Business related applications or investigates SCM concepts that are enabled by and rely upon various technologies (Gorane and Kant, 2015). This fosters the basic view that SCMP share a critical common enabler, namely technology, and their adoption can be studied by examining the underlying technologies applied. Furthermore, in order to investigate the adoption of SCMP, it is helpful to have a framework from which hypotheses can be drawn. A theoretical framework will enable the evaluation of observed business behavior and predictions on whether SCMP impacts the operational and financial performance of an organization. Therefore various technology and innovation adoption frameworks were investigated in order to develop a suitable framework that supports the thesis’ goals.

2.2.1 Technology and innovation adoption frameworks

In order to study the adoption of various technologies and innovations in general, a plethora of models and variations or combinations of these models have been suggested in literature, such as (1) technology acceptance model (TAM; Davis, 1989), (2) theory of reasoned action (TRA; Ajzen and Fishbein, 1980), (3) theory of planned behavior (TPB; Ajzen, 1991), (4) innovation diffusion theory (IDT; Rogers, 2010), (5) unified theory of acceptance and use of technology (UTAUT; Venkatesh et al., 2012), (6) technology-organization-environment (TOE; Tornatzky et al., 1990), (7) resource-based view (RBV; Barney, 1991), (8) motivation, opportunity and ability model (MOA; Jaworski and MacInnis, 1989), and (9) human organization and technology fit (HOT-fit; Yusof et al. 2008). The following table (Table 1) lists these models and outlines their relevant characteristics, such as main dependent and independent constructs, originating areas and level of analysis.

The theories of TAM and TOE specifically target technology acceptance and are embraced by many researchers to investigate adoption aspects at organizational level. TAM is largely focusing on technology oriented determinants of adoption, leaving out social and psychological parameter (Venkatesh and Bala, 2008). Therefore, it is often combined with other models in order to increase its explanatory and predictive power (Awa et al., 2016).

TOE on the other hand follows a more holistic approach by incorporating additional determinants through the integration of organizational as well as environmental constructs. The TOE framework identifies three aspects of a firm’s context that may influence adoption of technological innovation (Tornatzky et al., 1990): (a) the technological context describes both the existing technological infrastructure and the expertise in using new technologies relevant to the organization; (b) the organizational context refers to characteristics of the organization such as organizational culture, resources and size; and (c) the environmental context describes the framework in which a firm conducts its business, referring mainly to its industry, its business partners, its competitors and its dealings with the government.

Adoption theory	**Main dependent construct**	**Main independent construct**	**Originating area**	**Level of Analysis**
Technology acceptance model (TAM)	Behavioral intention to use, system usage	Perceived usefulness, perceived ease of use	Information systems	Individual
Theory of reasoned action (TRA)	Behavioral intention, behavior	Attitude toward behavior, subjective norm	Social psychology	Individual
Theory of planned behavior (TPB)	Behavioral intention, behavior	Attitude toward behavior, subjective norm, perceived behavioral control	Social psychology	Individual
Innovation diffusion theory (IDT) or Diffusion of innovations (DOI)	Implementation success, Technology adoption	Compatibility of technology, complexity of technology, relative advantage	Social psychology	Group, Firm/ organization, Industry, Society
Unified theory of acceptance and use of technology (UTAUT)	Behavioral intention, Usage behavior	Performance expectancy, effort expectancy, social influence, facilitating conditions, gender, age, experience, voluntariness of use	Information systems	Individual
Technology organization environment framework (TOE)	Likelihood of adoption, intention to adopt, extent of adoption	Technological context Organizational context Environmental context	Organizational psychology	Firm/ organization
Resource-based view (RBV)	Competitive advantage, organizational performance	Assets, capabilities, resources	Strategic management, Micro-economics	Firm/ organization
Motivation, opportunity and ability model (MOA)	Behavioral intention, behavior	Motivation, opportunity, ability	Social psychology	Individual
Human organization and technology fit (HOT-fit)	Net benefits	Human component, organization component, technology component	Information systems	Firm/ organization

Table 1: Listing and classification of relevant adoption theories

2.2.2 Studies based on the TOE framework

A search of the literature on technology adoption revealed that the TOE framework has received consistent empirical support. The three aspects of technological, organizational, and environmental characteristics have been validated in various business sectors by several researchers, although the specific factors within each of the three contextual components may vary across studies. Among others, TOE has been used to explain the adoption and diffusion of information systems (Thong, 1999), e-business (Zhu and Kraemer, 2005), e-commerce (Salwani et al. 2009), electronic data interchange (EDI) (Kuan and Chau, 2001), enterprise resource planning (ERP) systems (Pan and Jang, 2008), cloud computing (Hsu et al., 2014) and radio frequency identification (RFID) (Lee and Shim, 2007). The review of existing literature revealed several studies that used the TOE framework to explore aspects of technology adoption as listed in table 2. The table presents the sectors where these studies were performed, includes the selected constructs within the technological, organizational and environmental context and depicts the ones that have been found to be significant in explaining technology adoption.

Reference	Technology/ Innovation	Sector	Technological Context	Organizational Context	Environmental Context
Chau and Tam (1997)	Open systems	89 organizations from industries including manufacturing, utilities, transportation, trading, finance, construction and retail, Hong Kong	Perceived Benefits Perceived Barriers* Perceived Importance of Compliance to Standards* Interoperability, and Interconnectivity*	Complexity of IT Infrastructure, Satisfaction with Existing Systems*, Formalization on System Development and Management	Market Uncertainty
Thong (1999)	IS adoption	166 small firms, cross sector, Singapore	Relative advantage of IS*, Compatibility of IS*, Complexity of IS*	Business size*, Employees' IS knowledge*, Information intensity, CEO's innovativeness*, CEO's IS knowledge*	Competition
Kuan and Chau (2001)	EDI	575 small firms, cross sector, Hong Kong	Perceived direct benefits*, Perceived indirect benefits	Perceived financial cost*, Perceived technical competence*	Perceived government pressure*
Lee and Shim (2007)	RFID	126 hospitals, USA	Perceived benefits*, Vendor pressure	Presence of champions*	Performance gap*, Market uncertainty*
Mishra et al. (2007)	Internet in Procurement	424 Firms within four US industries that manufacture industrial machinery, electrical and electronic machinery, transportation equipment, and measuring and controlling instruments	Procurement process digitization*	Diversity of organizational procurement knowledge*, Organizational perceptions of technological uncertainty	Suppliers' sales process digitization*

Reference	Technology/ Innovation	Sector	Technological Context	Organizational Context	Environmental Context
Ramdani et al. (2009))	Enterprise Systems	300 SMEs, cross sector, UK	Relative advantage*, Compatibility, Complexity, Trialability*, Observability	Top management support*, Organizational readiness*, IS experience, Size*	Industry, Market scope, Competitive pressure, External IS support
Zhu and Kraemer (2005)	e-Business	624 firms, retail industry, 10 countries (United States, Brazil, China, Denmark, France, Germany, Japan, Mexico, Singapore, and Taiwan)	Technology competence*	Size*, Financial commitment*, International scope	Regulatory support*, Competitive pressure
Huang et al. (2008)	EDI	219 firms, cross industry, USA	Relative advantage, complexity*, Strategic use of communication technology*, Trust in technology*, Compatibility, Network externality	Top management support*, Organizational slack*, Organizational size	Potential power*, Trust in partner*, Competitive pressure*, Relationship commitment*, Dependency on partner, Exercised power
Lin and Lin (2008)	e-Business	163 firms, cross industry, Taiwan	IS expertise*, IS infrastructure*	Expected benefits*, Organizational compatibility	Trading partner readiness*, Competitive pressure*

Reference	Technology/ Innovation	Sector	Technological Context	Organizational Context	Environmental Context
Salwani et al. (2009)	e-Commerce	165 firms, tourism sector, Malaysia	Technology competence*	Firm size, Firm scope*, Web-technology investment*, Managerial beliefs	Pressure intensity*, Regulatory support
Pan and Jang (2008)	ERP	99 firms, communications industry, Taiwan	Technology readiness*, Infrastructure	Size*, Perceived barriers*	Production and operations improvement*, Enhancement of product and services, Competitive pressure, Regulatory policy
Hsu et al. (2014)	Cloud Computing adoption intention	200 firms Taiwan, ICT manufacturing and service, general manufacturing and service	Perceived benefits*, Business concerns*	IT Capability*	External pressure
Lin (2014)	e – Supply Chain Management	283 firms, cross industry, Taiwan	Perceived benefits*, Perceived costs*	Firm size, Top management support*, Absorptive capacity*	Trading partner influence, Competitive pressure*

Table 2: Prior studies using the TOE framework

Note: * characterizes the factors that have been found to be significant

2.2.3 Studies based on the combination of the TOE framework with other models

The TOE framework, however, does not accentuate an important factor identified as part of the literature research, namely the impact of perceived benefits on technology adoption, as adopters evaluate an innovation based on its relative advantage (the degree to which a new technology is perceived as better than the one it supersedes). This factor, which is stemming from Roger's theory of innovation, has been included in eminent technology adoption studies, such as the work by the Iacovou et al. (1995) on EDI adoption, where the suggested model included three dimensions: perceived benefits, organizational readiness and external pressure. Hence, in order to investigate determining aspects of SCMP adoption, the present thesis resorts to model synthesis and forms an integrated framework by combining the TOE model with the perceived benefits theory, following similar approaches of other scholars (Gangwar et al., 2015; Oliveira and Martins, 2010). Table 3 presents indicative prior studies identified as part of the initial literature search that utilized the TOE framework combined with other theories in order to investigate technology adoption. The table presents the sectors where these studies were performed, includes the selected constructs within the technological, organizational and environmental context and depicts the ones that have been found to be significant in explaining technology adoption.

Reference	Technology/ Innovation	Sector	Theories	Technological Context	Organizational Context	Environmental Context
Gangwar et al. (2015)	Cloud computing	280 firms, cross industry, India	TAM/TOE	Relative advantage*, Compatibility*, Complexity*	Organizational competency*, Training & education*, Top management support*	Competitive pressure*, Trading partner support*
Oliveira et al. (2014)	Cloud computing	369 manufacturing and service companies, Portugal	IDT/TOE	Technology readiness*	Top management support*, Firm size*	Competitive pressure, Regulatory support
Wang et al. (2010)	RFID	133 firms, manufacturing sector, Taiwan	IDT/TOE	Complexity*, Compatibility*, Relative advantage	Firm size*, Top management support, Technology competence	Competitive pressure*, Trading partner pressure*, Information intensity*
Li (2008)	e-Procurement	120 firms, manufacturing sector, China	IDT/TOE and Institutional Theory	Relative advantage*, Complexity Compatibility	Financial slacks, Top management support*, Technological readiness	External pressure*, External support*, Government promotion
Gibbs and Kraemer (2004)	e-Commerce	278 firms, cross sector, 10 countries (Brazil, China, Denmark, France, Germany, Japan, Mexico, Singapore, Taiwan, US)	TOE and Institutional theory	Technology resources*	Perceived benefits*, Organizational compatibility, Financial resources*, Firm size	External pressure*, Government promotion*, Legislation barriers*

Reference	Technology/ Innovation	Sector	Theories	Technological Context	Organizational Context	Environmental Context
Chong et al. (2009)	Collaborative commerce	109 firms electronics industry, Malaysia	DOI/TOE	Relative advantage*, Compatibility*, Complexity*	Top management support*, Feasibility*, Project champion characteristics*	Expectations of market trends*, Competitive pressure*
Zhu et al. (2006)	Enterprise digital transformation	1415 companies, manufacturing, retail and service sectors (Finland, France, Germany, Italy, Spain and U.K.)	DOI/TOE	Technology competence*	Organization size*	Competitive pressure*, Partner readiness*

Table 3: Prior studies using the TOE framework in combination with other models

Note: * characterizes the factors that have been found to be significant

2.2.4 TOE framework based studies within the healthcare sector

After the initial search of related literature that confirmed the role of the TOE framework in investigating aspects of technology adoption in various business sectors and related to various technologies, a systematic approach was followed in order to narrow down to the scope of the thesis by searching for relevant studies particularly within the healthcare sector. The literature search was performed in four scientific databases (Scopus, Web of Science, Science Direct and PubMed) using adequate keywords ("Technology Organization Environment", TOE, framework, model, hospital, health). The keywords had to be part of the title, the abstract or the keywords of the papers. There were no limitations concerning the year of publication and the language of publication. The results of the initial search performed were the following:

Scopus database

- "technology organization environment" AND hospital = 14 results
- "technology organization environment" AND health = 20 results
- TOE AND framework AND hospital = 21 results
- TOE AND framework AND health = 33 results
- TOE AND model AND hospital = 80 results
- TOE AND model AND health = 164 results

Web of Science database

- "technology organization environment" AND hospital = 10 results
- "technology organization environment" AND health = 12 results
- TOE AND framework AND hospital = 15 results
- TOE AND framework AND health = 25 results
- TOE AND model AND hospital = 33 results
- TOE AND model AND health = 99 results

ScienceDirect database

- "technology organization environment" AND hospital = 7 results
- "technology organization environment" AND health = 3 results
- TOE AND framework AND hospital = 8 results

- TOE AND framework AND health = 8 results
- TOE AND model AND hospital = 14 results
- TOE AND model AND health = 34 results

PubMed database

- "technology organization environment" AND hospital = 3 results
- "technology organization environment" AND health = 3 results
- TOE AND framework AND hospital = 10 results
- TOE AND framework AND health = 14 results
- TOE AND model AND hospital = 160 results
- TOE AND model AND health = 115 results

The articles gathered from the search were initially examined using their titles and their abstracts in order to exclude articles that had no relevance with the thesis (such as papers investigating clinical procedures and technologies), resulting into 32 articles under consideration. After filtering out a few articles that were either lecture notes or not accessible or from the same authors with similar content, 24 articles were accepted and further addressed. The following table shows these articles depicting selected information with relevance to the study, such as country, method, subject and underlying framework.

The review of these articles showed that they all had the following characteristics: a) they addressed a single technology within the hospitals researched, b) they focused on the determinants of adoption of the selected technology without investigating its impact on performance, c) they utilized the TOE framework (14 articles) or the TOE framework combined with another theory (10 articles), and d) they used either a qualitative case study methodology (7 articles) or a quantitative survey based methodology (17 articles).

Reference (Year)	Country / methods	Subject	Technologies investigated	Underlying framework
Aboelmaged, M., Hashem, G. (2018)	United Arab Emirates / online questionnaire of 311 managers, technicians, physicians and nurses of public and private hospitals	RFID application in patient and medical asset operations management: A technology, organizational and environmental (TOE) perspective into key enablers and impediments	RFID	TOE framework
Dash, M. , Anusandhan, S.O. (2018)	India / questionnaires of 189 qualified respondents within private hospitals	Exploring Cloud Computing Adoption in Private Hospitals in India: An Investigation of DOI and TOE Model	Cloud computing	TOE framework combined with DOI model
Shahzad, K., Jianqiu, Z., Zia, M.A., Shaheen, A., Sardar, T. (2018)	Pakistan / case study based research of hospitals in two major cities	Essential factors for adopting hospital information system: a case study from Pakistan	Healthcare Information Systems (HIS)	TOE framework
Lo, M.F., Ng, P.M.L. (2018)	Hong Kong, England / case study based research in 3 healthcare institutions	Knowledge management for health care and long-term care in the technology-organization-environment context	Knowledge management	TOE framework
Ahmadi, H., Nilashi, M., Shahmoradi, L., Ibrahim, O. (2017)	Malaysia / online survey of 131 public hospitals	Hospital Information System adoption: Expert perspectives on an adoption framework for Malaysian public hospitals	Hospital Information Systems (HIS)	TOE framework combined with HOT-fit model
Liou, J.J., Lu, M.T., Hu, S.K., Cheng, C.H., Chuang, Y.C. (2017)	Taiwan / data collection from 20 healthcare industry experts via questionnaires and personal interviews	A hybrid MCDM model for improving the electronic health record to better serve client needs	Electronic Health Records (EHR)	TOE framework combined with decision making techniques

Reference (Year)	Country / methods	Subject	Technologies investigated	Underlying framework
Faber, S., van Geenhuizen, M., de Reuver, M. (2017)	Netherlands / questionnaire of 30 hospitals	eHealth adoption factors in medical hospitals: A focus on the Netherlands	Electronic Health Records (EHR)	TOE framework combined with resource based view (RBV)
Alkraiji, A.I., Jackson, T., Murray, I. (2016)	Saudi Arabia / multiple case study with semi-structured interviews of decision makers in 6 tertiary healthcare organizations	Factors impacting the adoption decision of health data standards in tertiary healthcare organizations in Saudi Arabia.	Health data standards	TOE framework
Hung, S.Y., Huang, W.M., Yen, D.C., Chang, S.I., Lu, C.C. (2016)	Taiwan / survey of 28 hospitals with academic teaching capabilities	Effect of information service competence and contextual factors on the effectiveness of strategic information systems planning in hospitals	Strategic Information Systems (SIS)	TOE framework
Alam, M.G.R., Masum, A.K.M., Beh, L.S., Hong, C.S. (2016)	Bangladesh / structured questionnaire survey of 92 private hospitals	Critical factors influencing decision to adopt human resource information system (HRIS) in hospitals	Human resource information system (HRIS) in hospitals	TOE framework combined with HOT-fit model
Alaboudi, A., Atkins, A., Sharp, B., Balkhair, A., Alzahrani, M., Sunbul, T. (2016)	Saudi Arabia / Interviews with 83 strategic level decision makers representing all types of healthcare facilities	Barriers and challenges in adopting Saudi telemedicine network: The perceptions of decision makers of healthcare facilities in Saudi Arabia	Telemedicine	TOE framework combined with Unified Theory of Acceptance and Use of Technology (UTAUT)
Dey, A., Vijayaraman, B.S., Choi, J.H. (2016)	USA / online survey of 86 hospitals	RFID in US hospitals: an exploratory investigation of technology adoption	RFID	TOE framework

Reference (Year)	Country / methods	Subject	Technologies investigated	Underlying framework
Venkatraman, S., Sundarraj, R.P., Seethamraju, R. (2015)	India / case study based research with semi-structured interviews at a medium sized hospital	Healthcare Analytics Adoption-Decision Model: A Case Study	Healthcare Analytics	TOE framework combined with IS success model
Yaghoubi, N.M., Shukuhy, J., Jafari, H.R., (2015)	Iran / survey of 60 experts in health information technology	Identifying and Ranking Key Factors Influencing the Adoption of Cloud Computing in Electronic Health	Cloud computing	TOE framework
Sulaiman, H., Magaireah, A.I. (2014)	Jordan / case study based research with open-ended interviews with IT healthcare experts	Factors affecting the adoption of integrated cloudbased e-health record in healthcare organizations: A case study of Jordan	Electronic Health Records (EHR)	TOE framework
Lian, J.W., Yen, D.C., Wang, Y.T. (2014)	Taiwan / survey of 106 medical centers and metropolitan hospitals	An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital	Cloud computing	TOE framework combined with HOT-fit model
Lai, H.M., Lin, I.C., Tseng, L.T. (2014)	Taiwan / field survey of 102 hospitals	High-level managers' considerations for RFID adoption in hospitals: An empirical study in Taiwan	RFID	TOE framework
Yang, Z., Kankanhalli, A., Ng, B.Y., Lim, J.T.Y. (2013)	Asia / cross case analysis of two large public hospitals	Analyzing the enabling factors for the organizational decision to adopt healthcare information systems	Healthcare Information Systems (HIS)	TOE framework

Reference (Year)	Country / methods	Subject	Technologies investigated	Underlying framework
Chong, A.Y.L., Chan, F.T. (2012)	Malaysia / survey of 183 healthcare companies and hospitals	Structural equation modeling for multi-stage analysis on Radio Frequency Identification (RFID) diffusion in the health care industry	RFID	TOE framework combined with DOI model
Cao, Q., Baker, J., Wetherbe, J.C., Gu, V.C. (2012)	USA / survey of 168 Healthcare CIOs	Organizational Adoption of Innovation: Identifying Factors that Influence RFID Adoption in the Healthcare Industry	RFID	TOE framework
Liu, C.F. (2011)	Taiwan / self-administered questionnaire of 70 nursing homes	Key factors influencing the intention of telecare adoption: An institutional perspective	Telecare	TOE framework
Sulaiman, H., Wickramasinghe, N. (2010)	Australia / Case study with conceptual focus	Critical Issues in Assimilation of Healthcare Information Systems	Healthcare Information Systems (HIS)	TOE framework combined with resource based view (RBV) and innovation assimilation theory
Chang, I.C., Hwang, H.G., Hung, M.C., Lin, M.H., Yen, D.C. (2007)	Taiwan / questionnaires of 53 medical centers and regional hospitals	Factors affecting the adoption of electronic signature: Executives' perspective of hospital information department	Electronic signature	TOE framework
Lee, C.P., Shim, J.P. (2007)	USA / survey of 126 senior executives in hospitals	An exploratory study of radio frequency identification (RFID) adoption in the healthcare industry	RFID	TOE framework

Table 4: Studies in the healthcare sector based on the TOE framework

2.2.5 Conclusion

The healthcare industry is one of the most important industries in modern societies. In recent years we have seen challenges arising from legislative and regulatory obstacles as well as spread of globalization, cuts in state funding, severe competitive pressures and increasing operating costs. These factors are forcing healthcare organizations worldwide to streamline their processes and lower their costs without compromising the level of quality demanded by the users of the healthcare services. The key for their success seems largely to lie in the optimal management of their supply chains. Implementing SCM concepts in order to assist in the realization of these tasks is not always easy, as there are many barriers, especially organizational and people-related. The existence of limited academic research related to these significant areas of healthcare SCM supports the necessity of more research, especially regarding SCMP.

As previously stated, although SCMP are both technology and process driven, with the emerge of new innovative technologies even process related SCMP are increasingly linked to technology applications, making this distinction harder and less relevant. As an example, the use of ERP systems, which has been investigated in many technology adoption studies, facilitates the application of many process related SCMP, as they are embedded in the standard business process design of these systems (Ruivo et al., 2013). ERP systems are multi-module application software platforms that help organizations manage their businesses processes. They focus on integrating information and activities across the organization via a common platform and centralized database system, which allows information to be entered once and made available to all users. Therefore, the adoption of SCMP will be examined by studying the underlying technologies applied, the role of ERP systems will be highlighted and the term “Supply Chain Management Practices” will be used to reference all those technology based practices and policies that have been identified as success facilitators for organizations (Theriou and Chatzoglou, 2014; Srivastava, 2013).

Drawing upon the prior literature findings, the empirical evidence provided in related studies and the theoretical perspectives discussed above, an enhanced TOE based framework was favored to study SCMP adoption in hospital supply chains. The application of technology-enabled SCMP is expected to depend on organizational and technological readiness, to be impacted by environmental factors and to be influenced by perceived benefits. In order to expand the scope of previous research in this field, a holistic approach was targeted, which would allow the examination of the adoption of a comprehensive set of SCMP rather that focusing on a single practice or technology, as well as the inclusion of a performance dimension, which would enable the investigation of the highly relevant business benefit component of SCMP adoption.

In order to gain insights on the specifics of SCMP adoption in Greek healthcare settings, it was decided to initially perform two case studies in major Greek public hospitals by applying selected SCMP. The qualitative nature of these studies would enable the exploration of the practical relevance of the performed research and assist in developing the research model and designing a suitable research methodology for the quantitative part of the thesis. For this purpose, SCM experts and Healthcare experts were consulted and it was decided to closer investigate e-Procurement, data segmentation and inventory replenishment optimization as they represent indicative SCMP that appear to combine promising results regarding supply chain improvements and comparatively easy implementation. Therefore, these practices were initially theoretically researched in order to be able to apply them in real business settings and draw the relevant conclusions.

2.3 Theoretical background on selected SCM practices

As outlined in the previous chapter, three SCMP (e-Procurement, data segmentation and inventory replenishment optimization) were selected to be applied in Greek healthcare delivery settings in order to gain insights on the specifics of their adoption and their outcomes. Before their application, the theoretical background of these SCMP was investigated.

2.3.1 Theoretical background on e-Procurement

Nowadays companies target maximizing mutual profits with their supply chain members since having strong partners helps firms to increase their operations' efficiency (Al Saa'da et al., 2013). A study by Lee et al. suggests that successful implementation of SCM is attained through continuous SC innovation with supplier cooperation, which in turn improves organizational performance (Lee et al., 2011). This also stands true for the healthcare services sector, as developments towards better cost consciousness and process outcome change the role of the supplier, who formerly was considered as an opponent within price negotiations, into a business partner who contributes an added value to the hospitals and therefore needs to be better integrated into the procurement processes. This new, elevated role of the suppliers is represented by the supplier relationship management (SRM) concept, which combines traditional operational purchasing activities together with organizational and strategic aspects of sourcing (Mettler and Rohner, 2009). According to Herrmann and Hodgson, SRM is focused on maximizing the value of a company's supply base by providing an integrated and holistic set of management tools focused on the interaction of the company with its suppliers (Herrmann and Hodgson, 2001).

SRM related management tools and technologies have been developed mainly in highly competitive sectors such as retail and automotive, however their usage cannot be reflected into the healthcare sector due to its unique characteristics such as the extensive governmental control and its criticality for the public wellbeing. The purchasing function in the healthcare chain is still considered to be a purely cost driving function rather than a value added factor contributing to revenue increase and knowledge acquisition (Mettler and Rohner, 2009). Although the relationships with suppliers is widely recognized by procurement managers as the most important success factor in procurement (Eyholzer and Hunziker, 1999), hospital buying agents often focus exclusively on the best prices, which reflects into weak relationships and collaboration with suppliers. The role that SRM plays in this regard in the healthcare sector will be in the spotlight of this section.

Regarding the management of supplier relationships, four phases can be identified. The first one is *Strategic sourcing,* which relates to all necessary instruments for the retrieval of information such as product information, terms and conditions which are required for the negotiation and configuration of contracts. It also includes tools for the integration and evaluation of suppliers. The second one is *Operational procurement,* which relates to all necessary instruments for ordering and conclusion of a contract, such as payment and invoice verification. The third one is *Extended Cooperation*, which includes collaborative planning and design and concepts such as Vendor Managed inventory (VMI). The fourth one is *Monitoring and controlling,* which relates to all necessary instruments to measure and control the performance of strategic and functional procurement processes (Schweiger et al., 2009; Mettler and Rohner, 2009).

The importance of strategic sourcing is highlighted by a recent report of the Aberdeen Group, as it shows that 68 % of companies surveyed indicate that strategic sourcing plays a prominent to critical role within their organization, demonstrating a shift from tactical short-term cost cutting to value creation which considers wider organizational objectives (Dwyer, 2010). The report identifies the major benefits of strategic sourcing (increased level of cost savings, better alignment of sourcing and business objectives, more robust management of key spend categories), the major drivers (corporate mandate to reduce cost and increase savings, need to improve sourcing performance in a dynamic global environment) and the most significant barriers (the lack of advanced techniques such as supplier optimization and the inability to integrate sourcing activities with spend analytics and supplier management) (Dwyer, 2010). Operational or functional procurement on the other side has less of a strategic orientation since it is deals with the day to day execution of the purchase to pay cycle: the processing of the purchase requisitions, the gaining of approval, the purchase order processing, the monitoring of the goods receiving, invoice verification and payables processes. The remainder of this chapter will focus on the technologies that enable the abovementioned phases of strategic sourcing and functional procurement.

At this point, the use of the terms "procurement", "sourcing" and "purchasing" for the purpose of this study should be clarified, as these terms are used in research and in business in different, sometimes overlapping, sometimes contradicting ways. The approach taken is in alignment with Eyholzer and Hunziker, who define (Eyholzer and Hunziker, 1999):

- Purchasing as "*rather operational and administrative tasks that are carried out more or less by one department, namely the purchasing department"*
- Procurement as "*being broader in scope than "purchasing" and including activities of strategic relevance, such as sourcing, negotiating with suppliers and coordination with R&D"*
- Sourcing as *"finding and choosing the right suppliers for a product, being a cross-functional process that involves - in addition to people from the purchasing department - people from engineering, manufacturing, marketing and other departments"*

There are different technologies enabling strategic sourcing and functional procurement, among them e-Sourcing, e-Purchasing and e-MRO (Maintenance Repair and Operations) (De Boer et al., 2002). Furthermore, Electronic data interchange (EDI), Enterprise resource planning (ERP), e-Marketplaces and e-Collaboration can be added to this list (Bakker et al., 2008). Implemented procurement e-Enablement technologies provide an important opportunity to significantly enhance the capability to manage procurement information, improve commercial and procurement processes and remove waste and duplication, as shown in the case of UK's NHS (National Health Service) (Hodson-Gibbons, 2009). The technologies of e-Sourcing and e-Purchasing are considered to be at the forefront of SRM and will be taken a closer look at in the next sections.

- ***e-Sourcing***

The perception of what e-Sourcing entails has strongly evolved over the last years from a very narrow focus on e-Auctions into what is now generally accepted as e-Sourcing, namely "*the Sourcing process enabled with the appropriate web-based, collaborative technology in order to facilitate the full life-cycle of the procurement process for both buyers and suppliers"* (BuyIT, 2004). More specifically, e-Sourcing is the strategic activity conducted by the procurement professional to establish, manage and monitor a compliant contract and covers the buying process including specification, e-RFx, e-Tender, e-Auction, contract evaluation/ negotiation, tracking, forecasting and monitoring savings. Organizations can utilize enabling technologies within the e-Sourcing arena, which allow them to benefit from strategic sourcing in a scalable way in areas previously not addressed by purchasing. While the Return on Investment for e-Sourcing can be very positive, the primary goal should be to form a part of an integrated approach to elevate the purchasing function by addressing all elements of change: strategy, structure, systems, process and people. Therefore, e-Sourcing is considered to be the backbone of modern strategic sourcing as it automates and streamlines strategic sourcing processes such as RFx's and reverse auctions. Furthermore it enhances flexibility and transparency in the buyer-seller relationship. As shown in a report by the Aberdeen Group, e-Sourcing is the widest adopted technology solution by Best-in-Class enterprises (63%) for the purpose of supporting and streamlining their strategic sourcing programs (Limberakis, 2012).

The operational benefits of e-Sourcing as identified in a study by Booz-Allen and Hamilton are: a) streamlining of processes due to simpler/faster ordering, reduced paperwork, easy online comparison, fewer human errors and lower inventory costs and b) purchasing cost reductions due to transparency of spend, buy aggregation, better compliance, reduced maverick (out of contract) buying, comparability and competition, efficient market and pricing mechanisms, data for strategic sourcing and virtual buying organizations to increase bargaining power (Baker et al., 2000). Some of these benefits were quantified as part of a research conducted by the Aberdeen Group, namely 5– 20% reductions in material costs, reduced sourcing cycle times by 25 – 30% and time-to-market by 10 – 15% (Presutti, 2003). Due to these anticipated benefits, suppliers are facing increasing demand from the buyers to turn to online applications, such as e-RFx and e-Auctions systems, for negotiation and trading purposes (Ivang & Sorensen, 2005). However, the adoption of e-Sourcing represents substantial challenges for a company such as the change management required, the resulting new organizational roles, the expected speed of implementation, the management of existing suppliers, the definition of the right content management strategy and the integration with back office systems (Baker et al., 2000). Furthermore, the reluctance of suppliers can be a major reason for failure, as they perceive that e-sourcing will undermine their established relationships with their partners, which are based on human contact and communication, by performing the comparison with their competitors solely on the basis of price (White and Daniel, 2004).

As previously stated, e-RFx and e-Auctions are commonly used tools for supporting e-Sourcing. RFx stands for RFI (Request for Information - an open inquiry spanning a broad base of potential suppliers), RFQ (Request for Quotation - an opportunity for potential suppliers to competitively cost the intended purchase), RFT (Request for Tender - an opportunity for potential suppliers to submit an offer to supply goods or services against a detailed tender) and RFP (Request for Proposal - a business requirements-based request for specific solutions to the sourcing problem, sometimes based on a prior RFI) (Mhay and Coburn, n.d.). An e-Auction is a form of electronic negotiation and an electronic reverse auction (ERA) is a type of e-Auction frequently used in B2B commerce. An ERA represents a price determination method which is enabled by technology in contrast to the traditional methods of face to face negotiations and sealed bidding (Caniels and van Raaij, 2009). In a reverse auction several suppliers compete for the business to supply products or services by bidding against each other online and by successively lowering their bids, thus driving the prices down (Beall et al., 2003). The selection of the right e-Sourcing tools is crucial to the success of the company’s sourcing strategy, therefore it is necessary to carefully evaluate whether e-Sourcing is appropriate and which tool should be used for the different types of commodities to be procured (Puschmann and Alt, 2005).

- ***e-Purchasing***

The use of electronic media in procurement activities can lead to a significant cost and time reduction compared to managing the purchasing process by traditional means, as it involves the streamlining of the procurement process by eliminating paper–based documents and conducting the purchasing process via web-based systems (Zunk et al., 2014). DeBoer et al. consider e-Purchasing as the application of web based technology throughout the purchasing process (DeBoer et al., 2002). A more comprehensive definition is given by Tatsis et al., who define e-Procurement as "*the integration, management, automation, optimization and enablement of an organization's procurement process, using electronic tools and technologies, and web-based applications"* (Tatsis et al., 2006).

In the healthcare industry, e-Purchasing typically allows for automated drug-inventory reporting and control, drug replenishment alerts, online purchase of drugs and related medical supplies (Smith and Flanegin, 2004). Nowadays almost anything can be purchased online, from large medical equipment to rubber gloves and pharmaceuticals. The days of leafing through outdated paper catalogues are over as online ordering gives the purchaser real-time information on any given product (Ketikidis et al., 2010). As the healthcare industry is increasingly looking for innovative technologies and creative management solutions to handle the procurement processes in a competitive manner, e-Purchasing has gained strategic visibility and has emerged as the driving force behind several supply chain practices (Nzuve, 2013), as it offers to healthcare establishments notable advantages such as convenience, efficiency, broad selection, favorable pricing, information on new products and others (Ketikidis et al., 2010).

Tools used for the e-Enablement of operational procurement are (de Boer et al., 2002; Matunga et al., 2013):

- Web-based EDI-applications providing an efficient and effective way to automate the exchange of information between sellers and buyers.

- Web-based ERP Systems facilitating the creation and approval for purchase requisitions, the placement of purchase orders and their transmission to the suppliers, the goods receipts process and the payment for the goods.
- e-MRO facilitating the creation and approval for purchase requisitions, the placement of purchase orders and their transmission to the suppliers, the receiving and payment process for non-product related MRO supplies.
- e-Marketplaces, where buying communities can access preferred suppliers' products and services, add to shopping carts, create requisitions, seek approval, receive purchase orders and process electronic invoices with integration to suppliers' supply chains and buyers' financial systems.
- e-collaboration where web based systems integrate across companies fostering cooperation
- Specialized applications such as content management and catalogue building, application integration, payment and fulfillment services.

Benefits of e-Purchasing applications

The literature on e-Procurement is rich with estimates of its benefits (financial and non-financial, strategic, tactical and operational) such as: Accelerated flow of information and improved collaboration between supply chain members, reduced paperwork and administrative hours, reduced ordering costs, reduced purchasing cycle times, higher price transparency, improved accuracy, improved auditing and security controls, simplified fund transfers, reduced inventory levels and associated inventory costs (Bof and Previtali, 2007; Min and Galle, 2003; Zheng et al., 2006; Davila et al., 2003; Gunasekaran and Ngai, 2008; Panayiotou et al., 2004; Calipinar and Soyzal, 2012). According to a survey by Gunasekaran, 66,7% of surveyed companies believe that successful e-Procurement implementation can improve long term organizational performance and 34,8% believe that successful e-Procurement implementation can improve short term organizational performance (Gunasekaran and Ngai, 2008). Furthermore, technology usage in purchase activities is inevitable due to the globalization, the increasing number of suppliers with the expanding complexity of products and the growing use of outsourcing and due to the fact that technology usage in procurement activities plays a pivotal role in determining the performance of firms (Batenburg, 2007).

These developments towards better cost consciousness and process reengineering is expected to also affect the procurement activities in the healthcare sector. A survey in Germany revealed that approx. 70% of the hospitals and medical products suppliers utilize e-Purchasing solutions (BVMed Survey, 2007). The same survey identified reduced order cycle times (60% of respondents), less errors due to automation of processes (59%) and procurement process optimization (42%) as the top three benefits, whereas the price transparency was deemed as less important (Krankenhaus IT-Journal, 2007).

Barriers for e-Purchasing applications

However, although e-Purchasing accelerates and simplifies the purchasing process between buyers and sellers, there are some barriers for its adoption, which can be categorized as (Leal, 2010):

- Security related: implications for organizations transacting over the internet
- Technology related: high cost of technology, lack of systems integration and data standardization, lack of interoperability with existing ERP systems, immaturity of e-Purchasing based services
- Human factor related: end user resistance to change, lack of technical expertise and e-Purchasing knowledge, fear about being replaced by automated systems, unwillingness of suppliers to embrace this technology (Zunk et al., 2014)

According to Davila et al., the risks associated with the adoption of e-Purchasing technologies are (Davila et al., 2003):

- Internal business risks, such as systems integration issues and lack of overall accepted standards
- External business risks, such as dependency on suppliers for successful adoption of e-Purchasing models
- Technology risks, such as the selection of the right tools which fit the specific needs of the company
- Process risks, bridging business and technology, such as control systems in order to ensure reliability and detect unauthorized interventions as part of electronic interchange of data

Bof and Previtali stated that the abovementioned barriers and risks tend to increase within the public sector, which requires that a bureaucratic procedure be followed due to the nature of the institutions involved and embraces audit, accountability and compliance standards with national and international rules to ensure supply competition and transparency in the awarding of contracts (Bof and Previtali, 2007). In a case study concerning the Greek governmental purchasing process, Panayiotou et al. noted that the inhibiting factors affecting the adoption and diffusion of e-Purchasing concepts in the public sector include the challenges posed by public policy and legislative constraints and the increased need for transparency in procurement (Panayiotou et al., 2004). These barriers result into relatively low adoption rates, as shown by a similar study in the Italian public healthcare sector, which found that the adoption rate of e-Procurement solutions was 21% (Bof and Previtali, 2007).

Due to the rapidly increasing financial pressures, the healthcare services sector and hospitals in particular are constantly seeking more cost- and time-saving methods to acquire supplies (H.I.D.A., 2012). Considering the outlined benefits of e-Sourcing and e-Purchasing tools, it seems that they could contribute significantly towards this direction. In order to verify this assumption, a case study in a Greek public hospital was planned to be conducted as part of the qualitative research part of the present thesis, in an attempt to provide insights on the e-Sourcing and e-Purchasing tools implementation and to identify benefits and barriers for their adoption (see chapter X).

2.3.2 Theoretical background on data segmentation

The second SCMP investigated was data segmentation, which allows inventory and procurement managers to focus on items that are expected to yield more cost savings, rather than waste their time on items, where the achieved benefits would be incremental. As typical hospitals carry different categories of items such as drugs, biomedical equipment, and linens for beds, it would be inefficient to devote equal planning attention to each one of them. The inventory control and planning efforts should be based on the relative importance of the various items in inventory, which can be classified using the classic method of the ABC analysis (Liu and Wu, 2014). The ABC analysis can be applied using a number of parameters, however the usage (or consumption) value of items stands out as the traditional base for calculations (Thongmal Larsson, 2010).

Based on this technique, inventory items can be divided into the following three classes according to their consumption value (value per unit multiplied by the consumption quantity): A (very important items), B (moderately important items), and C (marginally important items). There are no fixed thresholds for each of these classes, however A-items generally account for about 10 to 20 percent of the items in total inventory, but for 70 to 80 percent of the consumption value. B-items are moderate in terms of inventory percentage and consumption value. Finally, C-items may represent 50 to 60 percent of the items, but only 5 to 10 percent of the consumption value (Levin and Jayakrishnan, 2014) (Figure 4). Although those percentages may vary based on the specifics of each company and the industry sector it belongs to, for most facilities relatively few items will account for a large share of the value or cost associated with an inventory (Swamidass, 2000).

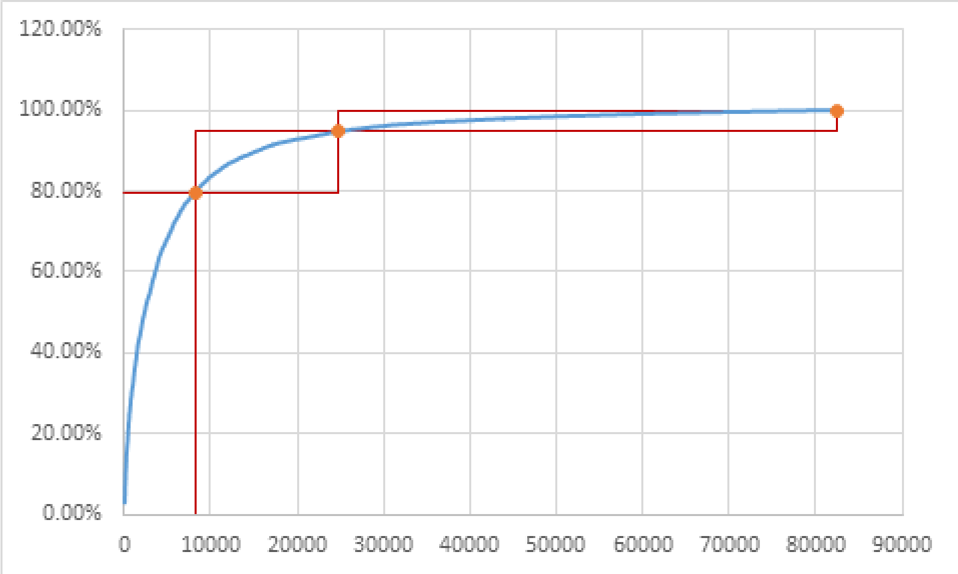


Figure 4: Typical ABC Analysis graph

The ABC analysis aims to draw inventory managers' attention on the critical few (A-items) and not on the trivial many (C-items), and is a widely employed technique, especially in the SCM functions (Gunasekaran *et al.*, 2004). However, it is one-dimensional, as it is based on one single metric (in this case the consumption value), and may not capture different aspects of criticality of an item (Kumar *et al.*, 2014). Thus, multiple criteria for inventory classification should be considered, as has been stressed in the literature (Ramanathan, 2006; Wan Lung, 2007; Chu *et al.*, 2008; Teunter *et al.*, 2010). Especially in hospitals, where drug administration is complex and drug shortages can have an impact on human lives, the ABC classification alone cannot adequately support drug inventory management (Chen *et al.*, 2008; Mousnad *et al.*, 2016). Addressing this issue, some scholars propose to also take the drug's clinical importance into account (Xi, 2007; Arustamyan *et al.*, 2013; Kritchanchai and Meesamut, 2015; Devnani *et al.*, 2010), something that can be achieved by adjusting the ABC analysis results based on this factor. The identification of vital drugs can be done by subject matter experts or with the help of formalized drug classification schemas such as VEN (Vital, Essential, Non-Essential) or VED (Vital, Essential, Desirable) (Devnani *et al.*, 2010; Kaur *et al.*, 2006).

Besides the consumption values and the clinical importance of items, a third factor can be the basis for data segmentation, namely the consumption pattern of the items (Hoppe, 2008). In order to incorporate this parameter, an XYZ analysis can be performed in addition to the classic ABC analysis, aimed at distinguishing between items according to their fluctuations in consumption (Bulinski *et al.*, 2013). The XYZ classes can be summarized as follows:

- **X:** Relatively constant consumption, fluctuations are rather rare
- **Y:** Fluctuations in consumption, usually for trend related or seasonal reasons
- **Z:** Irregular consumption pattern

The XYZ analysis is based on the variation coefficient, which is the ratio of the standard deviation of item consumption over a certain period and the average consumption, and it permits the inclusion of seasonal developments. The selection of the appropriate forecasting methods in order to classify the items into one of the XYZ classes can be supported by the automated analysis of the time series pattern by hospital ERP Systems, as shown in figure 5. The system analyzes the historical data and selects the most suitable model (constant, trend, seasonality, seasonality and trend) (Catt, 2007; Adebanjo, 2009). The time series used can be the daily consumption values of drugs and medical supplies in the hospital. As forecasts from time series data assume that future values can be predicted based on past values, the analysis of time series can identify the behaviour of the series in terms of trend and seasonality in order to ensure that an appropriate forecasting model is selected (Makridakis *et al.*, 1998). A trend is a gradual long term upward or downward movement in data and seasonality refers to short term, relatively frequent variations generally related to factors such as weather, holidays and vacations (Ozcan, 2009).

An adequate time horizon for the calculation should be defined in order to allow the system to include sufficient historical data from the past, and in order to search all available statistical forecasting procedures and parameter combinations, for the purpose of selecting the one that produces the best forecast accuracy in the specified time segment for each material. The selection of the forecasting model and the estimation of the necessary parameters should be updated regularly (e. g. every year), but not too often, as this would result in too much nervousness (Kilger and Wagner, 2015).

The ABC analysis (based on items' consumption values and adjusted by items' clinical importance) can function as the primary analysis and can be enhanced by the XYZ analysis (based on items' consumption patterns), resulting into the ABC-XYZ classification matrix (Scholz-Reiter et al., 2012; Hoppe, 2008), as shown in table 5. The main advantages of this approach are the integration of items with similar characteristics in order to process them with the same material planning parameters, and the identification of materials with high optimization potential (Bulinski et al., 2013). Since the demand of an item over the past cycles is crucial for its classification, it is important to actualize the item classification within consistently defined periodic intervals in order to include possible changes promptly.

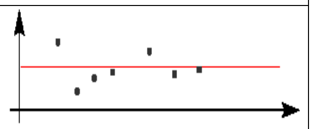
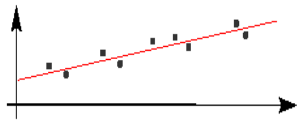
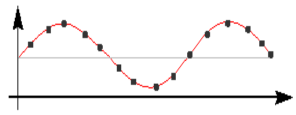
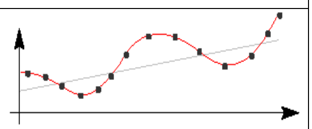
Time Series Pattern	**Forecast Model**	
Constant (class X)	Constant model (1st-order exponential smoothing)	
	Constant model with smoothing factor adaptation - (1st-order exponential smoothing)	
	Moving average model	
	Weighted moving average model	
Trend (class Y)	Trend model (1st-order exponential smoothing)	
	Trend model (2nd-order exponential smoothing model)	
	Trend model (2nd-order exponential smoothing model with parameter optimization)	
Seasonal (class Y)	Seasonal model (Winter's Method)	
Seasonal Trend (class Y)	Seasonal trend model (1st-order exponential smoothing model)	

Figure 5: Forecast models based on time series pattern (Catt, 2007)

	A	***B***	***C***
X	High usage value Constant consumption	Middle usage value Constant consumption	Low usage value Constant consumption
Y	High usage value Fluctuating consumption	Middle usage value Fluctuating consumption	Low usage value Fluctuating consumption
Z	High usage value Irregular consumption	Middle usage value Irregular consumption	Low usage value Irregular consumption

Table 5: ABC-XYZ Analysis (Hoppe, 2008)

The flexibility of data segmentation regarding the criteria of categorization allows its application in combination with other SCMP such as e-Procurement or inventory replenishment optimization, which will be discussed next.

2.3.3 Theoretical background on inventory replenishment optimization

Following the saying “what gets measured can be managed” the interest in supply chain performance measurement and management comes as no surprise (Seuring, 2008). Although detailed publications related to several supply chain management KPIs and metrics are available, they are mainly conceptual or literature based rather than supported by fieldwork (Cuthbertson and Piotrowicz, 2008), making the development of a set of practical guidelines for companies and SCM practitioners very challenging (Chae, 2009). Commonly used parameters are cost, time, quality and flexibility (Shepherd and Günter, 2006), with cost based parameters being used more widely due to their quantitative nature and their direct impact on financial performance (Gunasekaran and Kobu, 2007). Classic SCM performance measurement frameworks are the Supply Chain Operations Reference (SCOR) model, which lists a number of performance indicators to track the performance of a supply chain (Jamehshooran *et al.*, 2015), and the balanced scorecard approach, which integrates non-financial and financial measures into one management report (Brulhart and Btissam, 2015; Sürie and Reuter, 2015).

Within the field of Inventory Management in particular, various models are introduced to evaluate inventory performance and to optimize inventory functions. In this context, the cost of inventory is the most important factor considered by literature (Gunasekaran et al., 2004), with the service level being another important key factor taken into account (Teunter et al., 2010), where service level can be defined as “the ability to meet the demands of customer from stock” (Lysons and Gillingham, 2003). The abundance of suggested models however, indicates that no particular school of thought is clearly dominating this field, as the literature review did not provide any evidence of significant adoption and implementation of these models. This is attributed to barriers related to the complexity of their implementation, to the lack of incorporation of sector-specific aspects and to the fact that they require data that are not available or might not be in the right form when trying to use them in real business settings, as acknowledged by some of the authors proposing these models (Multanen, 2011; Radhakrishnan et al., 2009).

The same holds true for the healthcare sector in particular, as an extensive body of literature reflects the unique challenges and corresponding strategies that are deployed in the Inventory Management (IM) and Demand Management (DM) functions of this sector (Jack and Powers, 2009). The complexity of these aspects increases even more, as they are impacted by conflicting goals of the various stakeholders (physicians, pharmacists, Group Purchasing Organizations (GPOs), patients). Physicians, for example, favor the availability of a larger variety of drugs in order to better support the individual needs of their patients and might want to try new drugs entering the market, sometimes even influenced by sales representatives of drug manufacturers. On the other hand, a hospital's pharmacist aims to keep the range of drugs purchased and inventoried at a lower level, in order to achieve better prices due to economies of scale and to decrease the cost associated with holding and administering a larger variety of drugs (Kelle et al., 2012).

Thus, the need of a practical framework for improving inventory replenishment in healthcare facilities is evident, which should be characterized by implementability, cater for the specific requirements of this sector and lead to measurable results. This framework should prioritize the significant improvement of IM functions rather than their optimization, as practitioners are expected to favor implementing a straight forward, transparent and effective approach that significantly improves aspects of their IM, over implementing a high complexity, high effort framework that aims at optimizing their IM functions. As inventory replenishment is tied to MRP (Material Requirements Planning) strategies and lot sizing procedures, these terms will be briefly explained.

MRP strategies determine how a material is being planned, whether the planning is based on a reorder point logic, whether it is forecast based taking historical data into account, whether it is deterministic based on specific customer requirements or whether it combines a safety stock logic (Hoppe, 2008). Lot sizing procedures are methods used for the calculation of the adequate procurement quantities (lot sizes) and dates that will effectively cover the anticipated demand. Intensive research has been carried out to develop models and methods for the purpose of determining optimum lot sizes (Lee *et al.*, 2013; Uthayakumar and Priyan, 2013; Zhao and Zhang, 2002; Evans, 1985). However, the effort required in order to select and apply the optimum lot sizing method for an item to be purchased can be substantial, making it suitable only for high impact items (Chan *et al.*, 2009). Therefore, MRP strategies and lot sizing procedures can be viewed in combination with the data segmentation ABC-XYZ matrix discussed in the previous chapter. Following the ABC-XYZ classification, a suitable MRP strategy and lot sizing procedure can be defined for the resulting relevant item classes (Bulinski et al., 2013). The materials belonging to the non relevant classes of the ABC-XYZ matrix (classes BY, BZ, CY, CZ) do not need to be considered, since the effort required to optimize them would be high, due to their non-constant consumption, and would not lead to significant savings, as the materials belonging to these classes are characterized by mid to low usage values.

For each one of the relevant item classes of the ABC-XYZ matrix (classes AX, AY, AZ, BX, CX as shown in table 5), an appropriate MRP strategy can be defined (Figure 6).

- Items with relatively constant consumption (AX, BX, CX) do not require a sophisticated planning strategy, thus they can be assigned a simple, easy to implement MRP strategy, which is based on defining a suitable reorder point (Hoppe, 2008).

- On the other hand, items with fluctuating consumption and high usage value (AY) can be assigned a more sophisticated MRP strategy based on demand forecasting. The higher implementation effort that is required by this strategy is justified, as the identification of the suitable demand pattern can lead to a better alignment of the inventories to the actual demand (Scholz-Reiter et al., 2012).

- Finally, high usage value items with irregular consumption (AZ) can be assigned a simple MRP strategy, such as reorder point planning, since the prediction of their demand is nearly impossible. However the use of this strategy should be combined with high levels of safety stock, in order to ensure adequate service levels (Bai and Ade, 2015).

It should be noted, that modern ERP systems support the option of automatically calculating reorder points for materials, taking their average consumption and their delivery times into account (Hoppe, 2008). However, due to the high importance of items with high consumption value (AX, AY and AZ), subject matter experts should review the automatically generated reorder points and manually adjust them if needed.

Additionally, as previously outlined, the selection of a suitable lot sizing procedure should be based on the ABC-XYZ analysis matrix as well (Figure 6).

- Optimizing lot-sizing procedures, such as Economic Order Quantity (EOQ), can be chosen for AX and AY items. These procedures require a higher analysis effort, since the proposed order quantity needs to be calculated by taking the inventory holding costs into account and comparing them to the expenses incurred as part of placing and receiving a stream of orders. The higher analysis effort however is justified, as even small improvements are expected to have significant impact due to the high usage values associated with items belonging to these classes (Buxey, 2006).

- For less important items on the other hand (BX and CX items) straight forward, simple to use static lot-sizing procedures, such as fixed lot sizes can be used. In this case, every time there is a procurement need for a material, a fixed predetermined quantity is automatically proposed for ordering (Hoppe, 2008).

- Finally, for AZ items, as outlined before, the lot size procedure (whether based on EOQ logic or on fixed sizes) can incorporate a high safety stock, as the irregularity of demand could potentially threaten the needed service levels, unless the materials have a short lead time and can be replenished quickly in the case of unexpected demand (Evans, 1985).

	A	B	C
X	MRP strategy / Lot Sizing procedure	MRP strategy / Lot Sizing procedure	MRP strategy / Lot Sizing procedure
Y	MRP strategy / Lot Sizing procedure	N/A	N/A
Z	MRP strategy / Lot Sizing procedure	N/A	N/A

Figure 6: Assignment of appropriate MRP strategies and lot sizing procedures

Considering the outlined importance of inventory management (IM) and demand management (DM) in hospitals, the adoption of appropriate IM and demand forecasting strategies is expected to significantly contribute towards the reduction of hospital operating costs (Varghese et al., 2012). Researchers however indicate that related optimization models found in literature face limited adoption (Stanger et al., 2012). Therefore a case study in a large Greek public hospital was planned to be conducted as part of the qualitative research part of the present thesis, in an attempt to provide insights regarding the selection and implementation of appropriate IM planning techniques and in order to assess their effectiveness. The goal of generating practically relevant outcomes and implementable solutions for healthcare practitioners will assist in the development of the research framework and reinforce the link between theory and practice.

3 Qualitative research

This section outlines the two case studies that were performed in two Greek major public hospitals with the goals of (1) gaining insights on hospital SCM operations, (2) adapting SCM related practices suggested by literature and business studies to the healthcare context, (3) implementing these SCMP and examine related barriers and facilitators of their adoption, (4) measuring their impact on the hospitals' operational performance, and (5) assisting in developing the research framework on SCMP adoption. As previously outlined, the SCMP selected to be initially investigated were e-Procurement, inventory replenishment optimization and data segmentation.

The insights gained from the qualitative research performed as part of these case studies were expected to assist in building a strong and practically relevant foundation for the quantitative part of the research that would be following. The combination of both qualitative and quantitative research methods is expected to increase the depth and breadth of understanding of the investigated aspects and offset weaknesses inherent to using each approach by itself. While collecting both qualitative and quantitative data is time consuming and complex, it is expected to increase the robustness of the research study.

3.1 Case study on e-Procurement in a healthcare setting

The first case study reports on research investigating the benefits and barriers of e-Enabling Technologies, such as e-Sourcing and e-Purchasing in the healthcare sector. As outlined in the theoretical background section, healthcare services sector and hospitals in particular are constantly seeking more cost- and time-saving methods to acquire supplies (H.I.D.A., 2012). Considering the benefits of e-Sourcing and e-Purchasing tools, it seems that they could contribute significantly towards this direction. Therefore, a case study was conducted at a Greek public hospital, the KAT General Hospital (KGH), in order to examine aspects regarding the implementation of specific e-Sourcing and e-Purchasing tools, such as e-RFx and e-Auctions, focusing on the resulting benefits and the existing barriers of adoption.

3.1.1 Case study methodology

The case study method was chosen since it represents a qualitative research method highly effective when a small sample of participants in a single organization is involved (Stefanou and Revanoglou, 2006). The case study included interviews with procurement managers and procurement specialists of the hospital, interviews with suppliers as well as observations. It was conducted in four steps.

The first step was to identify a hospital in Greece, which had implemented and utilized e-Enabling Technologies as part of its procurement processes. For this purpose, two of the leading e–Sourcing and e-Purchasing technology suppliers in Greece (cosmoONE and Business Exchange) were contacted regarding their clientele and a hospital was identified that was on the list of both suppliers, namely the General Hospital KAT (GHK) in Athens, Greece. The General Hospital KAT is a public hospital and is considered to be the largest hospital for injuries in Greece specializing in injury-related and orthopedic cases. It employs 400 doctors and its scientific and administrative personnel counts 1800 employees. GHK is considered to be among the pioneers of utilizing e-Enabling Technologies for procurement in the Greek healthcare sector as it started implementing and using these technologies in

2012. In recognition to this achievement, it received the e-volution bronze award 2014 in the category “Enterprises utilizing e-Business”, an award that is given to Greek companies applying best practices in e-commerce.

The second step was to conduct semi-structured interviews with the GHK procurement manager who was in charge of the implementation of these projects, with the procurement department business experts who were using the relevant tools and with the technology-supplying vendors. The interviews were based on open-ended questions addressing the following subject areas: a) aspects of the pre-existing situation, b) benefits/issues of the new solution c) user acceptance d) management support.

The third step was to observe the traditional process of sourcing and purchasing in GHK (As Is Analysis) as well as the new process of planning and conducting e-Sourcing and e-Purchasing events and transactions (To Be Analysis). Finally, the fourth step was to gather relevant data in order to draw conclusions on the status and the benefits of e-Sourcing and e-Purchasing technologies adoption in the Greek healthcare sector.

3.1.1.1 As-Is analysis

The procurement department of GHK is responsible for the procurement of consumables (such as pharmaceutical products, implantable products, other medical supplies, medical gases, food and beverage and non-medical items), the procurement of durable goods (such as medical/surgical equipment, furniture, MRO items) and the procurement of services (such as cleaning, security, maintenance). The process of sourcing starts with the forecast-based planning and budgeting of the procurement items based on the previous years needs and consumptions. After gaining approval for the plan by the supervising authorities, the realization of the plan starts with conducting calls for tenders. After assessing the offers, contracts are awarded to the selected suppliers. Following the signing of the contracts, procurement activities for the abovementioned goods and services are executed with reference to the existing contracts. Unforeseen procurement needs such as special requests for specific patients or vaccines for flu outbreaks are handled on a case by case basis, following a special approval process. The process of tendering and evaluating the suppliers' quotations is highly bureaucratic and time-consuming due to public nature of the hospital. Drug and supply shortages occur because a single -even insignificant- error in the procedure can lead to objections by competing suppliers nullifying the whole process so that all steps have to be reinitiated. Agreed upon prices, whether related to contracts or to out-of-contract buying, have to be in line with the price observatory maintained by the HPC (Health Procurement Committee), a governmental agency reporting to the Greek Ministry of Health and Social Security.

The problems identified were:

- Lengthy procedures for planning and approving the yearly procurement plans and corresponding budgets
- Legislative hurdles due to the large number and complexity of relevant laws
- Huge variety of products due to evolution of technology and science
- Different technical specifications among public hospitals for the same products
- Lack of data standardization
- Obstacles due to easiness of lawsuit filing regarding contract award procedures from competing vendors
- Large product price variations between different hospitals
- Lack of tools and reports to control the consumption of goods and services within the hospital
- Lack of systems integration

3.1.1.2 To-Be model

In order to address some of these issues, GHK decided to implement e-Enabling technologies for procurement in a two-phased approach. The first phase entailed the implementation of e-Sourcing tools and the second phase would expand into e-Purchasing technologies. For this purpose, leading suppliers for procurement e-Enabling technologies based on ASP (Application Service Provider) models were selected and provided the tools necessary as well as facilitated the new processes. Firstly, it was decided which procurement items would be sourced using the new technologies, based on criteria like simplicity of products and repeatability of procurement processes. The suppliers were informed regarding the new procedures on e-RFx and e-Auctions, received access to the electronic platforms and participated in an online training session. Following that, mock auctions were held, in order to make sure that the suppliers felt comfortable with the tool and that there were no technical issues. Finally, the real e-Auctions were held, typically lasting one hour, with an automated two minute extension in case bids were made in the last two minutes of the session. Currently, as part of the second phase, GHK is in the process of evaluating options for the e-Purchasing tools, that should support purchase requisition creation and approval processes as well as purchase order processing through the access of online catalogs, which will be created based on the awarded contracts of the HPC.

3.1.2 Case study findings

The drivers for the introduction of e-Sourcing and e-Purchasing activities at the GHK were the expected cost savings due to lower purchase prices and reduced administrative costs, the reduced purchasing cycle times, the streamlining and standardization of the procurement processes resulting in freeing up resources for more value added procurement activities and the improved ability in regards to monitoring and controlling these activities. The successful implementation of the e-Sourcing tools was attributed among others to the high user acceptance and upper management support, as was pointed out in the interviews held. The abovementioned expectations were met to some extent after the successful implementation of e-Sourcing tools, namely e-RFx and e-Auctions, however it should be noted that the adoption of these technologies was not followed up by organizational and process changes. Thus, the strategic impact of e-technologies on SCM effectiveness and patient safety in a healthcare setting could not be verified. The cost of the implementation of e-Sourcing tools did not represent a barrier, as it was very low due to the fact that GHK utilized solutions readily available by ASP vendors and did not perform any type of business process reengineering. The perception of the involved stakeholders (procurement personnel, procurement managers, upper management) regarding the implementation and the outcome of these initiatives was positive.

e-Sourcing tools such as e-RFx and e-Auctions, were extensively used as part of the procurement department's sourcing activities. More specific, GHK managed to:

- generate cost savings
- drastically reduce the average time between the invitation and the response from the supplier
- significantly increase the average number of invitations by tender as can be seen in table 6.

		No. of tenders	No. of invited suppliers	No. of respon-ding suppliers	Avg. time between invitation and response	Avg. no. of invitations by tender
Medical / surgical supplies	Vascular Surgery Implants	80	224	168	0,09	2,80
	Haemostatics	4	12	10	0,25	3,00
	Blood sampling bags	6	33	21	3,17	5,50
	Diagnostic catheters	3	28	13	3,00	9,33
	Stents	9	50	26	0,67	5,56
	Haemodynamic supplies	22	277	122	3,41	12,59
	X-ray supplies	9	141	63	1,56	15,67
	Not classified	30	162	69	1,30	5,40
	Total	**163**	**927**	**492**	**1,04**	**5,69**
IT-related	Printers	2	10	0	4,00	5,00
	Total	**2**	**10**	**0**	**4,00**	**5,00**
Other supplies	Airconditioners	1	7	4	1,00	7,00
	Total	**1**	**7**	**4**	**1,00**	**7,00**
	Overall Total	**166**	**944**	**496**	**1,08**	**5,69**

Table 6: Impact on avg. time between invitation and response and avg. no. of invitations by tender

Over 100 auctions were organized and the price reductions achieved through the use of the e-Auctions tool were calculated to be 6,19 %.

3.1.3 Suggested improvements through data segmentation

The findings of the case study showed that although hospitals need to utilize expertise and technology in order to enhance their sourcing processes, the diffusion of e-procurement appears to be relatively slow. Previous research identified the need for practical frameworks aiming at providing healthcare practitioners with simple to implement approaches for initial e-procurement rollouts as well as for the improvement of ongoing e-procurement efforts. Following through with this suggestion, the case study was expanded in order to provide procurement managers in hospitals with a decision support model to complement their judgment, knowledge and experience by using SCM data segmentation for the purpose of optimizing their e-procurement efforts.

3.1.3.1 Data segmentation based on ABC-XYZ analysis

The case study showed that the implementation of e-procurement tools is largely intuitive and is lacking methodological foundation. Thus, a methodology for categorizing the various items that are procured through the purchasing department based on their suitability for e-procurement had to be defined, allowing hospital procurement managers to focus on the items that were expected to yield more cost savings, rather than waste their time on items, where the achieved benefits would be incremental. A widely employed technique for the classification of items, especially in the areas of purchasing and inventory management, is the ABC Analysis (Liu and Wu, 2014; Gunasekaran et al., 2004). This classification method can divide the items according to their purchasing value (price per unit multiplied by the purchasing quantity) into the following three categories:

- A (very important items),
- B (moderately important items) and
- C (marginally important items).

There are no fixed thresholds for each of these classes, however A-items generally account for about 10 to 20 percent of the items, but for 70 to 80 percent of the purchasing value. B-items are moderate in terms of percentage of total items and purchasing value and C-items may represent 50 to 60 percent of the items, but only 5 to 10 percent of the purchasing value (Levin and Jayakrishnan, 2014).

The ABC Analysis approach however is one-dimensional, as it is based on one single metric (in this case the purchasing value), and may not capture additional relevant aspects of an item (Kumar et al., 2008). Thus, multiple criteria for classifying items should be used, as has been stressed in the literature (Teunter et al., 2010; Chu et al., 2008; Ramanathan, 2006). In order to address this issue, besides the purchasing value, a second criterion impacting the suitability of items for e-procurement activities should be identified. Based on the analysis of the achieved cost savings on an item by item basis and based on consultations with the hospitals procurement specialists, the criterion with the highest impact was found to be the price sensitivity of an item, which indicates whether the price of an item is relatively constant or subject to fluctuations. Items with a rather constant price behavior were expected to yield lower cost savings compared to items with fluctuating or irregular price patterns. Thus, a two dimensional classification methodology was introduced (ABC-XYZ Analysis), in order to classify items based on the relevant characteristics of purchasing value and price sensitivity, which would allow their differentiated treatment from an e-procurement perspective.

Consequently, the proposed framework suggests the initial classification of purchased items by means of a classic ABC Analysis based on their purchasing value. Following that, the ABC Analysis is expanded into an ABC-XYZ Analysis by taking the price sensitivity of the items into account. The resulting ABC-XYZ matrix serves as the basis for the identification of the item classes that should be included in e-procurement efforts and of the item classes that should be left out, as the expected cost savings would not justify the required effort for applying the e-sourcing tools.

3.1.3.2 Application of data segmentation and results

For the purpose of applying the suggested framework in GHK, the ABC Analysis of the purchased items was based on their accumulated purchasing value (purchased quantity multiplied by the price) of the previous twelve months and the classification thresholds were set as follows:

- A: 0-70 percent of the accumulated purchasing value
- B: 70-90 percent of the accumulated purchasing value
- C: 90-100 percent of the accumulated purchasing value

The ABC analysis aimed at drawing the procurement managers' attention on the critical few (A-items) and not on the trivial many (C-items), as shown in the graph that resulted from the analysis of the data (Figure 7).

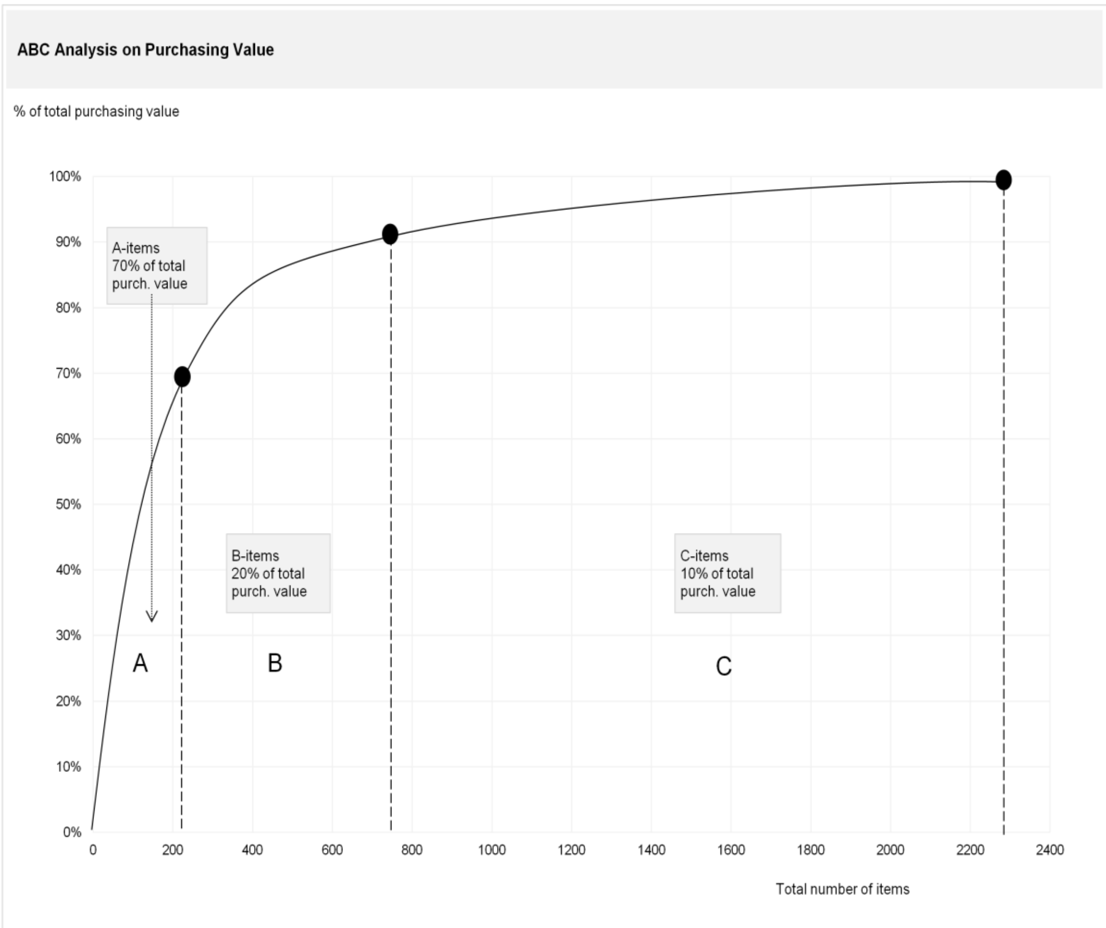


Figure 7: ABC-Analysis based on purchasing values

In order to incorporate the aspect of price sensitivity, a XYZ Analysis was performed in addition to the ABC analysis. Based on the historical purchasing data of the past three years, the XYZ classes were defined as follows:

- X: Relatively constant price, fluctuations are rather rare
- Y: Fluctuations in price, usually for trend related or seasonal reasons
- Z: Irregular price pattern

Utilizing the data contained within the hospital's Enterprise Resource Planning (ERP) system, the materials' price history of the past three years was analyzed. An item was categorized as a constant price item (X-item) if the percentage variance between the obtained price on a purchase order and the obtained price on the previous purchase order did not show a variance exceeding 5%. Using the 5% threshold for the variance resulted in a categorization of approx. 60% of the items as X-items, which was deemed as adequate for the purposes of the ABC-XYZ Analysis. The remaining 40% of items were categorized as either Y- or Z-items. Since both classes are of increased relevance for the optimization of e-procurement, there was no further effort put into distinguishing items within those two classes, as their treatment would not be differentiated. The combination of these two classification schemes resulted into the following classification matrix (A-X, B-X, C-X, A-Y/Z, B-Y/Z, C-Y/Z) as shown in figure 8.

Based on the ABC-XYZ Analysis, all active purchased items of the hospital were assigned to one of the resulting 6 classes. The proposed approach suggests that procurement managers should focus their e-procurement efforts primarily on items assigned to the categories A-Y/Z and B-Y/Z (grey shaded areas in figure 8) in order to optimize e-procurement performance, as these are the areas where the highest cost savings potential is expected. Thus, the implementation of the ABC-XYZ Analysis for the hospital's purchased items identified that the target group of items with the highest saving potential represented approx. 12% of the total purchased items. For a hospital with over 2,000 active purchased items, such as GHK, this would mean that the procurement process should be enriched with e-procurement tools for approx. 250 items in order to optimize the cost reduction potential. It should be noted that it is important to actualize the item classification within consistently defined periodic intervals in order to include possible changes promptly.

	A (≈10% of items)	***B (≈20% of items)***	***C (≈70% of items)***
X (≈60% of items**)**	High purchasing value Constant price pattern (≈6% of items)	Middle purchasing value Constant price pattern (≈12% of items)	Low purchasing value Constant price pattern (≈42% of items)
Y/Z (≈40% of items**)**	High purchasing value Fluctuating or irregular price pattern (≈4% of items)	Middle purchasing value Fluctuating or irregular price pattern (≈8% of items)	Low purchasing value Fluctuating or irregular price pattern (≈28% of items)

Figure 8: ABC-XYZ Analysis

In order to initially validate the proposed approach at GHK, the following two parameters were checked. First it was examined whether the results achieved as part of the ongoing e-procurement efforts up to the point of the current study would fall in line with the proposed methodology. More specifically, among the items that were procured using e-sourcing tools, the top 10 items and the bottom 10 items regarding the cost savings achieved were identified and positioned in the ABC-XYZ matrix, based on their classification in respect to their purchasing value and their price sensitivity. The results showed that each one of the top 10 items was classified as A-Y/Z or B-Y/Z item, whereas not a single item out of the bottom was 10 assigned to these two classes. This provided a first positive indication regarding the validity of the assumption, that the highest e-procurement related cost savings were associated with items of high purchasing value and non-constant price patterns. The second check consisted in the selection of the next e-sourcing activities to be performed in GHK by using the ABC-XYZ classification methodology and the calculation of the resulting cost savings. The average percentage of cost savings calculated as part of the applied methodology was measured to be 14.29%, suggesting a more than double-fold increase compared to the 6.19% measured for all e-sourcing activities that had been performed so far at the hospital without the use of any supporting methodology. This measurement, albeit inconclusive due to the small size of the events monitored, provides an additional positive indication in support of the proposed framework.

3.1.4 Case study conclusions

The research revealed that the implementation of e-Sourcing and e-Purchasing technologies is at an early evolutionary stage in the Greek Healthcare Sector, as can be seen by the findings of the case study on GHK, a public hospital considered to be in the forefront of e-business. E-Sourcing and e-Purchasing initiatives are focusing on e-RFx, e-Auctions and online catalog purchasing mostly for price sensitive goods. Benefits from using these technologies were identified and quantified.

For the case study hospital, in the two years following the implementation of the e-sourcing tools the procurement department extensively used e-auctions and e-RFx (electronic Request for Proposal/Quote/Information/Tender) as part of the procurement department's sourcing activities for the procurement of medical, surgical, IT-related and other supplies. As a result of this, GHK managed to:

- generate cost savings
- drastically reduce the average time between the invitation and the response from the suppliers
- significantly increase the average number of invitations by tender

This success was attributed among others to the high user acceptance and upper management support. However, it should be noted that the adoption of e-procurement technologies did not lead to any organizational or process changes. Thus, the strategic impact of e-technologies on SCM effectiveness and patient safety in a healthcare setting could not be verified. Regarding the key aspect of cost savings, it should be pointed out that the total cost reduction due to the new purchasing prices achieved compared to the previous purchasing prices obtained by using the traditional purchasing tools, was calculated to be 6.19%. However, examining the results on an item by item basis, the price reductions were ranging from insignificant levels (close to 0%) to very high levels (up to 46%). Thus, it became evident that the savings potential due to the adoption of e-procurement technologies varies widely depending on the categories of purchased items that are targeted, revealing an opportunity for the optimization of e-procurement implementation and performance. Consequently, the case study revealed that the approach to e-procurement activities in the health sector is largely intuitive and is lacking methodological foundation. This aspect negatively impacts the adoption of of e-sourcing and e-purchasing tools in hospitals, despite the fact that their implementation leads to cost savings and process improvements.

In order to overcome these issues, a framework was proposed that utilizes data segmentation SCMP such as the ABC and XYZ Analysis and provides hospital purchasing managers with a hands-on approach in order to identify and focus their e-procurement efforts on the relatively few items that have the most potential for cost savings. In order to allow for easy implementability, it utilizes readily available data contained within standard reports offered by a hospital's ERP System. The initial application of the proposed methodology achieved a doubled fold increase in cost savings, while demanding a relatively low implementation effort, as it allowed for a targeted concentration on the few items that were expected to produce the maximum results, leaving out the many items, where no significant improvements were expected.

Overall, the implementation of the proposed framework and the resulting quantifiable improvements presented in this study, strengthen the case that simple methods, tools and techniques, rather than complex algorithms, should be adopted within e-procurement practice in order to increase the impact on supply chain performance. Thus, the current study provides healthcare practitioners with a decision support model in order to complement their judgment, knowledge and experience with readily available tools and techniques for the purpose of improving their procurement decisions, and it aspires to increase the adoption of data segmentation techniques in hospitals.

The positive findings suggest that a diffusion of these technologies in the Greek healthcare sector should be expected in the coming years, driven mainly from a cost-cutting necessity viewpoint. A more comprehensive study across Greek hospitals should be performed in order to verify this assumption and in order to investigate potential differences regarding barriers and adoption rates between public and private healthcare facilities.

3.2 Case study on inventory replenishment optimization in a healthcare setting

The second case study examines current inventory control and demand management procedures implemented in hospitals, analyzes their weaknesses and proposes a practical framework for their improvement. A methodology is developed by utilizing suitable Material Requirements Planning (MRP) strategies, demand forecasting and lot sizing techniques based on a three-dimensional classification of inventory items, which relies on the relative importance of these items and their consumption fluctuation patterns. For validation purposes, the suggested approach is implemented in a large public hospital and the resulting impact on inventory management performance is quantified. The study builds on on-going operations management research and provides a practical, implementable solution, which allows healthcare practitioners to address real-business supply chain problems they are facing in their day to day operations. Although prior research has suggested various models aimed at optimizing inventory management performance, they have not been widely applied in practice, due to barriers discussed in the theoretical section of the thesis. In order to overcome these barriers, a practical, implementable framework for the improvement of a hospital's inventory management performance is suggested, which considers relevant Key Performance Indicators (KPIs) embedded in "best practices" approaches of Enterprise Resource Planning (ERP) Systems used by hospitals.

3.2.1 Case study methodology

The objectives of the case study were twofold; to investigate current research, practices and shortcomings in respect to managing inventories in healthcare facilities, and to develop, implement and evaluate a practical framework for the improvement of inventory management performance in hospitals. More specifically, the following research questions and objectives were formulated:

- *"Which KPIs for Inventory Management should be selected and monitored taking implemented best practices into account?"*

- *“Which Inventory Management strategies are applied in a typical healthcare setting in order to support the defined KPIs and what are their weak points?”*
- *“Based on the results of the research effort undertaken, a practical framework for the improvement of inventory management performance in hospitals needs to be defined, implemented and evaluated.”*

The empirical research was performed using a case study based approach, which is widely used in the SCM field, as it allows an in-depth analysis of the examined aspects, provided it is carried out in a structured and well documented way (Hilmola *et al.*, 2005). This field investigation technique was embraced as it better fits the outlined research objectives and is better prepared to solve real business problems (Voss *et al.*, 2002; Barratt *et al.*, 2011). In order to avoid possible shortcomings and pitfalls of this approach, emphasis was put on outlining how the various data were collected and analyzed, and on increasing the transparency and rigor of the research with the aid of standard reporting tools for data analysis, as suggested by Seuring (Seuring, 2008).

The study was conducted in five steps, following a review of existing literature in the related fields of inventory management and performance measurement with a focus on the healthcare sector which was presented in the theoretical background section. The literature review provided guidance and confirmed the value of the present research effort, assisting in carving out its exact direction and focus. The first step was the selection and definition of the appropriate KPIs, that would serve as the foundation for performance measurements in the areas of interest; the second step entailed the observation and analysis of the current processes of planning and procuring drugs and medical supplies in the pharmacy and warehouse of a selected hospital, resulting in the identification of possible gaps and deficiencies; the third step focused on the development of a methodology in order to improve inventory management performance on the basis of the previously selected KPIs; the suitability of tools and techniques utilized as part of this methodology, such as ABC-XYZ analysis, MRP and lot sizing strategies will be analyzed in the following sections; as part of the fourth step, a selective implementation of the proposed framework in a characteristic subset of inventory items was performed; finally, the fifth step entailed the monitoring and comparison of the selected KPIs before and after the implementation, in order to initially evaluate its effects on the supply chain performance. The sequence of steps is depicted in figure 9.

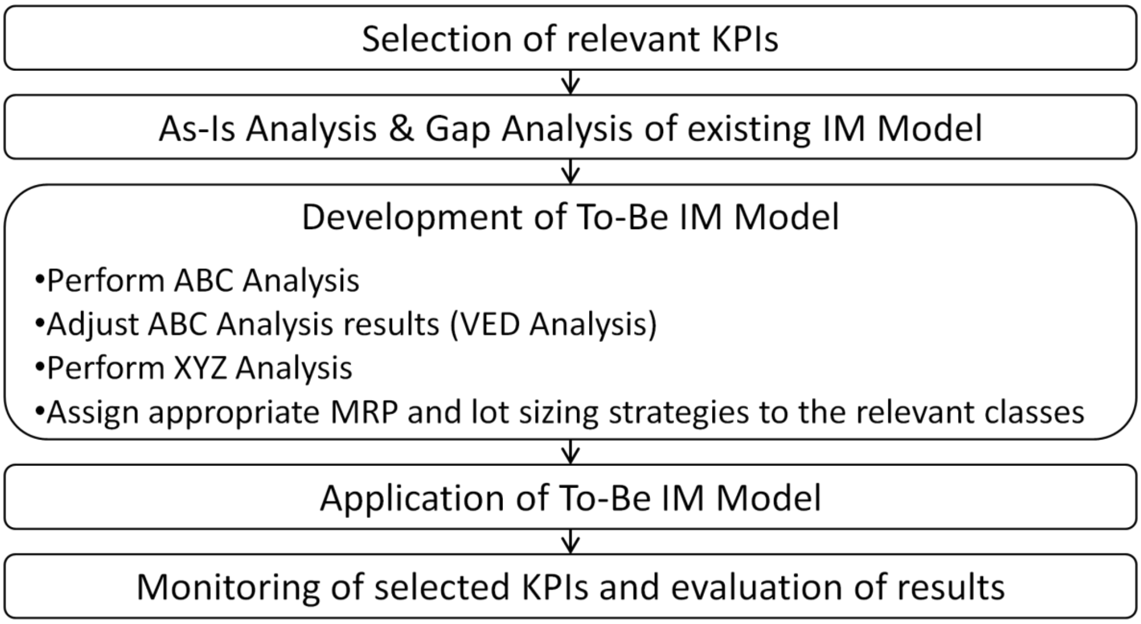


Figure 9: Case study methodology

In order to select a hospital for the purpose of conducting the case study, three major public hospitals in Greece were approached. Interviews were held with inventory managers, procurement managers and procurement specialists of the hospitals, observations as well as data analysis was performed. The interviews conducted were semi-structured, encompassing both open-ended and closed-ended questions, allowing for the interviewed persons to express opinions regarding the relevant business processes and to identify potential process improvement opportunities. Furthermore, observations of the day to day business process activities in the areas of inventory management and procurement took place, in order to help identify process gaps and weak points. In all three cases the assumption was verified, as there was a lack of a comprehensive methodology for optimizing their inventory management functions and the hospitals were facing similar inventory management related issues. Among the three hospitals, the one chosen in order to perform a comprehensive analysis and implement a new inventory management approach is a major public hospital that is considered to be in the forefront of Information Technology usage in the Greek healthcare sector. It was chosen for the particular study due to the fact that it is utilizing a state of the art ERP System which had been implemented over a decade ago, thus it possesses a multitude of historical data records regarding all stages of the supply chain, which can be accessed using readily available tools. Furthermore, the hospital's management showed a high level of interest and willingness to support the implementation of new procedures for the purpose of improving their supply chain performance by assigning the hospital's internal auditor and member of the hospital's Continuous Improvement Team to assist the research efforts.

3.2.1.1 Selection of relevant Key Performance Indicators (KPIs)

The first step of the case study focused on defining the appropriate KPIs that would be investigated and would serve as the basis for evaluating the effectivity of the proposed framework. The review of the current industry standards and best practices in supply chain performance measurement suggests that companies should focus on only a small list of KPIs which are critical for their operations management (Chae, 2009). Furthermore, in order for the KPIs to be widely accepted and measurable, it seemed plausible to identify and select KPIs which have been embedded in "best practices" approaches of most ERP system solutions, such as SAP, Oracle, i2 etc. (Cai et al., 2009). The concentration on a few critical KPIs and their availability as part of standard reports contained within ERP Systems was expected to contribute significantly towards the ease of implementation of the proposed framework. Furthermore, the use of widely accepted and available KPIs would facilitate the option of performing benchmarking analysis against other entities within the same business sector.

These findings and suggestions were reviewed with the subject matter experts in the areas of inventory management and procurement of the three hospitals involved, with the objective to determine inventory management performance by using a minimum number of KPIs that are practical, easy to measure, reliable and comparable to other hospitals' systems. Starting from a list of KPIs that the Supply Chain Council put together in order to monitor supply chain performance (SCOR model), the three hospitals' subject matter experts narrowed down this list to the KPIs that are important to their business, relate to inventory cost savings and can be measured as part of standard ERP system applications. As data collection and analysis are a major task in monitoring the performance using KPIs, the need for computerized information systems such as ERP systems to efficiently collect the right data is a necessity (Gunasekaran, 2007). As a result of this task, the research objective of this study was translated into: “Based on the results of the research effort undertaken, a practical framework for achieving inventory cost savings by means of improving stock levels without compromising service levels in hospitals needs to be defined, implemented and evaluated”. Accordingly, the underlying research question “Which KPIs for Inventory Management should be selected and monitored taking implemented best practices into account?” led to the selection of the following four KPIs, that related to inventory cost savings and that could be calculated from the data contained in the hospital’s ERP System (Hoppe, 2008):

- **Average stock value**, which provides information on the value of the stocks held in inventory and the resulting cost of carrying and holding this inventory. The average stock value is the mean value of an inventory throughout a certain time period. The basic way of its calculation is by adding the stock value at the beginning of an accounting period (e.g. fiscal month or fiscal year) and the stock value at the end of the accounting period and dividing by two. A reduction of the average stock value will decrease the stockholding costs and will result in a considerable improvement of the hospital’s performance (Hoppe, 2008). The importance of using the average stock value in order to determine the inventory costs is emphasized by many authors as part of their work related to lowering inventory levels and associated costs (Multanen, 2011).

- **Stock Range of Coverage (RoC)**, which provides information on the stock level in relation to demand and on how long a stock amount will last given a specific average daily requirement. The range of coverage is calculated as the ratio of current stock to average daily demand or usage and it allows the identification of materials with inadequate stock levels. As it is a relative value, the range of coverage can be an even more significant key figure than the avg. stock value, particularly in connection with the evaluation of potential for improvement (Erlach, 2013).

- **Dead stock value index**. The dead stock (excess stock) is the part of the warehouse stock that has not been used for a certain period of time, and its value is calculated by multiplying the dead stocks of the materials with their current valuation prices. A dead stock analysis allows the identification of materials with surplus stocks and the verification of inventory control parameters such as safety stock. In the healthcare sector specifically, excessive stocking of inventory items, such as drugs, for the purpose of satisfying the requirement for high service levels, has been recorded in many studies (Kritchanchai and Meesamut, 2015). Given however the perishable nature of drugs and medical supplies, high amounts of dead stock can lead to stock expirations in absence of drug demand, resulting into increased inventory waste and adversely impacting the cost of inventory (Weraikat et al., 2016).

- **Service level,** which can be calculated as the ratio between the number of times an item is provided on demand and the total number of times an item is demanded (Lysons and Gillingham, 2003). The service level indicates the number of stock-out incidents, where a requested stock item was not available and had to be ordered at that point resulting into delayed servicing of patients' needs. From a public health viewpoint, the higher the service level, the better, as long as inventory costs do not rise to insupportable levels.

As many hospitals have decided to adopt ERP systems to improve their business (Garg and Agarwal, 2014), inventory managers, pharmacists and procurement specialists of these hospitals can access the relevant data and calculate these KPIs utilizing standard, readily available reports. The inclusion of these "best practices" based KPIs facilitates the generalization of the suggested methodology as it enables its applicability to other hospitals.

3.2.1.2 As-Is analysis

Following the selection of relevant KPIs, an As-Is Analysis was performed in order to evaluate the current state of the business processes executed in the areas of MRP, inventory management and procurement of the hospital. The interviews taken with subject matter experts of the relevant departments and the observations made during the As-Is Analysis led to a number of findings:

- **The quality of the master data related to medical supplies was low**, as in many instances multiple material master records existed for the same item depending on the number of its sources of supply. Furthermore, no classification scheme was used for the purpose of categorizing materials in terms of their importance.

- **A generic simplistic MRP strategy for all drugs and medical supplies was used**. For each item, a reorder point was manually defined and a purchase requisition in the amount of a fixed predefined quantity was generated when the stock level of the respective item fell below the reorder point. No procedure for monitoring the appropriateness of the defined reorder points was in place.

- **No lot sizing methodologies were set up** in order to automatically propose the quantities that should be ordered for a needed material. The pharmacists and storeroom managers decided on the quantities to be ordered each single time based on their experience and judgment.

- **Demand forecasting was performed in a manual, non-automated way,** although the ERP System in place contained a large amount of historical data and supported various forecasting options.

- **The Inventory Controllers allocated a large time proportion into evaluating and adjusting the MRP proposals**, often relying on their personal judgment, intuition and experience, since they were not provided with the necessary tools to automate and streamline these processes.

- **No specific supply chain performance metrics were defined and monitored,** although the ERP system in place included a variety of standard reports with key figures that could support this objective.

The As-Is Analysis performed and the resulting Gap-Analysis identified weak spots of the current process of managing inventories, that could be improved by applying best practices and using available tools and techniques. The findings provided the answer to the research question *"Which Inventory Management strategies are applied in a typical healthcare setting in order to support the defined KPIs and what are their weak points?"* Generic, simplistic planning strategies based on reorder point logic were applied to all inventory items regardless of their characteristics, without utilizing lot sizing and demand forecasting techniques and without performance monitoring, thus confirming researchers assessment on lack of adoption of models suggested in literature (Stanger *et al.*, 2012). Weak points such as lack of data integrity, lack of streamlined processes, lack of visibility and transparency, error prone and time consuming procedures due to manual interventions, time spent on non productive rather than value added activities were identified as a result. Consequently, the findings of the As-Is analysis demonstrated a high improvement potential regarding the inventory management policies in place, which should result in significant cost savings for the healthcare institution. This validated the significance of the research objective, which targeted the definition, implementation and evaluation of a practical framework for the improvement of inventory management performance in hospitals, and which led to the development of the To-Be IM model.

3.2.1.3 To-Be model

Based on the results of the As-Is analysis, the following approach was followed in order to improve the IM performance for the hospital's pharmacy. Firstly, the improvement of data quality was targeted by enforcing the use of one material master per medical supply item, regardless of its number of supplying vendors, as this is fundamental for the correct management and planning of an item. Then, a classification methodology was introduced (ABC-XYZ analysis), in order to classify items based on relevant characteristics, which would allow their differentiated treatment from an inventory management perspective. The characteristics that influence how a material should be treated in the context of a hospital’s pharmacy, are its consumption value, its demand pattern and its clinical importance, as outlined in the next sections that describe the sequence of steps that are to be followed as part of the proposed methodology.

Perform ABC analysis

In order to initially apply and validate the suggested methodology, a characteristic subset of materials had to be selected, as the total number of materials managed by the hospital pharmacy was very large (> 6.000). For this purpose, a pre-existing classification of the materials into various material groups (such as “General drugs”, “Refrigerated drugs”, “Medical imaging supplies”, “Bandage Supplies”, “Chemical reagents” etc.) which was defined in the hospital’s ERP System, was used in order to choose a representative group. After calculating the stock values by material group at the end of the fiscal year (quantity on hand multiplied by the valuation price for each material belonging to the respective group), the material group with the highest stock value (Refrigerated Drugs) was chosen in order to apply the proposed methodology. The number of materials assigned to this material group was 588, which represented a sufficient sample for the evaluation purposes of the case study.

Following that, an ABC analysis based on past year’s consumption values, as described in the proposed framework, was performed on the materials belonging to the “Refrigerated Drugs” group, by applying the widely used 70-20-10 rule (A-items representing approx. 70% of the usage value, B-items representing approx. 20% of the usage value and C-items representing approx. 10% of the usage value) (Flores *et al.*, 1992). Based on this technique, inventory items were divided into the three classes according to their consumption value (value per unit multiplied by the consumption quantity): A (very important items), B (moderately important items), and C (marginally important items). The ABC analysis aims to draw inventory managers’ attention on the critical few (A-items) and not on the trivial many (C-items), and is a widely employed technique, especially in the SCM functions (Gunasekaran *et* *al.*, 2004). The analysis resulted in classifying 19 materials as A-items (usage values ranging from 110.272 € to 1.368.466 €), 37 materials as B-items (usage values ranging from 26.941 € to 107.983 €) and 532 materials as C-items (usage values ranging from 0 to 26.613 €) (Table 7, Figure 10).

Class	***Materials***		***Consumption Values***	
A	19	3,23 %	7.077.261,63 €	70,47 %
B	37	6,29 %	1.984.295,84 €	19,76 %
C	532	90,48 %	981.785,21 €	9,78 %
Total	588	100 %	10.043.342,68 €	100 %

Table 7 ABC Analysis for material group “Refrigerated drugs”

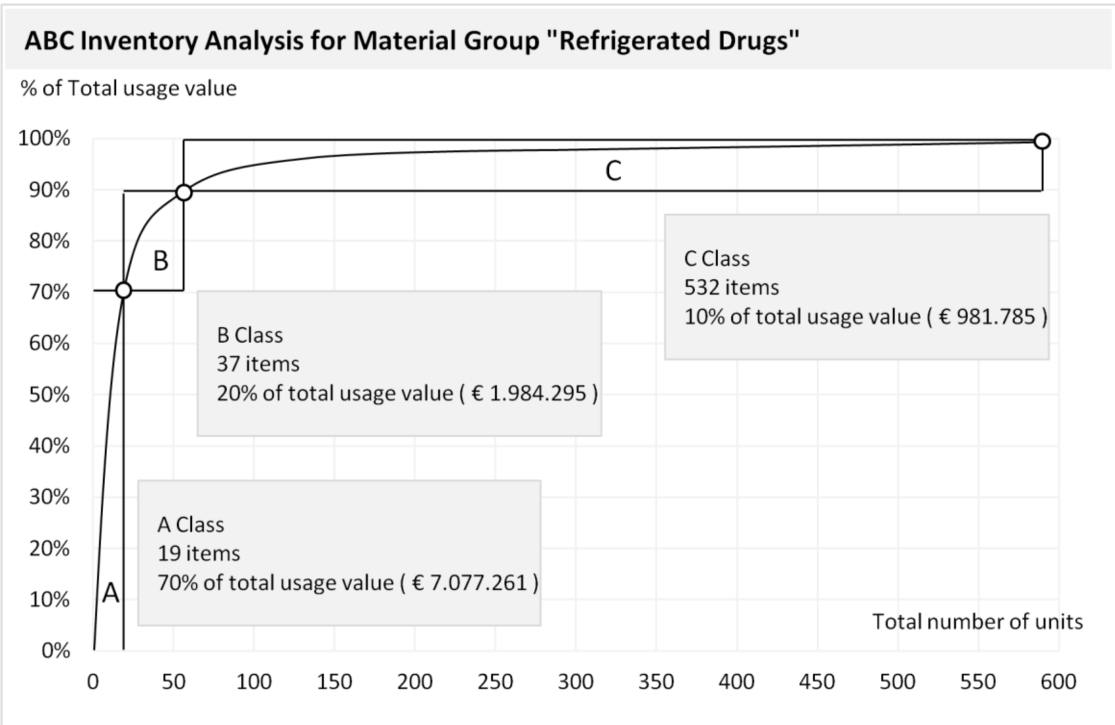


Figure 10: ABC Analysis graph

Adjust ABC analysis results (VED analysis)

As the classic ABC analysis does not incorporate the clinical importance of an item, it imposes the risk of assigning a low priority to an item because of its low consumption values, although this item might be of critical importance for human lives (e.g. a rarely needed, low cost anti-venum). In order to eliminate this risk, the vital drugs need to be placed in the A class regardless of their usage value. The identification of vital drugs was done by the hospitals' pharmacist with the use of a VED (Vital, Essential, Desirable) drug classification schema. The ABC classification was reviewed and vital items with critical clinical importance that were assigned to the B or C class were idientified. These items (3 B class items and 15 C class items) were upgraded to the A class. These adjustments did not significantly change the usage value percentages of the classes (70%, 20%, 10%), since they related to materials with low to mid value usages. The adjustment of the ABC analysis by incorporating the clinical importance of the items resulted into 37 items (6,29%) being classified as A-items, 34 items (5,78%) being classified as B-items and 517 items (87,93%) being classified as C-items. The identified vital drugs were characterized as such in their material master record in the ERP system and a fixed assignment to the A class was created. As a consequence, future ABC analysis performed via the hospital's ERP system will categorize them as A-items regardless of their usage value. In other words, the categorization of a health care item was upgraded from C or B to A, despite its low consumption value, if it was considered a vital material serving a crucial need of patient care.

Hence, the step of adjusting the ABC Analysis results introduces a business sector specific component into the proposed framework, as industries have different strategic objectives in regards to inventory and demand management (Crandall and Markland, 1996). Hereby it enables the inclusion of aspects related to the specifics of a sector, such as drug clinical importance in the case of a healthcare facility, in order to align the inventory management policies with strategic objectives of the business. Furthermore, this step enables the incorporation of the practitioner's experience, knowledge and judgement into the proposed framework, as it is an important factor to include considering the complexity of supply chain aspects (Chu, 2008; Williams and Tokar, 2008).

Perform XYZ analysis

A third factor can influence the selection of the appropriate inventory management strategy, namely the consumption pattern of the items (Hoppe, 2008). In order to incorporate this parameter into the methodology, an XYZ analysis can be performed in addition to the classic ABC analysis, aimed at distinguishing between items according to their fluctuations in consumption as follows:

- **X:** Relatively constant consumption, fluctuations are rather rare
- **Y:** Fluctuations in consumption, usually for trend related or seasonal reasons
- **Z:** Irregular consumption pattern

The XYZ analysis is based on the variation coefficient, which is the ratio of the standard deviation of item consumption over a certain period and the average consumption, and it permits the inclusion of seasonal developments. The threshold values of the coefficient of variation were classified as following as suggested by field experts (Scholz-Reiter *et al.*, 2012):

- X-items: coefficient of variation < 0.5
- Y-items: coefficient of variation between 0.5 and 1
- Z-items: coefficient of variation >1

Consequently, the ABC analysis was expanded by an XYZ analysis in order to distinguish between items according to their fluctuations in consumption. The classification of materials into the categories X, Y and Z was supported by the automated analysis of the daily consumption values patterns by the hospital's ERP System. The time horizon for the calculation was defined as a five-year period allowing the system to access a sufficient amount of historical data in order to select the forecasting procedure that produced the best forecast accuracy for each material. The results showed that approx. 60% of materials could be characterized as items with relatively constant consumption, approx. 10 % of materials as items with fluctuating consumption (trend, seasonality, seasonality and trend) and approx. 30 % as items that could not be assigned to a forecasting pattern (items with irregular consumption).

These percentages were in line with subject matter experts' anticipations expressed in previously conducted interviews. The resulting ABC-XYZ matrix is displayed in table 8.

	A ***37 items (6,3%)***	***B*** ***34 items (5,8%)***	***C*** ***517 items (87,9%)***
X ***345 items (58,7%)***	High usage value Constant consumption 22 items (3,8%)	Middle usage value Constant consumption 20 items (3,4%)	Low usage value Constant consumption 303 items (51,5%)
Y ***54 items (9,2%)***	High usage value Fluctuating consumption 3 items (0,5%)	Middle usage value Fluctuating consumption 4 items (0,7%)	Low usage value Fluctuating consumption 47 items (8 %)
Z ***189 items (32,1%)***	High usage value Irregular consumption 12 items (2 %)	Middle usage value Irregular consumption 10 items (1,7%)	Low usage value Irregular consumption 167 items (28,4%)

Table 8: ABC-XYZ Analysis for material group “Refrigerated drugs”

The proposed framework used the ABC analysis (based on items' consumption values and adjusted by items' clinical importance) as the primary analysis and was enhanced by the XYZ analysis (based on items' consumption patterns), resulting into the ABC-XYZ classification matrix. The main advantages of this approach are the integration of items with similar characteristics in order to process them with the same material planning parameters, and the identification of materials with high optimization potential.

Following the ABC-XYZ classification, a suitable MRP strategy and Lot Sizing procedure has to be defined for the resulting relevant item classes. The materials belonging to the non highlighted classes of the ABC-XYZ matrix (classes BY, BZ, CY, CZ) do not need to be considered, since the effort required to optimize them would be high, due to their non-constant consumption, and would not lead to significant savings, as the materials belonging to these classes are characterized by mid to low usage values.

Assign appropriate MRP strategies and lot sizing procedures to the relevant item classes

For each one of the highlighted item classes of the ABC-XYZ matrix (classes AX, AY, AZ, BX, CX as shown in table 5), an appropriate MRP strategy was defined.

- Items with relatively constant consumption (AX, BX, CX) were assigned a simple, easy to implement MRP strategy based on a reorder point logic.

- Items with fluctuating consumption and high usage value (AY) were assigned a more sophisticated MRP strategy based on demand forecasting.

- High usage value items with irregular consumption (AZ) were assigned a simple MRP strategy based on reorder point planning combined with high levels of safety stock, in order to ensure adequate service levels.

The suitable MRP strategies per item class are shown in figure 11. The hospital's ERP system automatically calculated reorder points for materials, taking their average consumption and their delivery times into account. However, due to the high importance of items with high consumption value (AX and AZ) the hospital's pharmacist reviewed the automatically generated reorder points and manually adjusted them in a few cases.

The selection of suitable lot sizing procedures was based on the ABC-XYZ analysis matrix as well.

- Optimizing lot-sizing procedures, such as Economic Order Quantity (EOQ), were chosen for AX and AY items. These procedures require a higher analysis effort, however even small improvements are expected to have significant impact due to the high usage values associated with items belonging to these classes.

- For less important items (BX and CX items) straight forward, simple to use static lot-sizing procedures, such as fixed lot sizes were used.

- For AZ items, the lot size procedure (whether based on EOQ logic or on fixed sizes) incorporated a high safety stock, as the irregularity of demand could potentially threaten the needed service levels.

Consequently, based on the ABC-XYZ analysis, appropriate MRP strategies and lot sizing procedures were defined for the highlighted areas of the ABC-XYZ matrix (AX, AY, AZ, BX, CX as shown in table 5) and were assigned to the materials belonging to these groups, based on the proposed methodology. Items with relatively constant consumption (AX, BX and CX, totalling 345 items or 58,7% of items) were assigned a simple MRP strategy based on a reorder point logic combined with a fixed lot size (BX and CX, totalling 323 items or 54,9% of items) or an EOQ lot sizing procedure (AX, 22 items or 3,8% of items). The reorder point should be calculated manually for the high usage items, such as AX items, in order to incorporate the planners' experience and judgment for these very important items, whereas it could be calculated automatically by the ERP system for the mid to low usage items (BX, CX). On the other hand, items with high usage values and fluctuating consumption patterns (AY, 3 items or 0,5% of items) were examined on a material by material basis and were each assigned a more sophisticated MRP strategy based on demand forecasting (forecast based planning strategy) combined with an EOQ lot sizing procedure. Finally, items with high usage values and irregular demand patterns (AZ, 12 items or 2% of items) were assigned a simple MRP strategy based on a manual reorder point logic and a lot sizing procedure supporting a high safety stock level, in order to be prepared for uncertainties in the demand. The materials belonging to the non highlighted areas of the ABC-XYZ matrix (BY, BY, CY and CZ, totalling 228 items or 38,8% of items, as shown in table 8) were not optimized due to their mid to low usage values as explained in the proposed methodology.

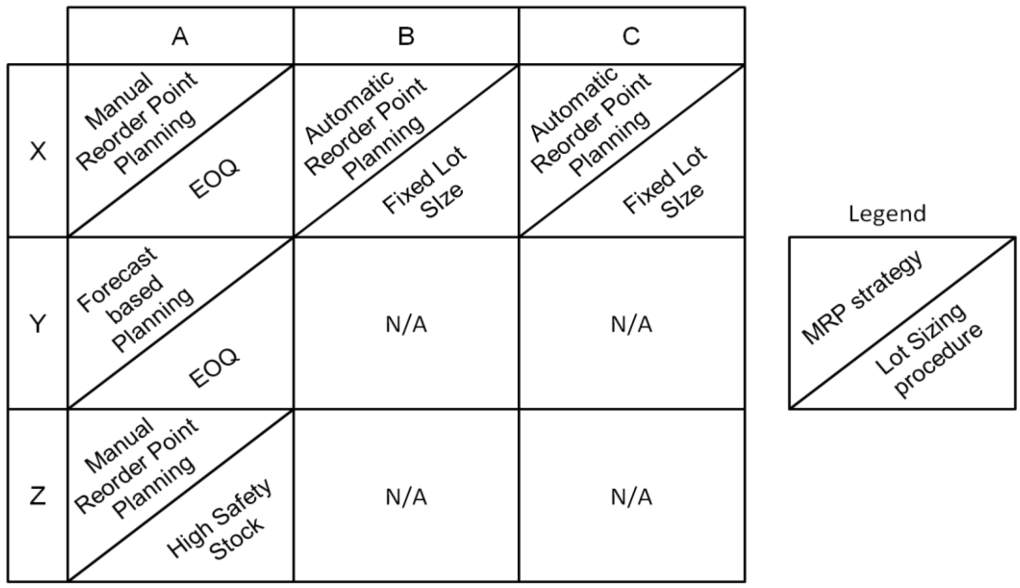


Figure 11: Assignment of appropriate MRP strategies and lot sizing procedures to selected classes

With the assignment of the suitable MRP and Lot Sizing techniques to the item classes (as shown in figure 11), the steps involved in the proposed practical framework were completed, leading to the next step of the research effort, which was the implementation of the To-Be Inventory Management Model for the purpose of evaluating its effectiveness.After these strategies were implemented, the defined KPIs were measured and their values were compared to the respective values before implementation, in order to measure the impact on inventory management performance. As the new strategies were implemented at the beginning of the year and monitored throughout it, they allowed for year to year comparisons with previous year's data on record.

3.2.2 Case study findings

The results showed significant improvements regarding the measured KPIs, indicating the value of the proposed approach in improving the inventory management performance of a hospital pharmacy. In particular, the previously selected relevant KPIs were measured and compared to the previous year's values, producing the following results. In order to better assess the impact of applying the proposed framework on the KPIs of the selected material group, the KPIs were also measured for the other material groups of drugs not included in the methodology, thus providing a basis for comparison.

- **Avg. Stock Value.**

The average inventory was calculated over the course of the previous and the current fiscal year. Since two points do not always accurately represent changes in inventory over different time periods, the inventory values at the end of each month were counted and added together and the result was divided by 12 in order to determine the average stock value for each year. The average stock value year to year comparison showed a reduction of approx. 12 % for the drugs included in the study (Table 9).

Material Group "Refrigerated drugs"				
Month	**Previous Year**	**Current Year**	**Difference**	**%**
01	806.935 €	607.357 €	-199.578 €	-24,73
02	542.301 €	776.885 €	234.584 €	43,26
03	542.077 €	613.368 €	71.292 €	13,15
04	804.118 €	541.788 €	-262.330 €	-32,62
05	812.923 €	726.902 €	-86.021 €	-10,58
06	516.298 €	516.561 €	262 €	0,05
07	669.281 €	717.244 €	47.963 €	7,17
08	759.571 €	590.221 €	-169.350 €	-22,30
09	803.592 €	530.081 €	-273.512 €	-34,04
10	806.670 €	546.796 €	-259.874 €	-32,22
11	598.233 €	690.617 €	92.384 €	15,44
12	812.083 €	576.021 €	-236.063 €	-29,07
Avg.	**706.173 €**	**619.487 €**	**-86.687 €**	**-12,28**

Table 9: Avg. stock value comparison on a year to year basis

- **Stock Range of Coverage (RoC)**

The Stock RoC was calculated as the ratio of current stock to average daily usage of the materials. The RoC fell from 127 days in the previous year to 103 days in the current year, which translates into a reduction of approx. 19 % for the drugs included in the study (Table 10).

	Previous Year	Current Year	Difference	%
Avg. RoC for material group "Refrigerated drugs" (Number of materials = 588)	127,53 days	103,27 days	-70,94	-19,02

Table 10: Average Range of Coverage (RoC) comparison on a year to year basis

- **Dead Stock Value**

The dead stock was calculated as the part of the warehouse stock that had not been used for a year and the dead stock value was calculated by multiplying the dead stocks with the valuation prices of the materials. The year to year comparison showed that the dead stock value dropped by approx. 17% for the drugs included in the study (Table 11).

	Previous Year	Current Year	Difference	%
Dead stock value for material group "Refrigerated drugs" (Number of materials = 588)	48.922 €	40.708 €	- 8.214 €	-16,79

Table 11: Dead stock value comparison on a year to year basis

- **Service Level**

The year to year comparison showed that the service level slightly increased from 93,3 % to 93,9 % for the drugs included in the study (Table 12).

	Previous Year	Current Year
Service level for material group "Refrigerated drugs" (Number of materials = 588)	93,3 %	93,9 %

Table 12: Service level comparison on a year to year basis

The results showed significant improvements for the material group of Refrigerated Drugs in the three KPIs identified without negatively impacting service levels, indicating that the proposed methodology considerably improves the inventory management performance of a hospital's pharmacy. The stockholding costs were reduced due to the lower average stock value, the inventories were better synchronized to the demand as the stock range of coverage decreased and excess inventories were reduced as the dead stock decreased. Furthermore, based on the inventory and procurement manager's feedback, the application of a straight forward methodology combined with readily available tools also proved advantageous regarding other aspects, as it led to a reduction of the daily processing times in the areas of planning, procurement and inventory management by streamlining the relevant processes, as it allowed to focus on specific measurable targets, and as it improved transparency. Thus, the proposed framework reduced the time wasted on non value added activities and allowed the practitioners to devote more time on solving real business problems.

The results also showed, that albeit lowering inventories, the service levels were not negatively impacted, in fact they slightly increased. It should also be noted, that patient satisfaction surveys conducted in the hospital showed a year to year improvement by 7% regarding patient satisfaction among hospitalized patients, which would be the ones negatively impacted if the service levels should deteriorate. Thus, these findings lead to the conclusion that the effectivity of the framework proposed in the current case study is fully supported by the empirical results.

3.2.3 Case study conclusions

The in-depth As-Is Analysis performed on inventory management, planning and procurement processes in a healthcare setting revealed significant weaknesses and highlighted the potential for substantial cost savings. The literature review concluded that various approaches regarding the optimization of these processes have been suggested. As supply chain processes are inherently complex, the models and methods used to optimize these processes are expectedly also complex, representing a significant barrier that hinders their wide adoption. In order to address these aspects, the current case study proposed a practical, easy to implement framework that assigns appropriate MRP strategies, demand forecasting and lot sizing techniques based on a three-dimensional classification of inventory items, which relies on the relative importance of these items (usage values and clinical importance) and their consumption fluctuation pattern. For the purpose of measuring performance as part of this framework, KPIs were selected that are embedded in “best practices” approaches of ERP systems. Addressing the case study’s research question *“Which KPIs for Inventory Management should be selected and monitored taking implemented best practices into account?”,* the Average Inventory Value, the Range of Coverage, the Dead Stock Value and the Service Level were selected as suitable KPIs.

The methodology was implemented in a relevant subset of the materials managed by the hospital’s pharmacy, and the identified KPIs were monitored and evaluated for an adequate time period in order to be able to calculate and quantify the improvements achieved. The initial results regarding inventory management performance are promising, as they show significant improvements in all KPIs, resulting into measurable cost savings as well as process improvements. The stockholding costs were reduced due to the lower average stock value, the inventories were better synchronized to the demand as the stock range of coverage decreased and excess inventories were reduced as the dead stock decreased, without negatively impacting the service levels. It is important to stress the fact that these improvements were achieved by using available tools and techniques included in ERP systems utilized by hospitals and by minimizing the effort involved based on the classification methodology suggested. EOQ strategies as an example, which represent a certain complexity, were applied to just 4,3% of the total items (AX and AY classes) and manual review of the automatically calculated reorder points was performed on just 5,8% of the total items (AX and AZ classes).

Theoretical implications

The study contributes to overall supply chain management research by extending the literature on improving inventory management efficiency. As previously noted, prior research has suggested various models that aim at optimizing the management of inventories. Their complexity however, the high effort required for their implementation, the missing availability of necessary data to support them and the missing consideration of business sector specific factors, represent barriers to their adoption. Thus, the current study highlights the disconnect between academia and best industry practices in this field, as sophisticated inventory models and algorithms suggested by most academics, although theoretically sound, are not found to be applied in practice (Stanger *et al.,* 2012).

Especially for the healthcare sector, limited research efforts have been devoted to developing a framework that provides an implementable methodology for improving hospital inventory management efficiency. Yet it is critical to examine the relevant factors and related KPIs, as the need of managing healthcare costs is crucial to maintaining an adequate yet affordable level of patient care in today's challenging business environment. Addressing the research question *"Which Inventory Management strategies are applied in a typical healthcare setting in order to support the defined KPIs and what are their weak points?",* it was found that no widely accepted framework was available to support healthcare practitioners in their decision making process regarding efficient inventory control, resulting in many identified shortcomings. The thesis extends prior research by developing and empirically testing a framework that encompasses the major relevant parameters identified in literature, such as the application of suitable MRP procedures, lot sizing methods, demand forecasting techniques, service level considerations as well as human judgment and experience. What distinguishes this framework from other suggested approaches in literature is its focus on ease of implementability due to low complexity and low effort required, and its reliance on data and tools available in common ERP systems.

Furthermore, in terms of theoretical contribution, the thesis introduces a methodology that classifies materials administered in hospitals in a three dimensional way. First, it takes into account the monetary value of the consumption of the materials in order to identify where the real optimization potential lies. Secondly, it incorporates the aspect of clinical importance of a material, as this is crucial to servicing patients' needs. Thirdly, it considers past consumption patterns as they influence the planning specifics of a material. This combination of criteria for classification purposes serves as the backbone of the proposed framework for IM performance improvement.

Practical implications

The current study included the research objective: *"Based on the results of the research effort undertaken, a practical framework for the improvement of inventory management performance in hospitals needs to be defined, implemented and evaluated."* This objective was met, as the study builds on on-going operations management research and provides a practical, implementable solution, which allows healthcare practitioners to address real-business supply chain problems they are facing in their day to day operations. The parameters influencing the management of inventories in a hospital are combined within a framework that uses readily available data contained within standard reports offered by a hospital's ERP System. Furthermore, the proposed solution achieves a high impact on inventory cost savings, while it demands a relatively low implementation effort, as it allows for a targeted application on the few items that are expected to produce the maximum results, leaving out the many items, where no significant improvements are expected.

The proposed framework includes a healthcare specific component, as it takes the clinical importance of materials into account, distinguishing between VEN (Vital, Essential, Non-Essential) or VED (Vital, Essential, Desirable) supplies. This represents a necessity, since the relative importance of an item in a healthcare setting is not solely based on monetary considerations. The inclusion of this sector specific component, which can be tailored to the specifics of a particular sector of interest, allows for a further generalization and expansion of the suggested methodology into other business sectors.

Overall, the implementation of the proposed framework and the resulting quantifiable improvements of the KPIs presented in this study, strengthen the case that simple methods, tools and techniques, rather than complex algorithms, should be adopted within inventory management practice in order to increase the impact on supply chain performance. Thus, the current study provides healthcare practitioners with a decision support model in order to complement their judgment, knowledge and experience with readily available tools and techniques for the purpose of improving their inventory control decisions.

Limitations and future research

In order to verify the assumption, that suggested inventory optimization models found in SCM literature are not widely adopted in practice, a closer look at the healthcare sector was taken and the related business processes in a large public hospital were researched. The empirical research approach was chosen to be predominantly of qualitative nature, as it allows for more flexibility and room for innovation (Silverman, 2013), Although the findings support this assumption, a broader research effort would need to be undertaken involving a large sample of hospitals in order to be able to generalize these findings. The approach taken in the thesis to focus on KPIs embedded in ERP systems might have left out other important KPIs that should be considered as part of optimizing IM efficiency. Although the goal of improving IM performance is met, a comprehensive study including all suitable KPIs might lead to even better results.

In order to address these aspects, further research efforts could entail the deployment of the methodology to multiple hospitals including the whole spectrum of materials inventoried, in order to obtain a more complete validation. Finally, researchers could modify the sector specific component of the model in order to apply and validate it in other business sectors as well.

4 Quantitative research

The results of the case studies performed as part of the qualitative research indicated that substantial operational performance improvements can be achieved through the application of SCMP in hospitals. This suggests that this line of research can significantly contribute towards reaching a major goal of healthcare executives, namely to deliver effective care at a lower cost.

In order to generalize these findings, the qualitative approach followed in the first phase was complemented with a quantitative approach entailing the conceptualization of a framework in order to investigate overall SCMP adoption in hospital supply chains and their impact. For this purpose the present thesis (1) drew on supply chain management and technology adoption literature, (2) identified applicable SCM practices within the healthcare context, (3) investigated the facilitating role of Enterprise Resource Planning (ERP) systems, (4) delineated the key factors influencing SCMP adoption in healthcare facilities, (5) examined their impact on hospital cost performance, and (6) targeted all hospitals within the Greek healthcare sector.

The findings that resulted from the qualitative phase of the thesis suggested (1) that the inclusion of an organizational performance element within the research framework would increase its explanatory power, (2) that SCMP should be viewed in a holistic way as synergies among them were demonstrated, and (3) that it is important to incorporate the unique contextual features of SCM in healthcare delivery into the research model. Therefore, the foundation was laid to build a theoretically sound and practically relevant research model to support the goals of the thesis.

4.1 Introduction

As previously outlined, healthcare supply chains are complex systems facing challenges in delivering high quality care while maintaining their cost effectiveness – two goals that are perceived as contradictory by many healthcare professionals. Research on inventory management and control, the heart of the healthcare supply system, has demonstrated that these targets can be reached by managing inventories efficiently while aiming at desired service levels. Although this can be enabled by adopting best practices in supply chain management functions, the healthcare sector appears to be lagging behind compared to other industries (Baltacioglu et al., 2007). Some scholars attribute this fact to the relative complexity exhibited in healthcare supply chains due to: (1) the existence of strong national and international regulatory frameworks; (2) the difficulty of predicting demand for medical supplies due to the high degree of patient heterogeneity, resulting into excess stock to safeguard against emergencies and unforeseeable demand; (3) the long developmental cycles of pharmaceutical products impacting capacity planning and supply chain strategies; and (4) limited knowledge of operations management (OM) techniques and practices by pharmacists and physicians who are key decision-makers regarding the procurement and inventory management of drugs (Schneller and Smeltzer, 2006; Shah, 2004). Others raise the concern that implementing best supply chain practices will negatively impact the physicians autonomy and limit their ability to make the best decision for their patients (Graban and Rona, 2011). These concerns are amplified by empirical evidence that provides mixed results on the relationship between process improvements and various measures of performance, such as financial performance and customer service performance (Dobrzykowski et al., 2016). The uncertainties over the effectiveness of SCMP and the lack of success in their adoption indicate the existence of implementation barriers, leading to a strong need to study the challenges of SCMP adoption in supply chain processes and functions within the healthcare sector. According to Dobrzykowksi et al. (2016) the downstream part of the healthcare delivery supply chain, which deals with the delivery of care (hospitals, clinical services), may offer more opportunities for cost improvements compared to its upstream part, which deals with the development of care (medical devices, equipment, pharma, biotech).

Accordingly, this thesis focuses on the downstream part of the healthcare delivery supply chain, specifically the adoption of SCMP in hospital supply chains.

Within this context, the thesis is seeking to make two main contributions. The first one is the development of a suitable integrated conceptual framework that will (1) lead to an understanding of the determinants and the underlying relationships of SCMP adoption in hospital supply chains, and (2) investigate the impact of SCMP adoption on hospital cost performance. A heightened awareness of the factors influencing the adoption of SCM related practices in hospital supply chains and their associated benefits is expected to facilitate their effective adoption and assist in overcoming some of the challenges outlined above. The second contribution is the empirical testing and validation of the framework's explanatory power in the Greek public healthcare sector, which is witnessing limited academic research as demonstrated by related literature. The following sections outline the adopted research model and its associated hypotheses, the research methodology followed and the data analysis results.

4.2 Research model

The research model was developed using the TOE framework combined with the perceived benefits construct as discussed in detail in chapter 2.4. Although the TOE framework forms a suitable basis for investigating the adoption of SCMP, it seems doubtful that a single theoretical explanation is able to describe the adoption and diffusion of various technologies in different business settings. Therefore, it was expanded in order to increase its explanatory and predictive power. A holistic research framework was developed by enriching the TOE framework with elements of other technology adoption theories, while attempting to address the following weaknesses identified by other scholars as part of previous technology adoption studies.

First point of concern is that the TOE framework has evolved very little since its original development, as the majority of the related theoretical development has been limited to enumerating the different factors that are relevant in various adoption contexts. No new constructs have been added to expand the framework and little theoretical synthesis has occurred (Baker, 2012).

Secondly, the TOE framework does not accentuate an important factor identified as part of the literature research, namely the impact of perceived benefits on technology adoption, as adopters evaluate an innovation based on its relative advantage (the degree to which a new technology is perceived as better than the one it supersedes). This factor, which is stemming from Roger's theory of innovation, has been included in eminent technology adoption studies, such as the work by Iacovou et al. (1995) on EDI adoption, where the suggested model included three dimensions: perceived benefits, organizational readiness and external pressure. Hence, in order to investigate determining aspects of SCMP adoption, the present thesis forms a synthesized framework by combining the TOE model with the perceived benefits theory. The integration of these theories will provide for a rich theoretical consideration of a wider range of contextual factors and their potential impact on SCMP adoption.

Thirdly, technology adoption frameworks leave out business performance considerations, which are of increasing importance in today's highly competitive environment. As suggested by other scholars, the dependent construct in the TOE model, the adoption of technologies, could serve as a basis for the expansion of the model through the inclusion of an element of organizational performance (Mishra et al., 2007; Zhu and Kraemer, 2005). Accordingly, the framework was expanded by adding a new construct for hospital cost performance into the research model seeking to investigate its relationship with SCMP adoption.

Fourthly, one major criticism of technology adoption research is that adoption is mainly viewed as a dichotomous outcome (either the innovation is adopted or not adopted) (Hoti, 2015). However, as it is widely recognized that technology adoption comprises different stages from initial adoption to full assimilation (Devaraj and Kohli, 2003; Zhu et al., 2006), leaving out this crucial parameter would compromise the research model's explanatory power with respect to the influencing factors and to the performance impact of SCMP adoption. Therefore, the framework needed to include a construct that is able to reflect the extent of SCMP adoption.

Lastly, aside from theoretically motivated additions to the model, an important enhancement for the TOE framework in order to be aligned with the goals of the thesis is its adaptation to the healthcare context. As technology adoption models were developed outside of healthcare, if used in their generic form, they may not capture some of the unique contextual features of SCMP in health care delivery while some of their core concepts and measures may not appear relevant to health care researchers (Holden and Karsh, 2010). Therefore, elements not pertaining to the healthcare specific context of the thesis were filtered out and a quality of care component was incorporated in the perceived benefits construct, making the framework more robust and relevant to healthcare.

Drawing upon the literature review findings, the empirical evidence provided in related studies and the theoretical perspectives discussed above, a synthesized framework is proposed that combines the established theoretical lens of the TOE model with the theory of perceived benefits, in order to form a richer theoretical framework that guides the understanding, explanation and prediction of the extent of SCMP adoption in hospital supply chains and their impact on hospital performance. The application of technology-enabled SCMP is expected to depend on organizational and technological readiness, to be impacted by environmental factors and to be influenced by perceived benefits. Thus, the research model proposed in the thesis features six dimensions: (1) extent of SCMP adoption (2) technological context; (3) organizational context; (4) environmental context; (5) perceived benefits; and (6) hospital performance. The specifics of these model variables in a healthcare setting and the related hypotheses are outlined in the next sections.

4.2.1 Extent of SCMP adoption in hospital supply chains

Researchers and practitioners have provided evidence on the positive link between application of SCMP and improved operational performance in many different industries, with several studies reporting significant inventory cost reductions as a result of the adoption of these practices in the supply chain (Kalchschmidt, 2012; Småros, 2007; Morita and Flynn, 1997). Demand planning and forecasting, data segmentation, inventory replenishment and optimization are some of the practices that have been reported to positively impact an organization's competitive advantage (Blanchard, 2010; Wild, 2007). The same holds true for the healthcare sector, where hospital supply chain performance has been seen as an enabler for improving operational efficiency and reducing costs (Baltacioglu et al., 2007).

The starting point for meeting the research objectives of the thesis was to identify a comprehensive set of SCMP that can be adapted to the needs of healthcare and are expected to improve overall SCM performance in hospitals. A panel of eight subject matter experts, comprising of 3 healthcare managers and 5 SCM specialists, was tasked with narrowing down a list of SCMP gathered from literature and business studies, and grouping them into clusters applicable to hospital supply chain processes and functions. This procedure was facilitated using the Delphi technique, which is a widely used method for gathering data from respondents within their area of expertise. Contrary to other data gathering analysis techniques, it employs multiple iterations designed to develop a consensus of opinion among the participating experts (Okoli and Pawlowski, 2004). Two Delphi rounds were performed resulting in the definition of eight SCMP clusters that are enabled by a variety of technologies ranging from mature and widely used ones, such as bar coding technology and ABC Analysis, to relatively specialized applications, such as demand planning and forecasting software. The one theme running through all of these technologies, however, is that all are primarily concerned with managing and controlling supply chain related data and activities and information exchange within and between organizations. The resulting SCMP clusters linked to their underlying technologies are reported in table 13, including selected literature sources that highlight their healthcare sector relevance.

	SCMP clusters	Description	Underlying technologies	References	Saidin index weighting
SCMP1	Inventory management KPI tracking and reporting	• Tracking and reporting of SCM key performance indicators (KPIs) such as inventory turnover, average stock values, service levels • Exception management (alerts when exceeding predefined KPI thresholds)	• Business Intelligence (BI) software • KPI tracking tools • ERP Systems	Cai et al. (2009) Wyatt (2004)	0.47
SCMP2	Inventory replenishment optimization	• Material requirements planning (deterministic, consumption-based) • Optimization of reordering parameters (reorder points (min/max), safety stocks, order quantities calculations (such as EOQ))	• Inventory optimization software • Warehouse management systems • ERP Systems	Varghese et al. (2012) Beier (1995)	0.73
SCMP3	Data segmentation	• Data standardization and classification of materials (drugs, medical supplies etc.) based on ABC analysis and criticality (VED - vital, essential, desired) • Application of structured inventory management policies for each material class (segment)	• ERP Systems	Varghese et al. (2012) Ramanathan (2006) Danas et al. (2006)	0.27
SCMP4	Demand forecasting	• Forecasting based on historical consumption data and anticipated future events or trends • Automated selection of appropriate forecasting algorithms	• Demand planning software	Van Wassenhove (2012) Kalchschmidt (2012) Varghese et al. (2012)	0.45
SCMP5	Supplier evaluation	• Formalized systematic evaluation of suppliers based on score calculation for criteria such as price performance, delivery performance, product quality, compliance • Integration with supplier selection process	• Vendor management software • Supplier Relationship Management (SRM) software • ERP Systems	Mettler and Rohner (2009) Kannan and Tan (2002) Tan et al. (1998)	0.70
SCMP6	Web-based procurement	• Web-enabled procurement processes through the use of web-based applications and tools (such as e-procurement, e-auctions, e-catalogues, e-tender, e-RFx)	• e-procurement software • e-auction ASPs • B2B e-commerce platforms	Puschmann and Alt (2005) Smith and Flanegin (2004)	0.35
SCMP7	Asset tracking	• Streamlining inventory movements (such as goods receipts, goods issues and physical inventory counts) through automated data entry • Monitoring mobile medical equipment	• Asset tracking software • RFID • Barcodes	Yao et al. (2012) Blanchard (2010) Lee and Shim (2007)	0.72
SCMP8	Supplier integration	• Integration of suppliers into the hospitals' inventory management business processes	• Electronic Data Interchange (EDI) • Vendor Managed Inventory (VMI) Systems	Schneller and Smeltzer (2006) Haavik (2000)	0.79

Table 13: SCMP clusters for hospital supply chains

Most technology adoption studies identified as part of the literature review treat adoption as a one-shot parameter, represented by a dichotomous variable (yes, no). Interestingly enough though, literature suggests that just adopting SCMP will only have relatively modest benefits. Morita and Flynn (1997) argue that although the adoption of SCMP is related to better levels of performance compared to using traditional practices, in order to exploit the relationship fully, these practices should be used extensively. Application of SCMP appears to be an evolutionary process, where an organization initially adopts and then has to assimilate them to be able to fully exploit their benefits and build a base for the adoption of the next SCMP clusters. However, after initial deployment, an organization often does not have sufficient knowledge to leverage the new technology, as stressed in studies reporting differences in the relationship between SCMP and performance based on how extensively these practices are used (Zhu et al., 2006). This suggests that an organization must have a learning culture (Lakomski, 2001) in order to reap the full benefits of SCMP adoption. Additionally, although it has been widely recognized that the effects of implementing SCMP will be amplified through the interaction between these practices, most investigations tend to deal with the influence of practices in isolation rather than collectively (Spina et al., 2015). Motivated by the existence of these learning curve and synergetic effects, the extent of SCMP adoption was incorporated into the research framework in order to reflect the breadth (which SCMP are utilized) and depth (to which degree are they utilized) of their adoption.

After establishing the evolutionary character of SCMP as a fundamental premise of the conceptualization of their adoption, the related construct had to be operationalized. The holistic approach in evaluating the aggregated impact of SCMP adoption on hospital cost performance led towards the creation of a composite index. The use of composite indices is increasingly popular among academics as they meet the need for consolidation, aggregating various indicators into a sole number that encompasses and summarizes a plethora of available information (Greco et al., 2017). While creating an index is a delicate task with potential pitfalls as it loses information regarding the performance benefits of isolated practices, it is the most suitable option to measure the degree of SCMP adoption aggregately in order to support the thesis' holistic view. Therefore, the extent of SCMP adoption was operationalized through the construction of an index representing a weighted sum of the practices that a hospital would report as being implemented. Measurement items for each one of the eight SCMP clusters were identified as to adequately capture the depth and intensity of its adoption. For the assignment of an aggregated SCMP adoption score to a hospital, the Saidin index methodology was applied, which has been suggested by Spetz and Baker (1995) for evaluating hospital technology adoption. The Saidin index is calculated as the weighted sum of the eight SCMP clusters, with each cluster weight being the percentage of hospitals that do not apply this cluster. Thus, rare SCMP receive higher weights compared to common ones, and lead to higher Saidin index scores for hospitals that are front runners in the path towards increased SCMP adoption.

$$s_i = \sum_{k=1}^{K} \left(a_k \tau_{i,k}\right) \qquad \text{where} \qquad a_k = 1 - \frac{1}{N}\sum_{i=1}^{N} \left(\tau_{i,k}\right)$$

s_i = Saidin index for hospital i

K = number of SCMP clusters

a_k = weight of SCMP cluster k

$\tau_{i,k}$ = 0 if SCMP cluster k is not adopted in hospital i

1 else

N = number of hospitals

Table 13 reports the Saidin index weightings that were calculated for each SCMP cluster as part of the data analysis phase. The weighted scores of these eight clusters were added according to the Saidin index logic in order to form a SCMP Adoption index (SCMPAI), which represents the extent of their adoption in the supply chain processes of a hospital. Similar approaches for measuring the technological breadth of companies have been followed by other scholars in OM disciplines, albeit on the basis of simple aggregated indices without weighting mechanisms for the technologies under consideration (Autry et al., 2010; Zhu et al., 2006; Marc et al., 2004; Gibbs and Kraemer, 2004).

4.2.2 Technological context of SCMP adoption in hospitals

The technological context of the conceptual framework is represented by the hospital's technological readiness, which comprises IT infrastructure, IT expertise and IT system integration (Zhu et al., 2006; Oliveira and Martins, 2010). IT infrastructure establishes a platform that provides the foundation for the implementation of SCMP, IT expertise entails the knowledge and skills to implement SCMP, and IT system integration facilitates SCMP by linking together different systems and applications to act as a coordinated whole (Zhu and Kraemer, 2005). Research has shown that firms with sophisticated IT infrastructure and skilled IT resources have increased chances of successfully implementing technology innovations (Lin and Lin, 2008). Evidence from literature also suggests that IT system integration(1) helps improve an organization's performance by streamlining operations, improving customer service and generating cost savings (Sanja, 2013), and (2) enhances compatibility with other technologies (Ruivo et al., 2013). These factors are expected to enable the technological capacity of an organization to adopt SCMP, as has been highlighted by several empirical studies, which identified technological readiness as an important determinant of IT adoption (Pan and Jang, 2008; Zhu et al., 2006).

Interestingly enough though, hospitals are lagging behind in the application of SCMP while they do not appear to be characterized by a lower level of technological readiness compared to other business sectors as healthcare is outpacing many other industries when it comes to investing in IT (Gartner Research, 2017). This could possibly cast doubts on whether the link between technological readiness and SCMP adoption is equally relevant for healthcare settings, considering that healthcare managers often claim that the unique characteristics of the healthcare supply chain represent a barrier for the adoption of SCMP. However, research did not reveal evidence suggesting healthcare-specific SCM related requirements are not supported, as technologies increasingly offer customization options to meet various sector-specific needs. Therefore it is argued that the aspects of complexity and uniqueness of healthcare supply chains cannot be used as an excuse for lower SCMP adoption and should not mitigate the dependency with technological readiness. Accordingly, it is postulated that the extent of SCMP adoption in a hospital's supply chain is positively impacted by the hospital's technological readiness, which is shaped by (1) IT infrastructure, (2) IT expertise, and (3) technology integration. The hypothesis on the causality between technological readiness and SCMP adoption is further strengthened if the role of ERP Systems is examined in this context. They can be used as a measure for an organization's technological integration and readiness while at same time they can be acting as enablers for various SCMP, thus establishing an additional argument for the plausibility of the hypothesized link.

Hypothesis 1: The extent of SCMP adoption in hospital supply chains is positively impacted by technological readiness

4.2.3 Organizational context of SCMP adoption in hospitals

A variety of organizational factors have been suggested to impact innovation and technology adoption. One factor included in many technology adoption studies is organizational readiness, which reflects an organization's internal capability to accept new technologies (Mehrtens et al., 2001; Iacovou et al., 1995). Organizational readiness is impacted by the organization's culture and whether it shows resistance or has a positive attitude towards change (Weiner, 2009). The availability of skilled, knowledgeable and well trained resources in regards to new technologies can also impact organizational readiness (Chwelos et al., 2001). Thong (1999) suggested that resources with greater information systems knowledge are likely to use these systems more extensively, thus increasing the chances of adopting new technologies. Consequently, adoption may not just depend on the skill level of an organization's IT professionals, which reflects the organization's IT expertise, but also on the ability and confidence of other employees who are tasked with operating the new technologies (Fillis et al., 2004).Finally, another aspect of organizational readiness considered crucial in many IT adoption studies is top management support and commitment (Thong and Yap, 1995), as it is necessary to ensure adequate resources and to overcome barriers and resistance to change inherent in the organization (Fernandez and Rainey, 2006).

The lower however adoption of SCMP in healthcare settings encourages the examination of whether the organizational readiness link is less prevalent in this sector. The findings from other studies may not be directly transferable to hospital settings due to several reasons (Sharma et al., 2016). Could the uniquely complex organizational structures and characteristics that are impacted by various stakeholders with different priorities and seemingly competing interests –effective care vs. efficient operations- influence the mechanics of organizational readiness as part of SCMP adoption? Could the increased formalization required to protect patient safety act as a barrier to letting organizational readiness translate into SCMP adoption? Trying to address these aspects, change management related research in healthcare was reviewed, where various evidence-informed approaches were found that guide healthcare organizations' decision makers on how to apply models, tools and techniques to effectively implement changes (Antwi and Kale, 2015). They can assist SCMP implementations by assuring all hospital stakeholders that the pursuit of better process efficiencies does not compromise and even enhances other seemingly competing priorities such as quality of care (Chen et al., 2013). Therefore, the unique organizational aspects of hospitals are not expected to alter the relationship between organizational readiness and SCMP adoption, and it is assumed that the extent of SCMP adoption in a hospital's supply chain processes is impacted by the hospital's organizational readiness, which comprises (1) pro innovation organizational culture, (2) resources that are skilled and educated on new technologies, and (3) top management support.

Hypothesis 2: The extent of SCMP adoption in hospital supply chains is positively impacted by organizational readiness

One of the most commonly researched variables in the organizational context is the size of the organization, as it is theorized to impact technology adoption (Lee and Xia, 2006). However, there has been some disagreement regarding the direction of the relationship (Kuemmerle, 2006; Patterson et al., 2003). Some scholars have suggested that smaller organizations are more likely to be innovative, because smaller size translates into higher flexibility and less bureaucracy (Zhu and Kraemer, 2005; Oliveira and Martins, 2010). More studies, however, conclude that this relationship has a positive sign (Mandel, 2011), since larger organizations are more likely to have the financial resources to invest in new technologies and absorb the associated risks (Hung et al., 2010; Pan and Jang, 2008; Hsu et al., 2006). This is expected to also hold true for the present thesis considering the inherent characteristics of the Greek Public Healthcare sector, which favor centralization and prioritize larger urban hospitals in terms of financial, people and other resources (Minogiannis, 2012), making it easier for them to adopt SCMP compared to smaller rural hospitals. Therefore, it is postulated that the extent of SCMP adoption in a hospital's supply chain processes is positively impacted by the hospital's size, where the size is determined by the number of beds, as this is a common practice in hospital research studies (Giancotti et al., 2017).

Hypothesis 3: The extent of SCMP adoption in hospital supply chains is positively impacted by hospital size

4.2.4 Environmental context of SCMP adoption in hospitals

The environmental context refers to influencing factors from the external world in which an organization conducts its business. Numerous innovation studies have recognized the importance of a variety of environmental factors and investigated their impact on the decision to adopt new technologies (Oliveria and Martins, 2011). In the present thesis, the focus will be placed on two key environmental variables, which are considered to be most important for SCMP adoption in healthcare institutions, namely business partner influence and government influence. The environmental factor of competitive pressure, which is included in many TOE based studies, was not incorporated into the model, as Greek public hospitals operate in a non market environment (Mitropoulos et al., 2013).

Pressure from supply chain partners constitutes an environmental factor that may influence an organization's adoption of technologies. A supplier may be an advocate for certain technologies and therefore suggest their adoption, or even use his power and influence to pressure his business partners to do so (Hsu et al., 2006). Characteristic example is the impact of suppliers on EDI technologies adoption, as organizations adopting EDI would attempt to influence their business partners to do the same in order to increase their own benefits of adoption (Truman, 2000). Literature has also provided evidence regarding business partners' influence on the adoption of e-procurement technologies (Lin and Lin, 2008). Even in the case where an organization is the initiator of new technologies adoption, this process might be impacted by the level of its business partner readiness, as compatibility between systems along the supply chain is crucial for integration beyond the walls of an individual organization (Soares-Aguiar and Palma-Dos-Reis, 2008). Conversely, a lack of business partner readiness may present a significant barrier to technology adoption.

Viewing these aspects from a healthcare sector specific angle, it is noteworthy that suppliers have been traditionally viewed as adversaries rather than business partners. Many healthcare providers confine their supply chain improvement efforts to pressuring their suppliers for price reductions (Global Healthcare Exchange, 2011). However, as more studies on healthcare supply chains are published, healthcare providers are expected to become more aware of the fact that the old rules of business are changing and that more supply chain collaboration with combined efforts between hospitals and their suppliers leads to mutual benefits. Therefore, it is reasonable to assume that the extent of SCMP adoption in a hospital's supply chain processes is positively impacted by its business partners' readiness.

Hypothesis 4: The extent of SCMP adoption in hospital supply chains is positively impacted by business partner readiness

Government influence constitutes another important environmental aspect that can encourage or discourage the adoption of innovations (Lin and Ho, 2009), as governments can provide incentives or, in the case of public entities, even mandate technology adoption. The regulatory environment and governmental institutions can in some cases have more influence than the markets, and can impact technology adoption, often via the ability of a government to promote specific technologies. Literature provides empirical evidence regarding government influence on the adoption of new technologies across business sectors (Zhu et al., 2006; Yen and Sheu, 2004). Lee and Jung (2016) argue that government-driven policies impact the adoption of new technologies such as EDI, especially in European countries where the size of the policy effect is much bigger compared to developing countries. They imply that governmental policy can play a critical role even in developed countries like the UK, where the government has been strongly pushing firms into adopting new technologies like RFID. Especially for the healthcare sector it is imperative to study whether governmental policies encourage or even dictate adoption of new technologies as it is considered to be one the most regulated sectors. Given that governments try to contain rising healthcare costs and supply chains are known to account for a large portion of these costs, it is anticipated that government policies can play a significant role in adopting SCMP in healthcare settings.

Hypothesis 5: The extent of SCMP adoption in hospital supply chains is positively impacted by government policies

4.2.5 Impact of perceived benefits on SCMP extent of adoption

Perceived benefits, also referred to as “relative advantage” in classical innovation literature, pertain to the anticipated advantages that SCMP adoption can provide to the organization (Iacovou et al., 1995). Oliveira and Martins (2010) reference various empirical studies validating that positive perception of the benefits of an innovation provides an incentive for its use. Furthermore, perceived benefits are expected to play a key role in overcoming SCMP adoption barriers, since the implementation of their underlying technologies requires technical and organizational competences (Hong and Zhu, 2006). Perceived benefits are associated with both direct and indirect benefits of SCMP adoption. Direct benefits encompass the operational savings that can be achieved, have an immediate effect and are easier to identify, for example inventory cost reductions. Indirect benefits represent opportunities derived from the impact of SCMP adoption in a hospital’s business processes, such as improvement of patient safety and quality of care, and may need more time in order to be visible.

Although other studies selected to incorporate perceived benefits in their technological or organizational contexts, it was favored to follow the approach of other scholars, such as Gibbs and Kraemer (2004) and Oliveria and Martins (2010), who treated perceived benefits as a separate construct. This seems plausible, considering they are distinct from other factors as they represent the decision makers' personal beliefs, rather than reflect attributes of the organization. Although the construct of perceived benefits has been operationalized in various ways across different studies, it has consistently been found to be a determinant of technology adoption as well as a determinant of the extent of technology adoption (Chwelos et al., 2001; Iacovou et al., 1995). Despite the fact that hospitals are characterized by complex decision making processes due to their dual or shared authorities model (administrative and clinical) (Rotar et al., 2016), this particularity is not expected to alter the anticipated impact of personal beliefs on technology adoption decisions. Thus, the following hypothesis is postulated:

Hypothesis 6: The extent of SCMP adoption in hospital supply chains is positively impacted by perceived benefits

4.2.6 Impact of SCMP adoption extent on hospital cost performance

Apart from studying the determinants and mechanics of SCMP adoption in supply chain related processes of hospitals, the aim was to research their impact on hospital performance. The challenge of demonstrating the link between technological innovations and organizational performance is not a new one. With respect to the healthcare sector in particular, several scholars have called for empirical evidence on the relationship between technology adoption and hospital performance (Avgar et al., 2012). Existing studies however yielded mixed results, ranging from positive impact (Menachemi, 2007; Bhattacherjee et al., 2006; Devaraj and Kohli, 2003) to minimal or even negative impact (McCullough et al., 2010; Koppel et al., 2005). According to Sharma et al., (2016) these conflicting findings can be the result of the focus on single technologies and the inclusion of hospital performance measures such as readmissions and mortality that are subjected to several patient characteristics.

. In order to overcome these limitations, a holistic view on SCMP adoption was followed by creating a composite index to investigate their aggregated impact as previously outlined, and opted to use a firm level performance measure that is not associated with patient characteristics. Considering the global trends towards healthcare cost reductions and the fiscal policies aiming at public healthcare spending cuts, the focus was placed on the cost side of hospital performance, while stressing that cost performance should be used in concert with quality performance -including process, outcome, patient experience- when assessing overall hospital performance. The hospital cost-function literature contains an extensive variety of empirical models and different methodological approaches for evaluating cost performance (Thomas, 2006). Some scholars use the operating costs incurred by a hospital divided by its number of beds as a metric (Sharma et al., 2016). Others choose to base their cost assessment on a per admission basis or on a per capita basis, which is more suitable for comparing aggregate costs for a geographic region's group of hospitals related to the population served (McCone, 2017).

To operationalize the cost performance of Greek public hospitals, the average cost per inpatient day was calculated. For this purpose, a database containing data from Greek public hospitals was utilized, which was accessed through the Greek Ministry of Health business intelligence health portal (BI-Health, 2017). Initially, the cost per patient was calculated by dividing the yearly total hospital costs by the number of hospitalized patients per year. The cost per patient is expectedly higher for hospitals treating more severe cases as they require higher length of patient stays; thus, this measure needs to be adjusted in order to be suitable for relative performance comparisons. Consequently, the average length of stay (ALOS) was calculated, which is often used as a hospital cost efficiency indicator by itself (OECD, 2017). All other things being equal, a shorter inpatient stay will reduce the cost per discharge and shift care from inpatient to less expensive post-acute settings. The ALOS refers to the average number of days that patients spend in the hospital, and is calculated by dividing the total number of days stayed by all inpatients during a year by the number of admissions or discharges, excluding day cases. By dividing the cost per patient by the ALOS, the average cost per patient day was calculated, which was used to benchmark the hospital's cost performance. As the adoption of SCMP in supply chain processes of hospitals is expected to improve their cost performance, a higher extent of SCMP adoption should be linked to a lower average cost per patient day. Therefore, the final hypothesis is postulated:

Hypothesis 7: Hospital cost performance is positively impacted by the extent of SCMP adoption in hospital supply chains

Figure 12 depicts the theoretical model with the associated hypotheses. To construct the model, related literature was thoroughly researched and methodological aspects were considered, addressing issues such as endogeneity and common method bias. Attempting to lessen possible endogeneity concerns beforehand, the model was built adapting well known theoretical frameworks, as their contextual soundness has been validated by many prestigious research studies. The application of established frameworks, even more so a synthesis thereof, lessens the possibility of omitting important model variables, which is perhaps the most common source of endogeneity problems (Ketokivi and McIntosh, 2017). Furthermore it ex ante lessens potential concerns on orthogonality between independent variables of a model. Factors such as technological and organizational readiness have been widely accepted as antecedents of technology adoption, whereas no previous work was found suggesting a contradiction in the direction of this relationship. Regarding the environmental context, it is also plausible to assume that supervisory factors, such as governmental or business partner predispositions, are unlikely to be impacted by a single organization's state of SCMP adoption. Finally, perceived benefits reflect the personal beliefs of the decision makers, which should be by default authentic and unaffected, lessening the room for different interpretation regarding the direction of their relationship to the organization's technology adoption. The second methodological aspect of common method bias was addressed as part of the data collection process described in the following section.

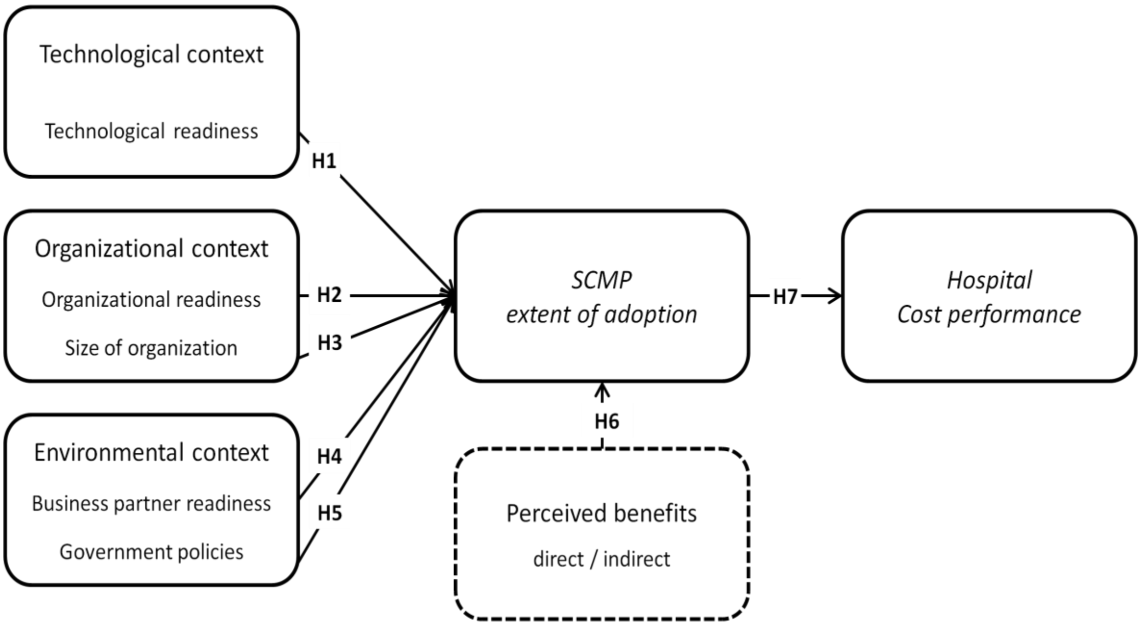


Figure 12: Theoretical research framework

4.3 Research methodology

After detailing the theoretical underpinning of the research framework, the research methodology followed is explained in detail. The widely used survey research method was employed to collect the primary data needed to test the hypotheses. The initial goal was to include the full population of hospitals operating within the Greek healthcare sector. However, during the data collection process it was discovered that private hospitals had a relatively low response rate compared to the public hospitals. Despite all efforts, they were very reluctant to provide data and information regarding their business processes and to discuss technical and organizational aspects. This might be attributable to the fact that the Greek private healthcare sector is facing a major consolidation process initiated by declining revenues, increasing competition and climbing costs, combined with a 40% decrease in healthcare spending (during the period 2009-2015) due to the country's severe financial crisis. This becomes apparent as the number of private hospitals has been drastically reduced by approx. 21% (with the average size increasing by approx. 5%) during the period 2012-2014 (Deloitte Greece, 2017). Therefore, the scope of the thesis was concentrated on the Greek public healthcare sector, which provided a sufficient base for performing the intended research, considering it represents over 72 % of the total sector in terms of hospital bed capacity (ICAP, 2013).

The questionnaire developed to support the survey can be viewed in Appendix A. It was accompanied by a cover letter providing information about the scope of the research as well as detailed instructions, and is divided into four parts. The first part relates to demographic information, such as the role of the participant in the organization, the type of the organization (public/private) and the hospital's size, which was determined based on the number of beds by applying a classification used in reports of the Greek Ministry of Health (small: ≤100 beds, medium: 101 to 400 beds, large: >400 beds) (Mitropoulos et al., 2013). The second part includes the previously defined list of the eight SCMP clusters (Table 13) with the goal of evaluating the extent of their utilization on a 5 point Likert scale (from 1 (Not at all) to 5 (To full extent)). The third part includes multiple items for measuring the independent variables of the model in order to increase the survey construct validity and reliability. The survey items, as depicted in table 14, were chosen on the basis of reflective scales, they represent manifestations of the related constructs, they share a common theme and dropping a measurement item does not alter the conceptual domain of its related construct. They were adapted from literature in accordance to other technology adoption studies and were verified as part of a pilot test. Additionally, they were validated through confirmatory factor analysis (CFA) as part of the data analysis phase. The fourth part has a section to capture additional comments and remarks from the survey participants.

	Construct	Adapted sources for constructs	Items	Item descriptions
Technological context	Technological readiness	Lian et al. (2014) Lumsden and Anabel (2013) Hsu et al. (2006)Teo and Ranganathan (2004) Chau and Hui (2001	TR1 TR2 TR3 TR4 TR5 TR6 TR7	Sufficient IT infrastructure (HW / SW) IT resources with adequate expertise Level of integration of internal IT applications IT system adaptability to new requirements Adequate use of ERP system Level of spending on new technologies Integration capability with external systems
Organizational context	Organizational readiness	Oliveira et al. (2014) Lian et al. (2014) Teo and Ranganathan (2004) Premkumar and Ramamurthy (1995) Rogers (1995)	OR1 OR2 OR3 OR4 OR5	Organization's favorable attitude towards change Personnel competent with new technologies Top management support Cross departmental cooperation Regularity of personnel training
	Organization size (single item)	Hung et al. (2010) Kimberly and Evanisko (1981)	SIZE	Classification of hospitals based on number of beds
Environmental context	Business partner readiness	Wang et al. (2010) Chau and Hui (2001) Hsu et al. (2006)	BPI1 BPI2 BPI3 BPI4	Business partners' capabilities Recommended by business partners Requested by business partners Cooperation level with business partners
	Government policies	Oliveira et al. (2014) Lian et al. (2014) Chau and Hui (2001) Low et al. (2011) Crow (1988)	GPI1 GPI2 GPI3 GPI4	Supported by government policies Mandated by government policies Sufficient regulatory environment Government incentives
Perceived Benefits	Perceived benefits (direct & indirect)	Low et al. (2011) Wang et al. (2010) Arunachalam (1997) Iacovou et al. (1995)	PB1 PB2 PB3 PB4	Reduced supply chain costs Improved supply chain process efficiency Improved quality of care Other resulting indirect benefits

Table 14: Measurement items, associated constructs and their adapted sources

Note: All items except SIZE measured through a 5 point Likert scale

Before final data collection, the questionnaire was piloted in two hospitals located in northern Greece to test and examine face validity. Personal interviews were conducted with inventory managers and purchasing managers, who were asked to comment on the content, clarity and scaling of the instruments. Based on their feedback, some questions were rephrased to improve their clarity and some minor revisions were applied to the questionnaire. In order to screen for possible common bias issues at this preliminary stage, the third part of the questionnaire (technological and organizational context) was distributed to at least three additional managers of different functional areas within each hospital. The responses were scanned for problematic items (e.g. existence of responses contradicting in their direction (agree/strongly agree direction as well as disagree/strongly disagree direction present for an item in a hospital)). This led to the detection of two items with discrepancies in the responses, resulting into wording changes after consulting with the respective managers.

The seven regional health directorates that are responsible for the public hospitals of the seven geographic regions of Greece were contacted in order to initially gain approval for conducting the study. As job descriptions are not available and not standardized across Greek public healthcare institutions, the expertise and opinions of these entities were used to initially select a key informant for each of their supervised hospitals. Besides possessing intimate knowledge of the hospital's supply chain functions based on their roles and their experience, the key informants needed to be in a position to assess organizational and technological characteristics of their hospitals. In most of the cases the person selected was the inventory/storeroom manager (72%), in some cases the procurement manager (22%) and in a few cases the financial manager (6%). Due to their role as active mid-level managers of Greek public hospitals, which are characterized by flat hierarchical structures (Minogiannis, 2012), they were expected to have a good understanding of intra-organizational characteristics besides being knowledgeable about the issues under investigation. After sending out the questionnaire to the selected key informants, all of them were contacted and personal interviews were set up (in person or via phone conference) where they were guided through the survey discussing all items and providing further clarifications when needed. As a result of this process, switches to a different key informant had to be made in a few cases were the above requirements were not met.

Although the use of single respondents for organization level studies is very common among empirical studies, there are known common method bias issues associated with this approach as already indicated (Pinsonneault and Kraemer, 1993). To lessen possible concerns, it was planned to apply Harman's single factor technique, a widely used statistical remedy designed to control for common method variance. Bearing in mind, that there are some serious problems inherent in the use of this technique (Ketokivi and McIntosh, 2017; Chang et al. 2010), it was additionally attempted to address these issues ex ante by (1) providing written instructions for the respondents, directing them to confine their responses to the context of the study and to respond as key informants for the hospital with the exception of the questions related to the perceived benefits construct, where they were specifically asked for their personal views, (2) assuring respondents of the anonymity and confidentiality of the study, that there are no right or wrong answers, and that they should answer as honestly as possible, (3) ensuring that individual items are formulated as concisely as possible and ambiguous, vague and unfamiliar terms are avoided, (4) mixing the order of questions relating to different constructs, and (5) using a different source of information for the dependent variable of cost performance. To increase response rates, follow-up phone calls were made and reminder emails were sent after sending out the questionnaires.

Out of 125 questionnaires sent to public hospitals, 107 were returned after the interviews with the selected key informants, including 4 incomplete ones, which were discarded. Thus, 103 useful questionnaires were obtained, exceeding by far initial expectations as approx. 82% of the total population of public hospitals was covered. On the contrary, out of 54 private hospitals contacted, only 8 were willing to participate and finally returned a completed questionnaire, thus reaching a far lower 15% response rate. Due to the severe imbalance in the public vs. private hospitals response rates, it was decided not to include private hospitals in the current study, as previously discussed. Additionally, after calculating the average cost per inpatient day, three hospitals were excluded from further analysis due to the strikingly low values they yielded, which were attributed to their distinctive character (mental health clinics).

After data collection, the possibility of non response bias was investigated by examining the differences in the mean of all measured variables between early and late respondents. The rationale behind such an analysis is that late respondents are more similar to non-respondents than to early respondents (Lin and Schaeffer, 1995). No statistically significant differences were found, suggesting that non response bias is not a serious issue for the study. Finally, the application of the previously discussed Harman's single-factor technique resulted into five factors accounting for 72,52% of the variance, with the first factor at 32,19%. Given that no single factor occured and no factor accounted for most of the variance, the single method of data collection appeared to be an acceptable risk based on this technique (Podsakoff et al., 2003).

4.4 Data analysis and results

Prior to data collection, the content validity of the survey instrument was supported through literature review, interviews with subject matter experts and pilot tests. After data collection, structural equation modeling (SEM) using the AMOS 22.0 software was employed to analyze the data, following the two-step approach suggested by Anderson and Gerbing (1988) for the assessment of both measurement and structural components. Due to the fact that the constructs of interest cannot be perfectly observed, employing SEM allows to address the common problem of measurement errors. This can be achieved through an observed and latent variable structure, simultaneous calculation of model parameters and test of overall fit of the model to the data, while paying attention to the chi square statistic (Antonakis et al., 2014). The power of SEM is fully exploited when multiple measurement items for each latent variable are tested through confirmatory factor analysis (CFA) to validate the conceptual soundness of the latent variables used in the structural model (Schreiber et al., 2006). Establishing the reliability of the underlying constructs is essential for the validity of the final data analysis results. Therefore, CFA was employed to examine the variables and path relationships hypothesized in the research model and to further test unidimensionality and reliability as described by Hair et al. (1998). For this purpose, the individual measurement items were mapped to the latent variables representing the constructs of the model. CFA is considered a rigorous method for assessing validity, requires fewer assumptions than traditional methods (Bagozzi et al., 1991) and helps in establishing unidimensionality of the indicators (Anderson and Gerbing, 1982), meaning that a set of measurement items measures only a single construct. Maximum likelihood was used as the estimation method, as several studies have shown that it outperforms other estimation methods, such as the generalized least squares or asymptotically distribution free methods, even in the case of non normality of data (Schermelleh-Engel et al., 2003).

4.4.1 Measurement model results

The analysis led to the removal of several items from individual constructs and the final measurement model consists of five latent variables, each measured by multiple indicators (table 14). The χ^2 of the model was calculated as 83,758 with 80 degrees of freedom. The resulting model fit statistics for the measurement model are reported in table 15. As suggested by Hair et al. (1998), the following widely used absolute indices (measuring how *well* the hypothesized *model reproduces* the covariance matrix obtained from the *sample data)* and incremental indices (measuring how *well* the hypothesized *model* provides benefits beyond the worst-case model*)* were calculated: $\chi 2$/df value=1.047; goodness of fit index (GFI)=0.901; adjusted goodness of fit index (AGFI)=0.851; root mean square error of approximation (RMSEA)=0.022; incremental fit index (IFI)=0.993; normed fit index (NFI)=0.864; non-normed fit index (NNFI) or Tucker Lewis Index (TLI)=0.990; comparative fit index (CFI)=0.993. Although one of the incremental fit indices, the NFI, is slightly below conventional levels, all other incremental indices are well above the recommended thresholds as depicted in table 15; thus, the measurement model results reflect acceptable absolute and incremental measurement model fit (Hair et al., 1998). Moreover, the calculated model fit indices are comparable to those of other SCM or OM studies (Dobrzykowski et al., 2016; Boyer et al., 2012; Zhao et al., 2011; Sarkis et al., 2010), further indicating unidimensionality, reliability and model acceptability.

Goodness of fit indices	Recommended Value (Source)	Measurement Model Results
Absolute fit		
χ^2/df Chi-square / Degrees of freedom	< 3.00 (Jöreskog and Sörbom, 1993)	1.047
GFI Goodness of Fit Index	> 0.90 (Jöreskog and Sörbom, 1993)	0.901
AGFI Adjusted Goodness of Fit Index	> 0.85 (Jöreskog and Sörbom, 1993)	0.851
RMSEA Root Mean Square Error of Approximation	< 0.05 (Steiger, 1990)	0.022
Incremental fit		
IFI Incremental Fit Index	> 0.95 (Hu and Bentler, 1999)	0.993
NFI Normed Fit Index	> 0.90 (Byrne, 1994)	0.864
TLI (NNFI) Tucker Lewis Index	> 0.95 (Hu and Bentler, 1999)	0.990
CFI Comparative Fit Index	> 0.95 (Hu and Bentler, 1999)	0.993

Table 15: Goodness of fit measures for the measurement model

After evaluating the fit of the measurement model, the reliability and the validity of the constructs were assessed, in particular the convergent validity and discriminant validity. Reliability and convergent validity were confirmed, as all five factors reached: (1) construct reliabilities (CR) exceeding the generally recommended 0.70 threshold (Anderson and Gerbing, 1988); and (2) average variances extracted (AVE) exceeding the suggested 0.50 threshold (Fornell and Larcker, 1981), indicating that more than 50% of a factor's variance is due to its measurement items. Discriminant validity was supported as well, considering that the inter-factor correlations are less than the square root of the factor's AVEs as advocated by Fornell and Larcker (1981). Furthermore, their values are not high enough to indicate potential orthogonality issues and conceptual overlap between any pair of factors. The above figures are exhibited in table 16.

	CR	AVE	TR	OR	BR	PB	GP
TR	0,829	0,618	**0,786**				
OR	0,749	0,508	0,589	**0,713**			
BR	0,754	0,511	0,127	0,369	**0,715**		
PB	0,768	0,529	0,059	0,104	0,411	**0,727**	
GP	0,849	0,654	0,602	0,554	0,410	0,368	**0,809**

Table 16: Construct Reliabilities (CR), Average Variances Extracted (AVE) and inter-factor correlations

Note 1: Diagonal elements (in bold) are the square root of the average variance extracted (AVE). Off-diagonal elements are the inter-construct correlations.

Note 2: **TR** = technological readiness; **OR** = organizational readiness; **BR** = business partner readiness; **PB** = perceived benefits; **GP** = government policies.

The above findings indicate that the analysis employed a well-explained factor structure and that the developed constructs can be used to test the conceptual model and the associated hypotheses.

4.4.2 Structural model results

After the positive assessment of the measurement model, the structural model was analyzed in order to test the hypotheses. Similarly to the measurement model, the following widely used absolute and incremental indices were calculated: $\chi 2$/df value=1.108; goodness of fit index (GFI)=0.984; adjusted goodness of fit index (AGFI)=0.904; root mean square error of approximation (RMSEA)=0.033; incremental fit index (IFI)=0.997; normed fit index (NFI)=0.966; non-normed fit index (NNFI) or Tucker Lewis Index (TLI)=0.982; comparative fit index (CFI)=0.996. The recommended values for the fit indices are included in table 17, which demonstrates that all the results were within the recommended ranges. No post-hoc modifications were conducted as all calculated fit indices for the structural model indicated the hypothesized model represents a good fit to the data.

Goodness of fit indices	Recommended Value (Source)	Structural Model Results
Absolute fit		
χ^2/df Chi-square / Degrees of freedom	< 3.00 (Jöreskog and Sörbom, 1993)	1.108
GFI Goodness of Fit Index	> 0.90 (Jöreskog and Sörbom, 1993)	0.984
AGFI Adjusted Goodness of Fit Index	> 0.85 (Jöreskog and Sörbom, 1993)	0.904
RMSEA Root Mean Square Error of Approximation	< 0.05 (Steiger, 1990)	0.033
Incremental fit		
IFI Incremental Fit Index	> 0.95 (Hu and Bentler, 1999)	0.997
NFI Normed Fit Index	> 0.90 (Byrne, 1994)	0.966
TLI (NNFI) Tucker Lewis Index	> 0.95 (Hu and Bentler, 1999)	0.982
CFI Comparative Fit Index	> 0.95 (Hu and Bentler, 1999)	0.996

Table 17: Goodness of fit measures for the structural model

Hypothesis 1 was supported ($\gamma=0.22$, $t=2.069$, $p<0.05$), confirming that technological readiness has a direct positive impact on the extent of SCMP adoption in hospital supply chains. Similarly, hypothesis 2 was supported ($\gamma=0.27$, $t=2.721$, $p<0.01$), demonstrating that organizational readiness has a direct positive impact on the extent of SCMP adoption in hospital supply chains. Hypothesis 3 was supported as well ($\gamma=0.16$, $t=2.052$, $p<0.05$), suggesting that organizational size has a direct positive impact on the extent of SCMP adoption in hospital supply chains. In contrast, hypothesis 4 was not supported ($\gamma=0.09$, $t=1.076$, $p=0.282$), indicating that business partners do not have significant impact on the extent of SCMP adoption in hospital supply chains. Hypothesis 5 was also not supported ($\gamma=0.06$, $t=0.640$, $p=0.522$), indicating that government policies do not have significant impact on the extent of SCMP adoption in hospital supply chains. Hypothesis 6 was supported ($\gamma=0.17$, $t=2.040$, $p<0.05$), confirming that perceived benefits have a direct positive impact on the extent of SCMP adoption in hospital supply chains. Finally, hypothesis 7 was supported ($\gamma=0.44$, $t=4.931$, $p<0.001$), suggesting that the extent of SCMP adoption in hospital supply chains has a significant direct positive impact on hospital cost performance (negative signs for γ and t-values were reversed due to the inverse relationship between cost performance and cost per patient day). A summary of the hypotheses test results is presented in Table 16 and visualized in Figure 13. These results demonstrate the explanatory power of the research model. The r^2 values show that technological readiness, organizational readiness, organizational size and perceived benefits explain 40% of SCMP adoption in hospital supply chains. Furthermore, 20% of hospital cost performance can be attributed to SCMP adoption. These results suggest some interesting interpretations, which will be discussed in chapter 5.

Hyp.	Path from	Path to	r²	t value	Path coeff.	p value	Supported
H1	Technological readiness	Extent of SCMP adoption	0.396	2.069	0.22*	0.039	Yes
H2	Organizational readiness			2.721	0.27**	0.007	Yes
H3	Organization size			2.052	0.16*	0.040	Yes
H4	Business partner readiness			1.076	0.09	0.282	No
H5	Government policies			0.640	0.06	0.522	No
H6	Perceived benefits			2.040	0.17*	0.041	Yes
H7	SCMP extent of adoption	Hospital cost performance	0.197	4.931	0.44***	<0.001	Yes

Table 18: Results of hypotheses

Note: $*p<0.05$, $**p<0.01$, $***p<0.001$

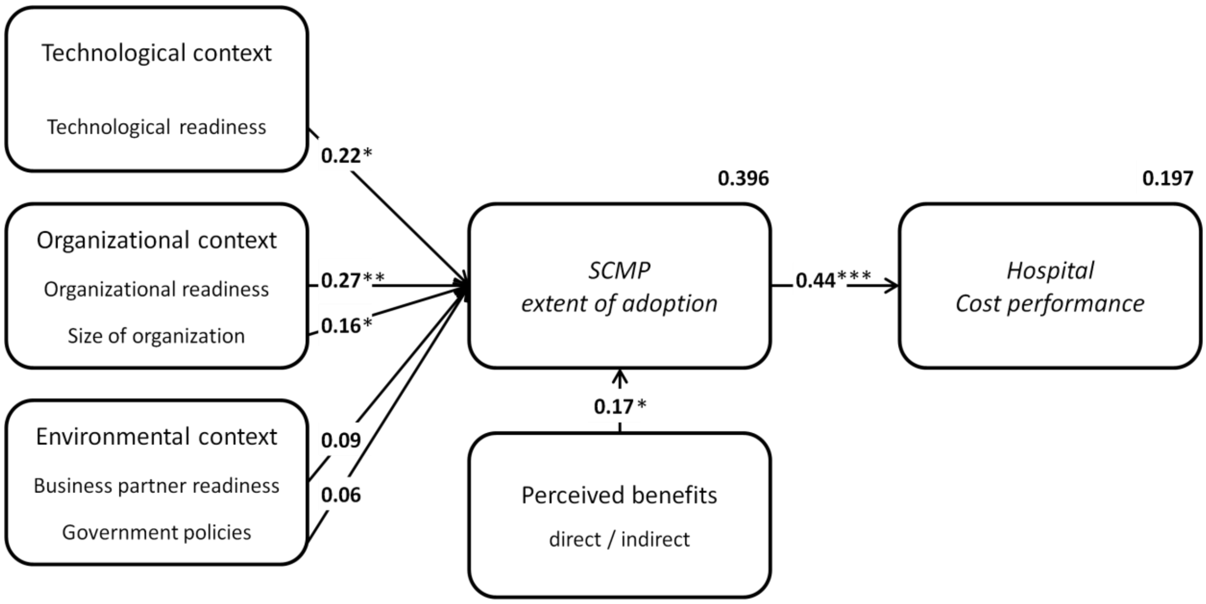


Figure 13: Structural model results with path coefficients.

Notes: The exogenous variables were freed to correlate with one another. Values are standardized.

$*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

4.4.3 Endogeneity and robustness

Recent literature on statistical modeling stresses the importance of addressing the endogeneity dilemma, as it can pose serious threats to the credibility of research findings (Ketokivi and McIntosh, 2017). According to Antonakis et al. (2014), one of the most potent and versatile tools available for treating endogeneity issues is the two-stage least squares (2SLS) estimation, as it deals with endogeneity resulting from omitted variables, measurement error, simultaneity and common method bias. Therefore, a two-stage least squares (2SLS) estimation procedure was chosen to be conducted focusing on the relationship between extent of SCMP adoption and cost performance, as this relationship goes beyond the boundaries of TOE based frameworks, which have been validated by many previous research studies. There is a possibility that improved cost performance could influence SCMP adoption, as someone could argue that lower costs might free up financial resources and direct them towards SCMP implementation. This potential endogeneity source could lead to biased and inconsistent results (Greene, 2008). In order to conduct the 2SLS estimation, predicted values for SCMP adoption were created on the basis of two valid instruments that were not part of the model and were uncorrelated with the dependent variable's error term. The existence of an ERP System was identified as the first instrument, as this is widely accepted to be linked with SCMP. On the other hand, it is not expected to influence the cost performance of public, non-profit hospitals in Greece, especially due to the fact that ERP Systems were implemented before the outbreak of the financial crisis, mainly driven by consolidated reporting needs rather than by cost reduction efforts (Garefalakis et al., 2016). The second instrumental variable identified was the location of the hospital, as literature suggest that urban hospitals are associated with increased aptitude for SCMP adoption compared to rural ones (Culler et al., 2006), whereas location is not expected to be linked with cost performance. The 2SLS regression results revealed that the predicted variable of SCMP adoption has a statistically significant relationship with cost performance ($p<0.01$), thus verifying the stability of the evidence regarding potential endogeneity bias stemming from reverse causality and omitted variables (Antonakis et al., 2010). Considering that it is infeasible to completely rule out endogeneity, the efforts undertaken in addressing this topic create confidence that the variables in question can be considered plausibly exogenous as suggested by Conley et al. (2012).

To further increase the confidence in the validity of the research findings, effort was placed into lessening and controlling possible sources of bias. Due to using a survey for data collection purposes, common method bias is a cause of concern and could threaten the empirical findings, especially when measures for independent and dependent variables are collected from the same source (Antonakis et al., 2010). This issue was addressed procedurally by evaluating the hospital's cost performance using secondary data from a different source, rather than using the survey as the only source of data and relying on the hospital's key informants to provide their subjective estimates. Besides providing a more fine-grained analysis, this also reduces the possibility of potential informant bias and random errors, as the measures of the hospital's cost performance construct are objective (Schmidt and Hunter, 2014).

Finally, for the purpose of further increasing the robustness of the findings, the model was evaluated based on two variations. Firstly, following other OM scholars' approach (Bendig et al., 2017, Zepeda et al., 2016), the model was re-tested using one year lagged values for the endogenous variable of hospital cost performance. The nature of the determinants of SCMP adoption, which decreases the chances of drastic changes, and the associated procurement cost and implementation time of their underlying technologies, allows to hypothesize that lagged values of cost performance are correlated with a hospital's SCMP adoption. Secondly, the SCMPAI was calculated by simply adding the scores of the individual SCMP clusters, without using a weighting mechanism such as the previously outlined Saidin index logic. A non-weighted score ranging from 8 (no adoption of any SCMP cluster) to 40 (full depth of adoption of all SCMP clusters) was formed for each hospital, representing the extent of its SCMP adoption. In both cases, the data analysis yielded consistent results with the ones from the main analysis. The model goodness of fit statistics continued to exceed the acceptable thresholds and the supported hypotheses stayed robust regarding direction and significance. Hence, further support was provided to the overall robustness of the empirical findings, the implications of which are discussed in chapter 5.

4.4.4 Descriptive statistics

The analysis of the data revealed some additional findings regarding the adoption of specific SCMP in Greek public hospitals and the measures used in the survey. This section graphically displays descriptive statistics for all SCMP and measurement items used in the survey, differentiated by hospital size (small, medium, large) and hospital location (urban, rural).

4.4.4.1 SCMP descriptive statistics

With respect to the SCMP investigated, the three most commonly used were found to be data segmentation, web-based procurement and demand forecasting. The three least used SCMP were found to be supplier integration, asset tracking and inventory replenishment optimization.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Data segmentation	100	1	5	3.26	1.260	1.588
Web-based procurement	100	1	5	3.12	1.423	2.026
Demand forecasting	100	1	5	2.78	1.404	1.971
KPI tracking and reporting	100	1	5	2.66	1.304	1.701
Supplier evaluation	100	1	5	2.01	1.345	1.808
Inventory replenishment optimization	100	1	5	2.00	1.247	1.556
Asset tracking	100	1	5	1.88	1.289	1.662
Supplier integration	100	1	5	1.72	1.138	1.295
Valid N (listwise)	100					

Table 19: SCMP descriptive statistics

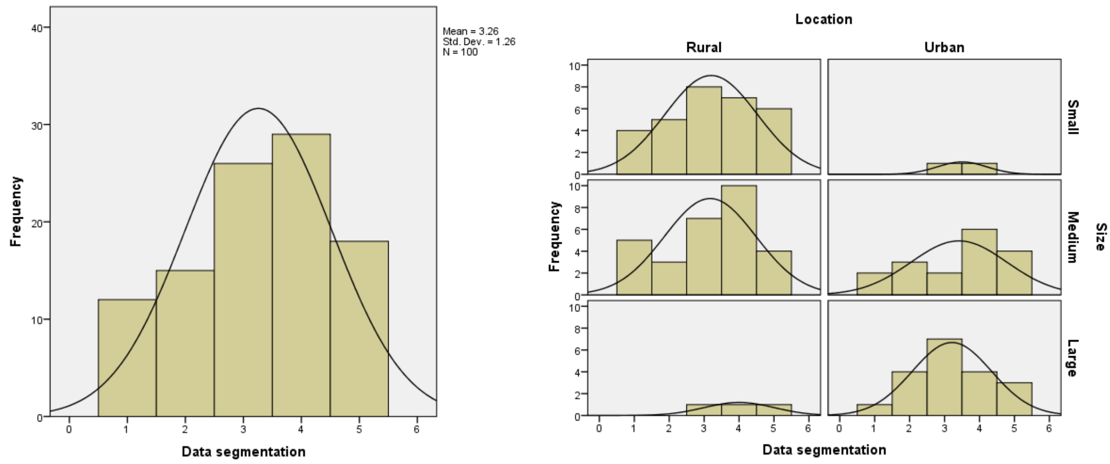


Figure 14: Data segmentation descriptive statistics

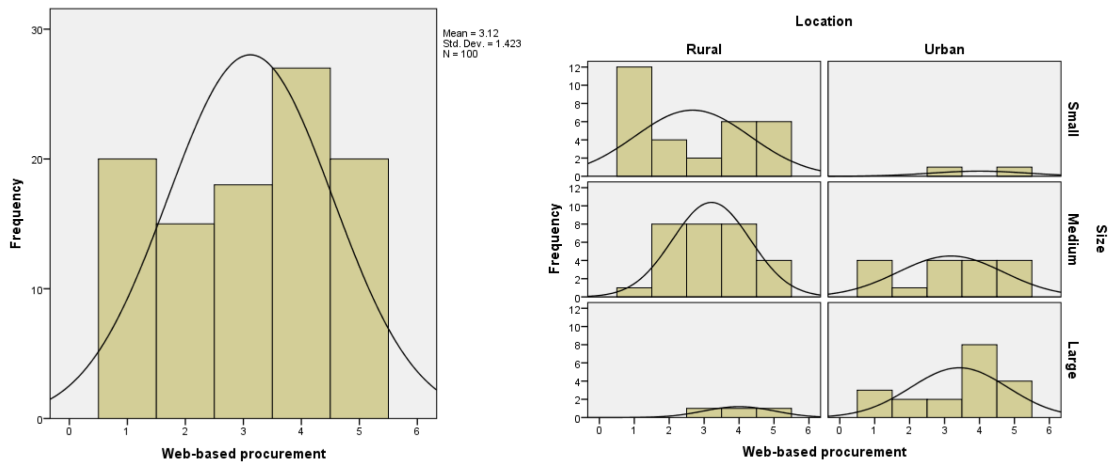


Figure 15: Web-based procurement descriptive statistics

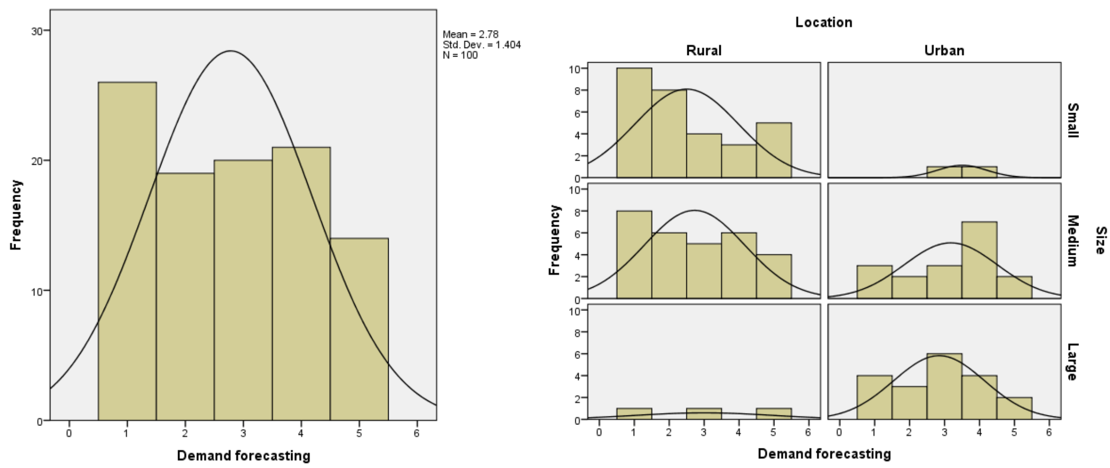


Figure 16: Demand forecasting descriptive statistics

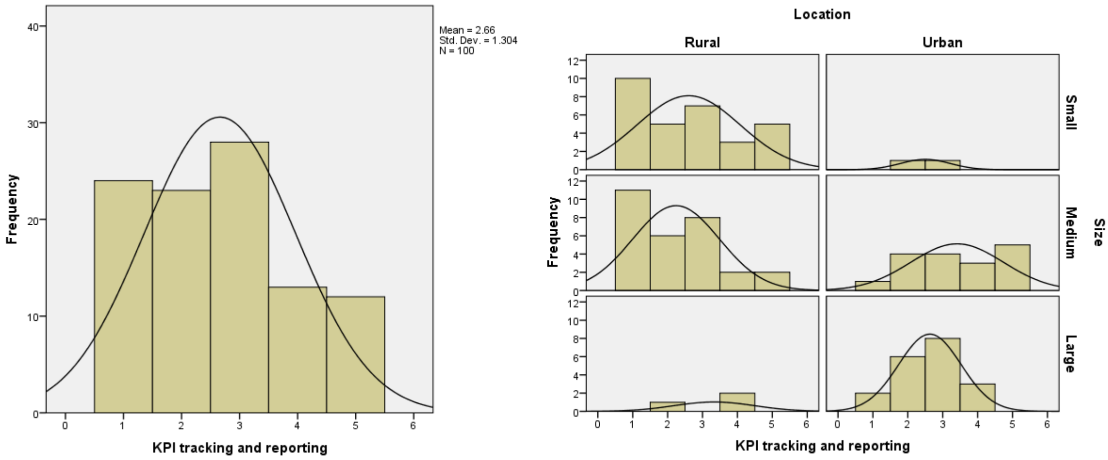


Figure 17: KPI tracking and reporting descriptive statistics

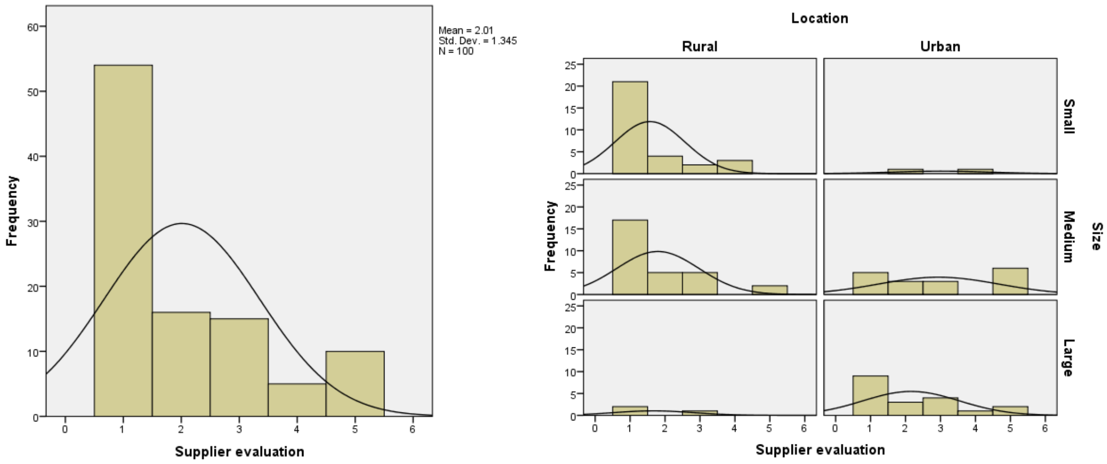


Figure 18: Supplier evaluation and reporting descriptive statistics

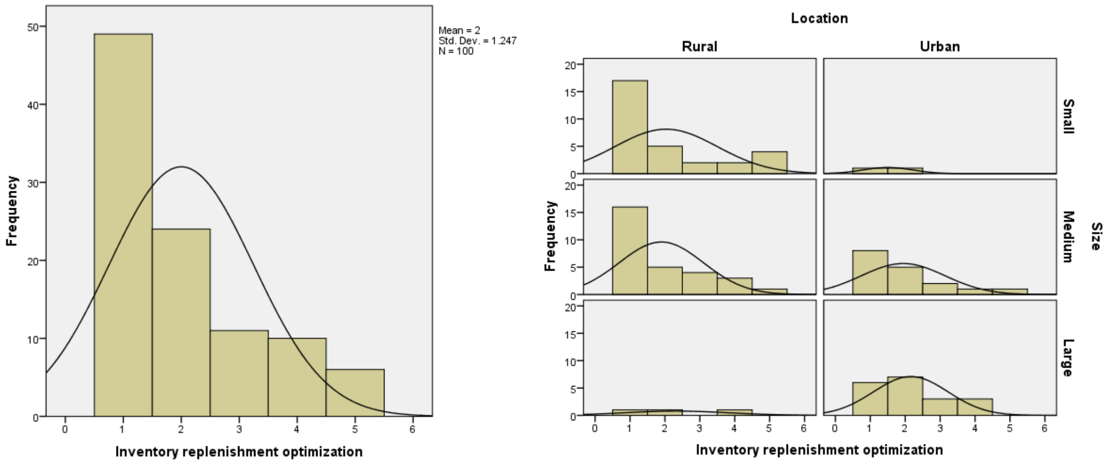


Figure 19: Inventory replenishment optimization and reporting descriptive statistics

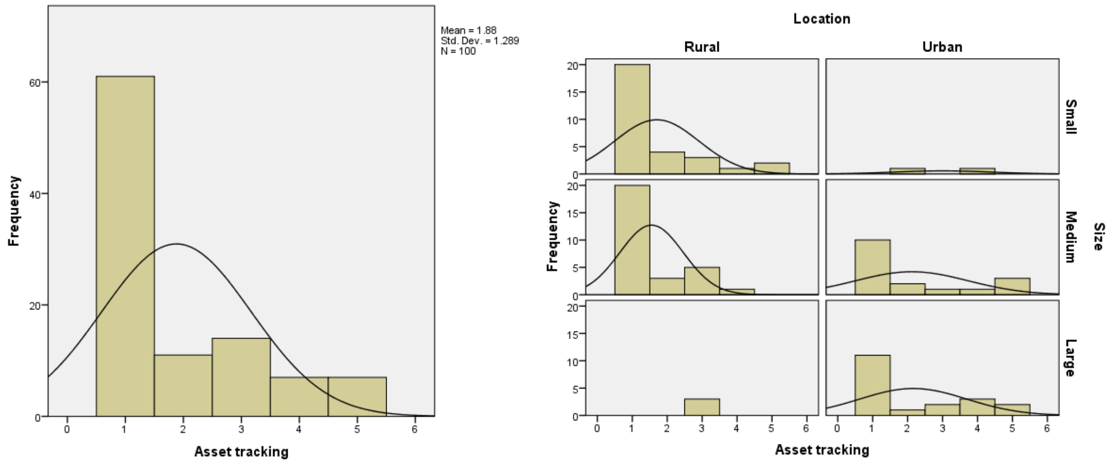


Figure 20: Asset tracking descriptive statistics

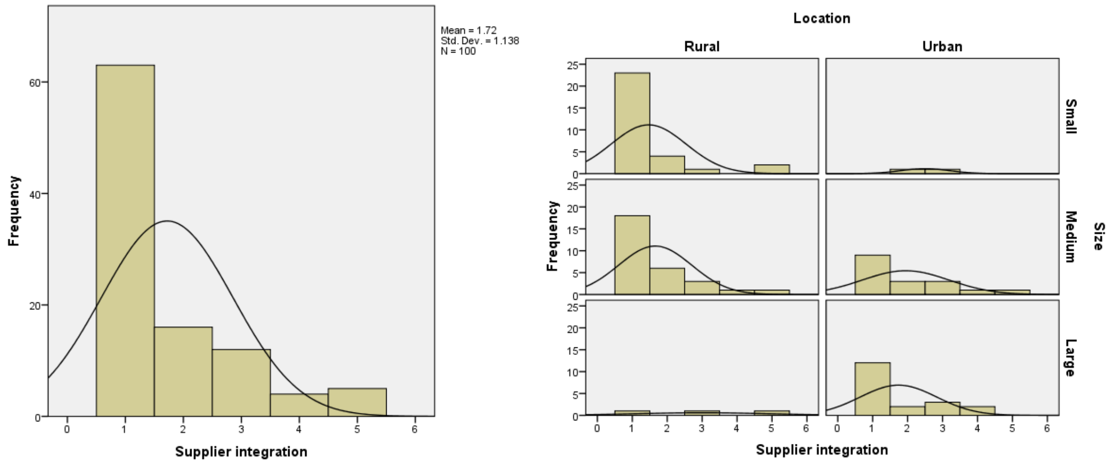


Figure 21: Supplier integration descriptive statistics

4.4.4.2 Measurement items descriptive statistics

With respect to the measurement items, the three items with the highest means were found to be the indirect benefits expected, the improvements in the supply chain processes and the lower supply chain costs. The three items with the lowest means were found to be the government mandate, the supplier encouragement and the supplier mandate.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Indirect benefits	100	2	5	4.55	.716	.513
Improved supply chain processes	100	1	5	4.35	.796	.634
Lower supply chain costs	100	1	5	4.05	1.029	1.058
Improved quality of care	100	1	5	4.03	1.000	.999
IT Personnel competent	100	1	5	3.67	1.129	1.274
Management Support	100	1	5	3.56	.988	.976
ERP system usage	100	1	5	3.53	1.068	1.141
Supplier capabilities	100	1	5	3.22	.871	.759
Supplier cooperation	100	1	5	3.15	.936	.876
Government incentives	100	1	5	3.13	1.143	1.306
IT system adaptability	100	1	5	3.10	1.096	1.202
SW/HW sufficiency	100	1	5	3.10	1.030	1.061
IT systems internal integration	100	1	5	3.10	1.010	1.020
Personnel positive attitude	100	1	5	3.05	1.123	1.260
IT integration with external systems	100	1	5	2.97	1.096	1.201
Investment in adoption of new technologies	100	1	5	2.97	.979	.959
Personnel cross team cooperation	100	1	5	2.86	.954	.909
Personnel knowledgeable	100	1	5	2.62	.896	.804
Government support	100	1	5	2.42	1.065	1.135
Sufficient legal framework	100	1	5	2.39	.942	.887
Personnel regurarly trained	100	1	5	2.36	1.000	1.000
Government mandate	100	1	5	2.34	.966	.934
Supplier encouragement	100	1	5	2.12	1.047	1.097
Supplier demands	100	1	5	1.63	.761	.579
Valid N (listwise)	100					

Table 20: Measurement items descriptive statistics

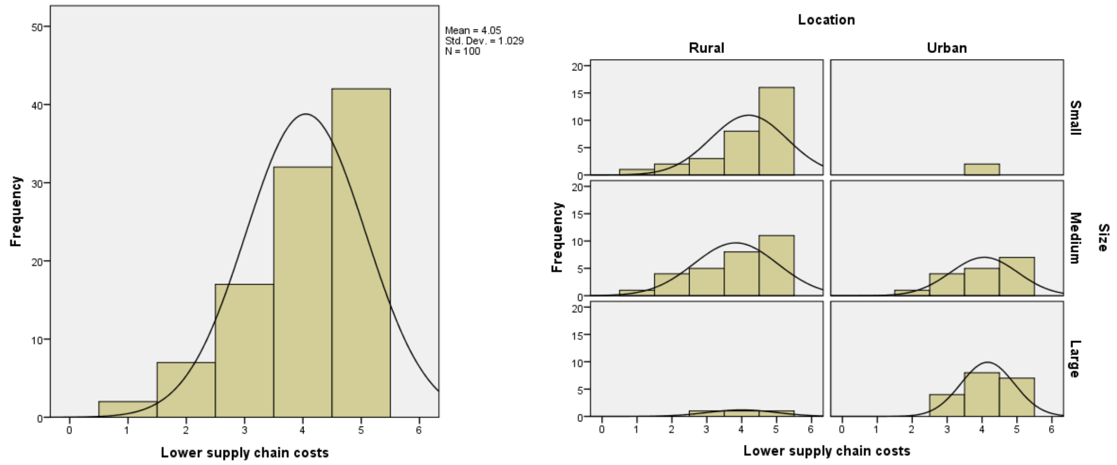


Figure 22: Lower supply chain costs descriptive statistics

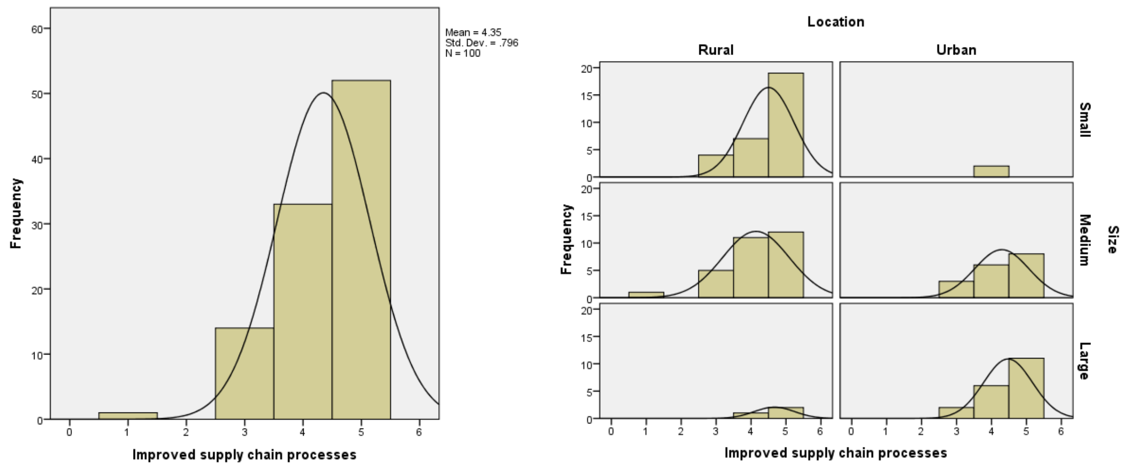


Figure 23: Improved supply chain processes descriptive statistics

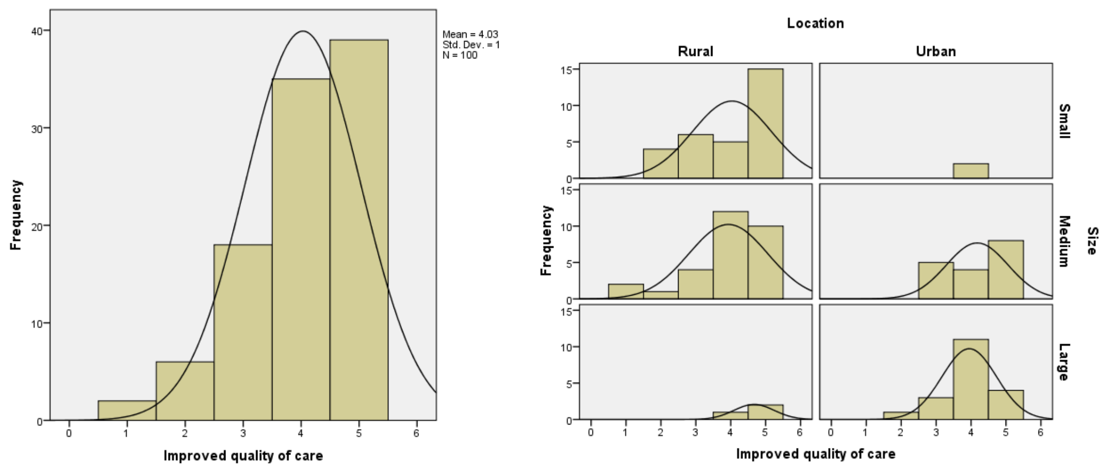


Figure 24: Improved quality of care descriptive statistics

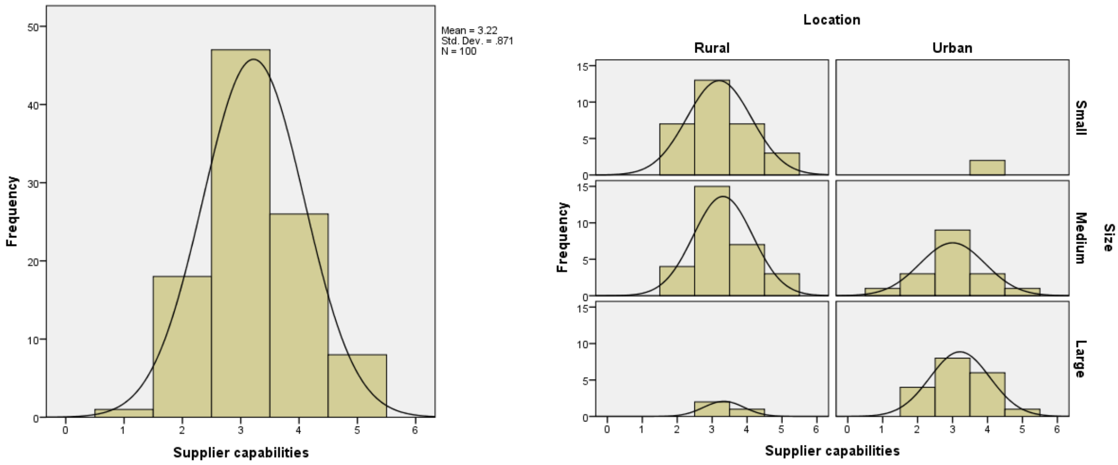


Figure 25: Supplier capabilities descriptive statistics

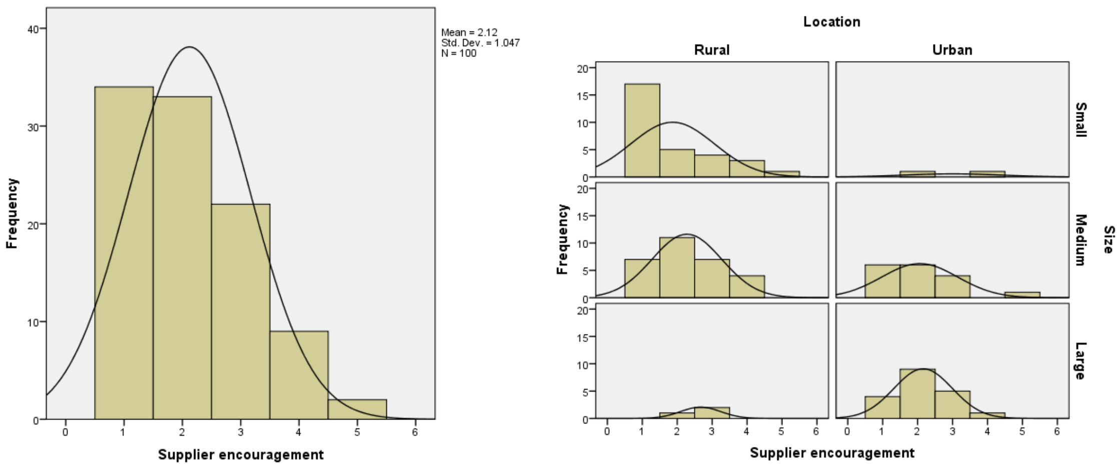


Figure 26: Supplier encouragement descriptive statistics

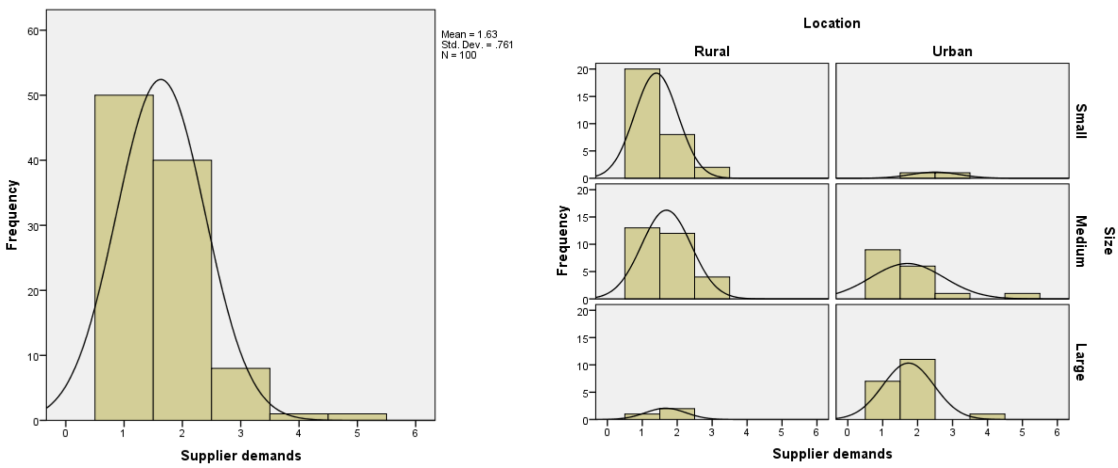


Figure 27: Supplier demands descriptive statistics

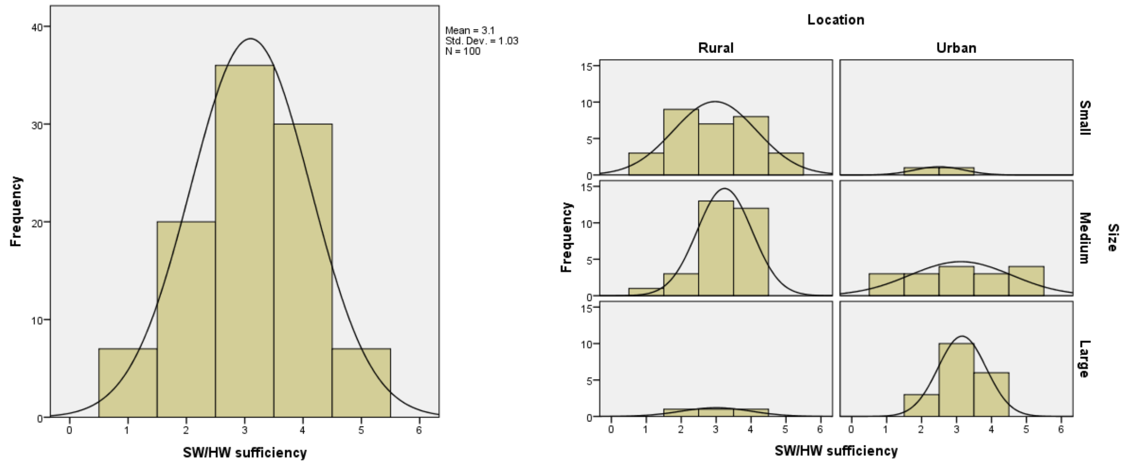


Figure 28: SW/HW sufficiency descriptive statistics

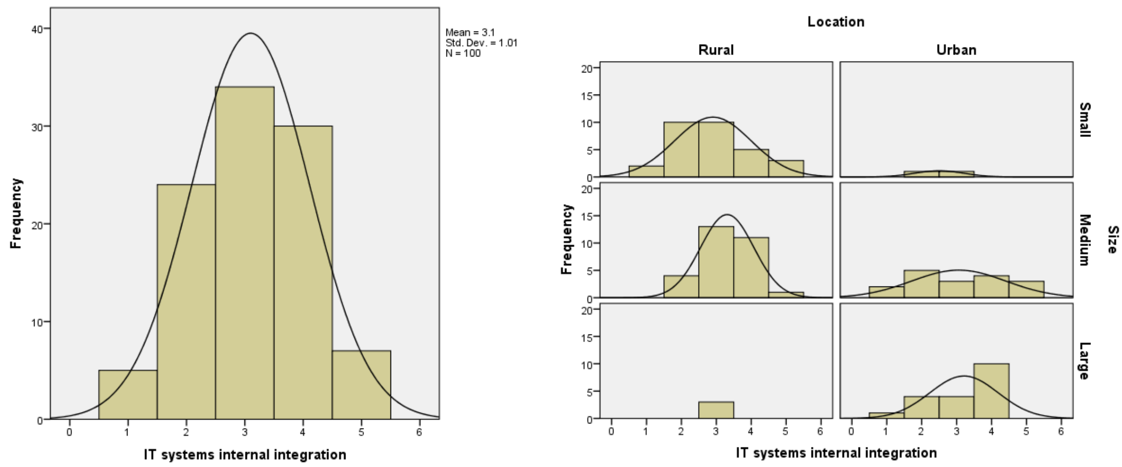


Figure 29: IT systems internal integration descriptive statistics

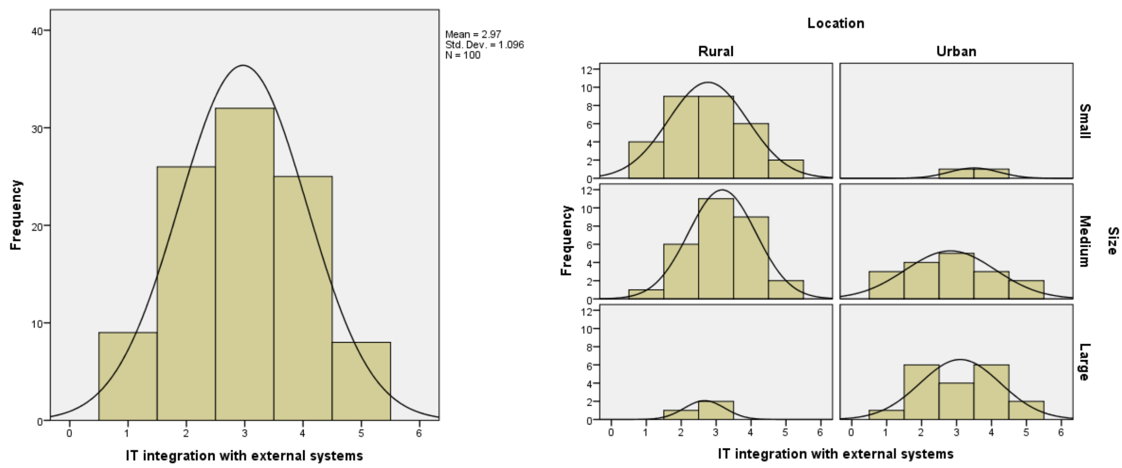


Figure 30: IT integration with external systems descriptive statistics

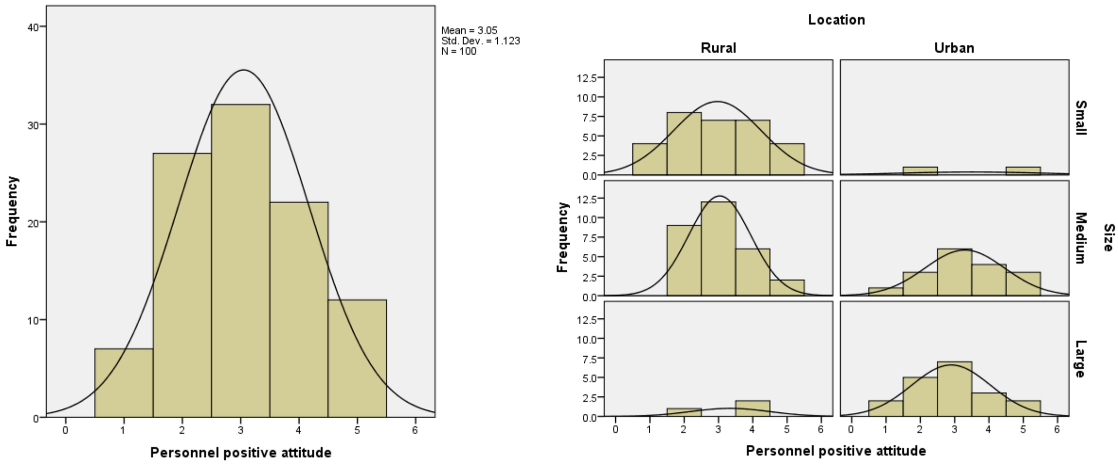


Figure 31: Personnel positive attitude descriptive statistics

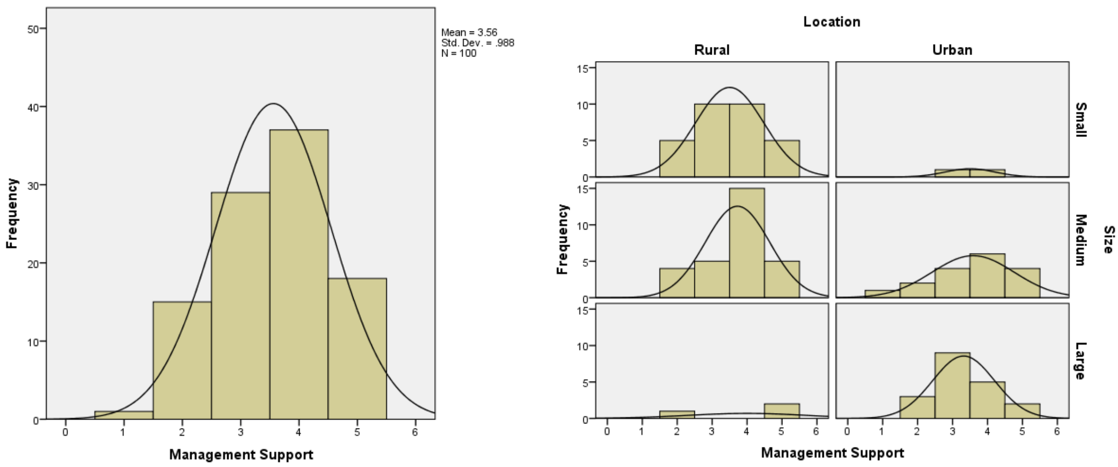


Figure 32: Management support descriptive statistics

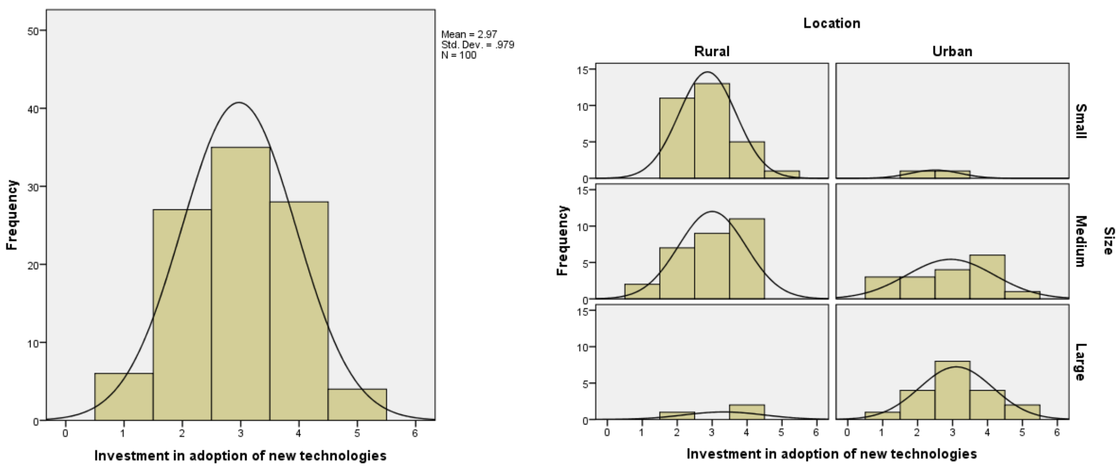


Figure 33: Investment in adoption of new technologies descriptive statistics

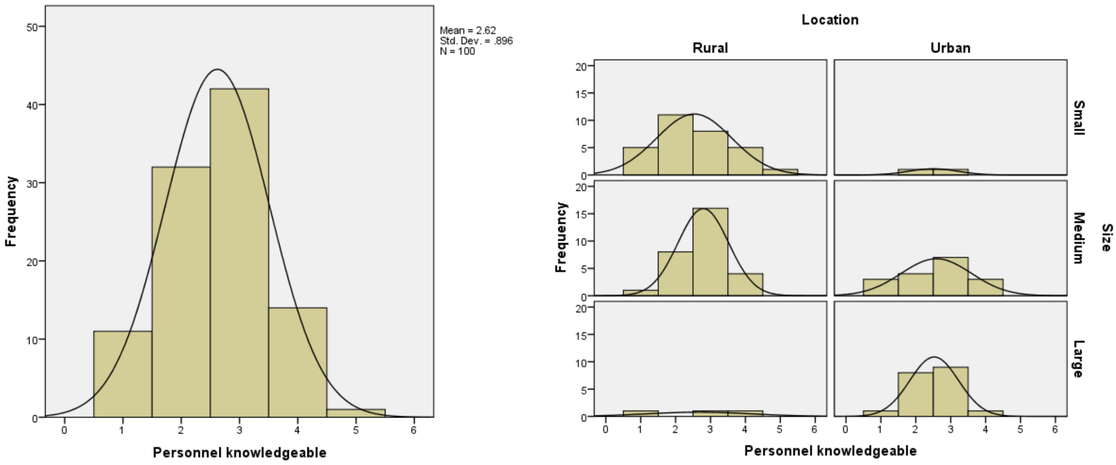


Figure 34: Personnel knowledgeable descriptive statistics

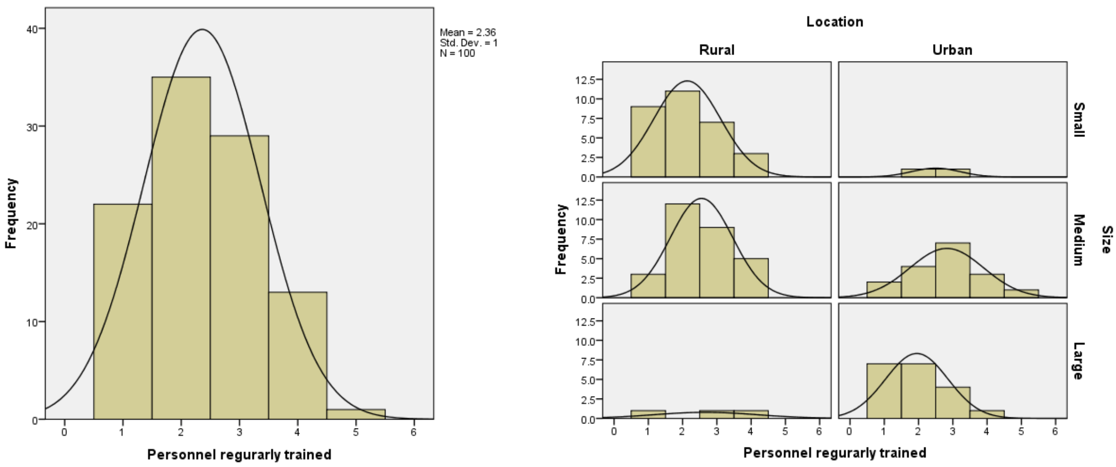


Figure 35: Personnel regularly trained descriptive statistics

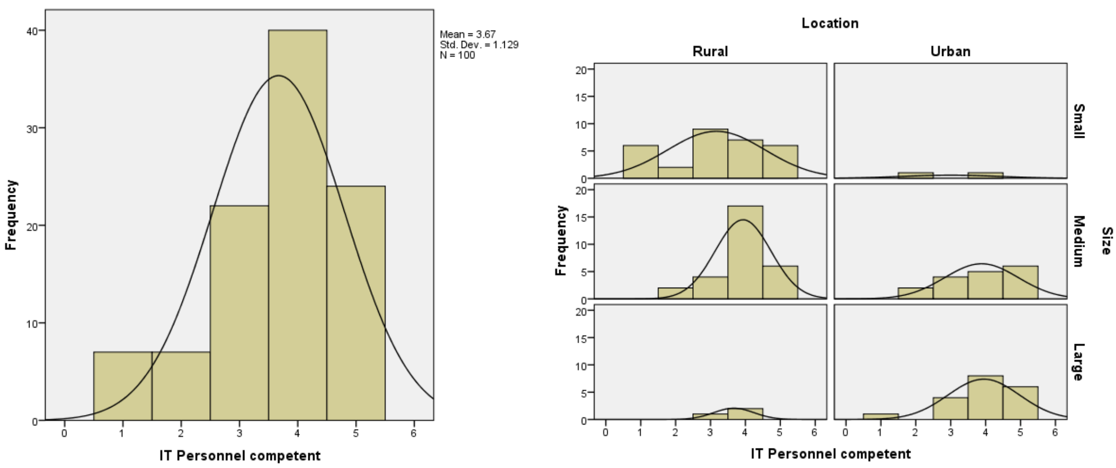


Figure 36: IT personnel competent descriptive statistics

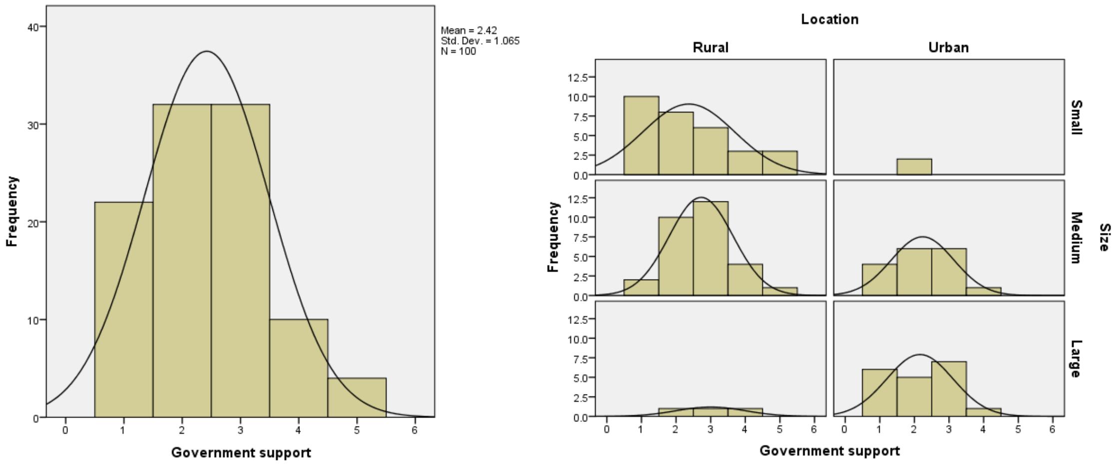


Figure 37: Government support descriptive statistics

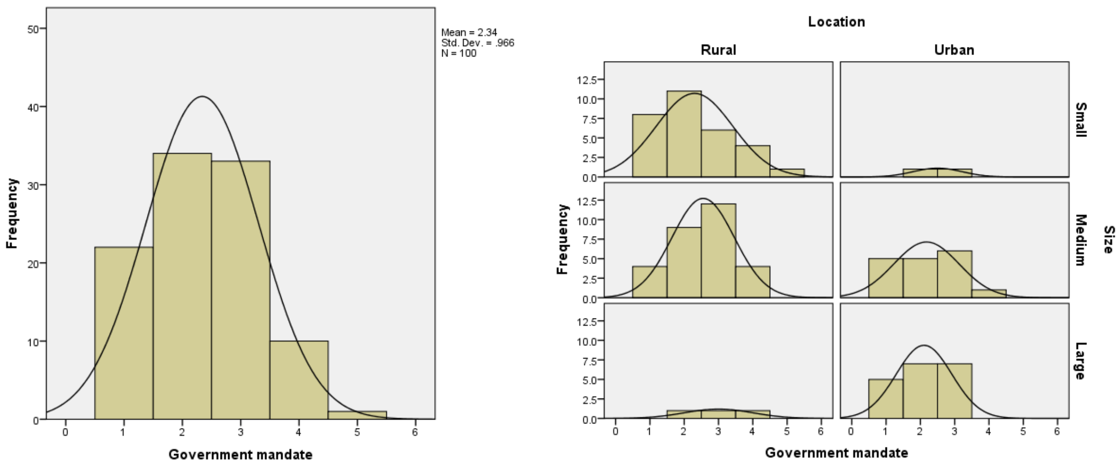


Figure 38: Government mandate descriptive statistics

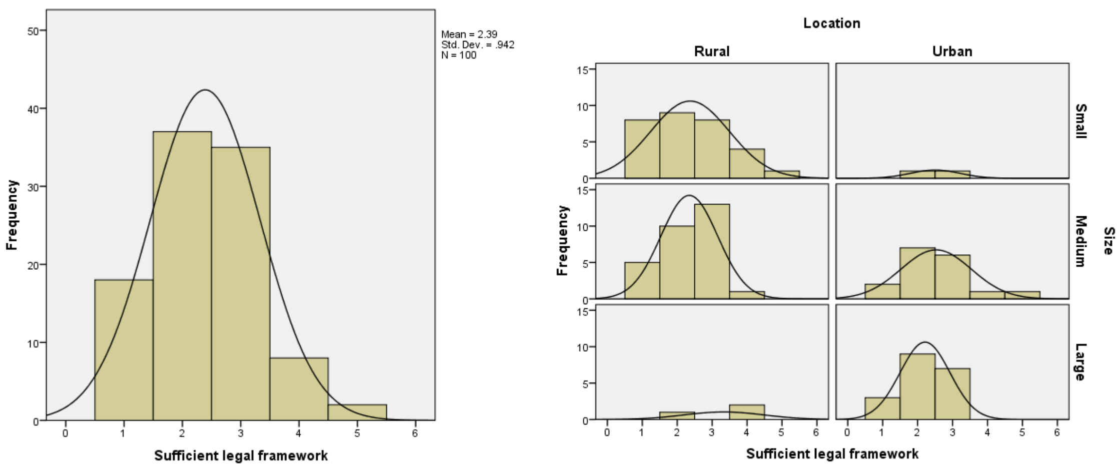


Figure 39: Sufficient legal framework descriptive statistics

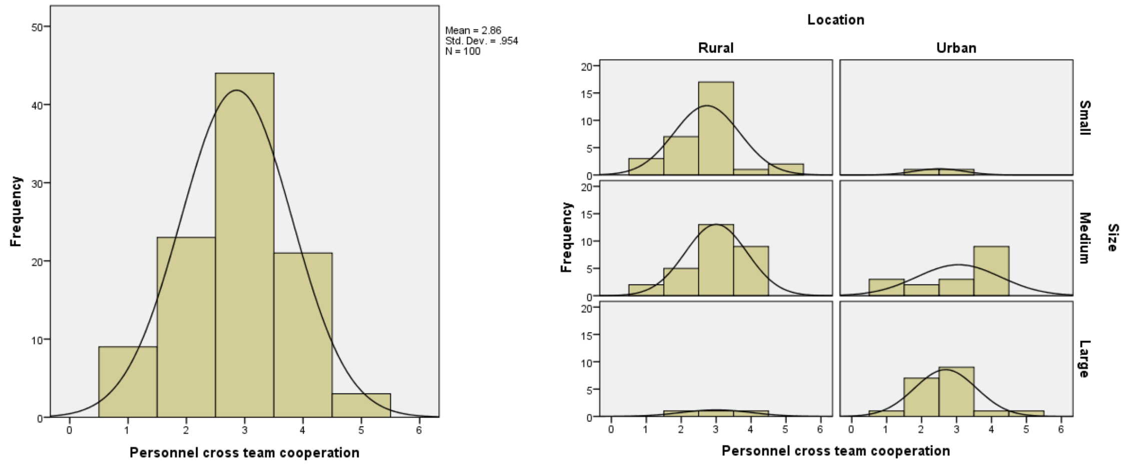


Figure 40: Personnel cross team cooperation descriptive statistics

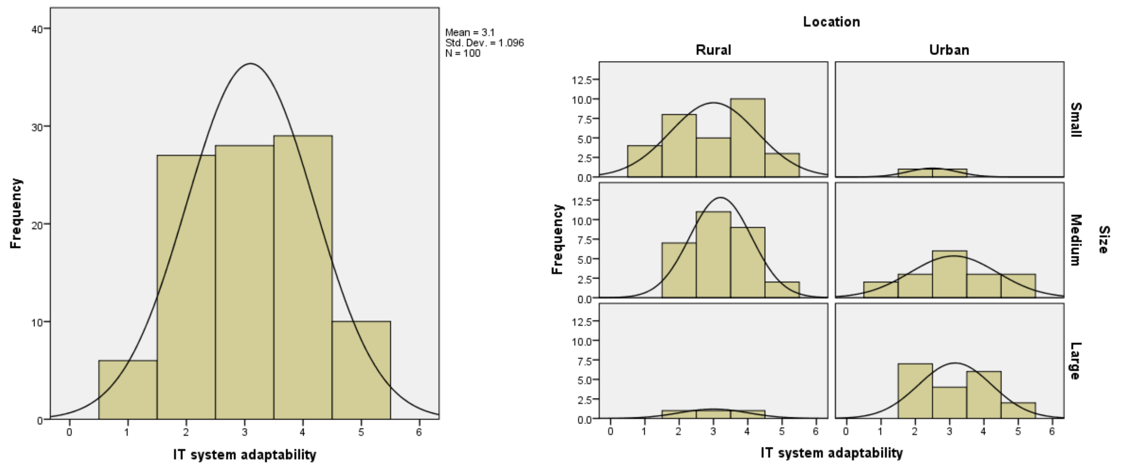


Figure 41: IT system adaptability descriptive statistics

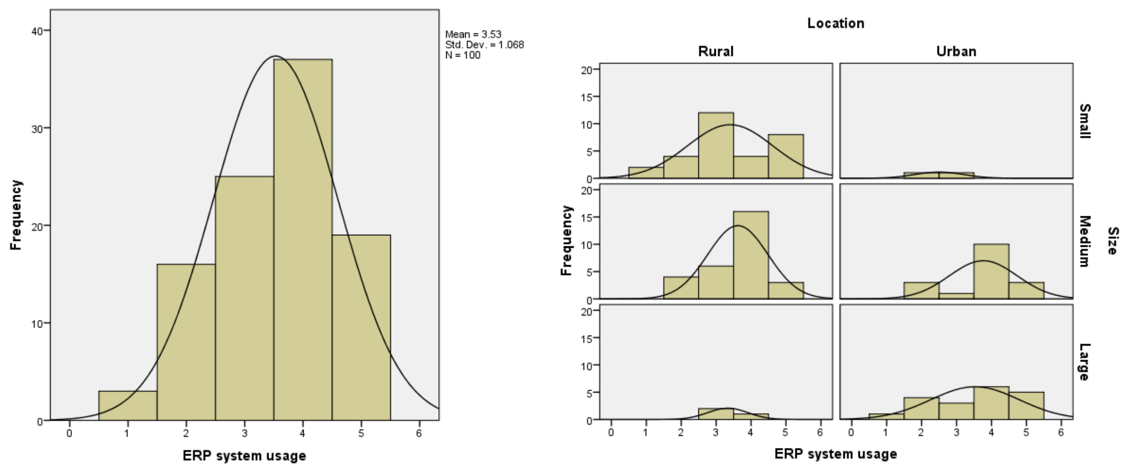


Figure 42: ERP system usage descriptive statistics

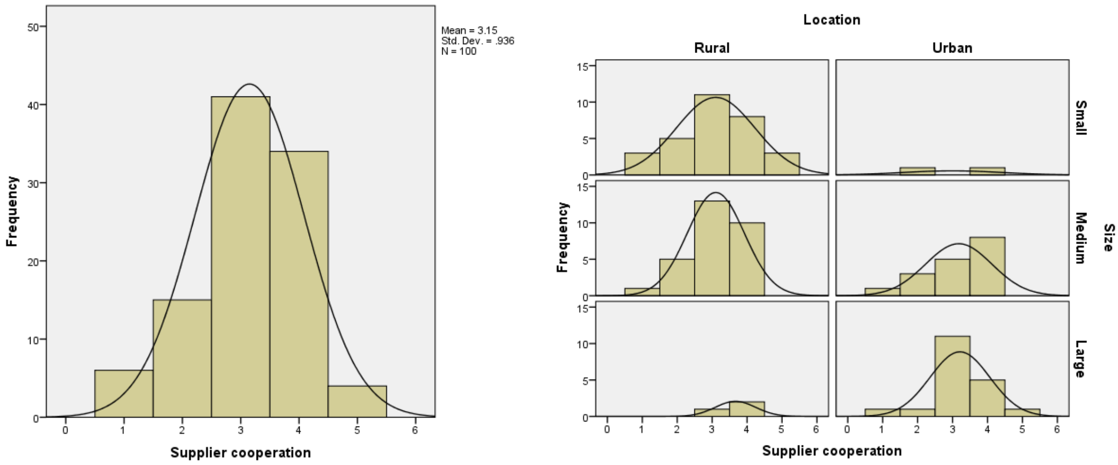


Figure 43: Supplier cooperation descriptive statistics

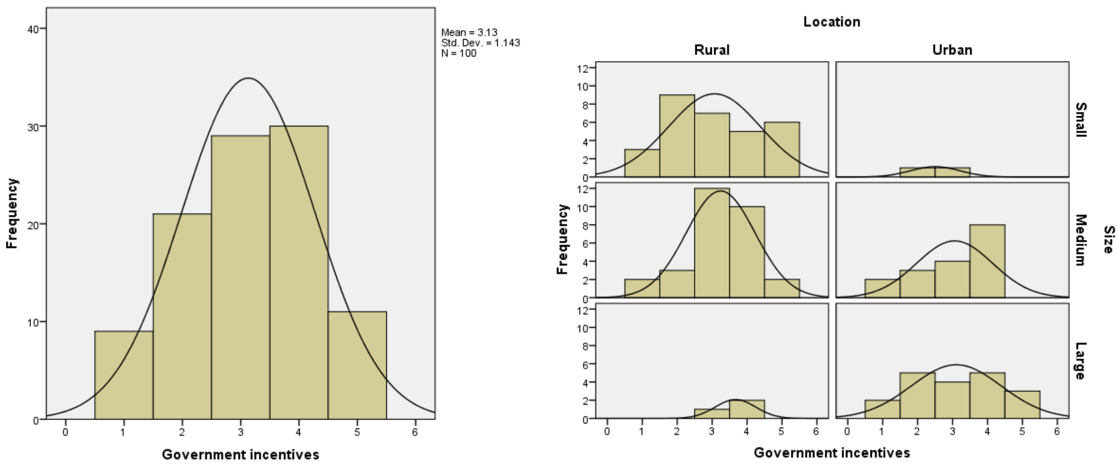


Figure 44: Government incentives descriptive statistics

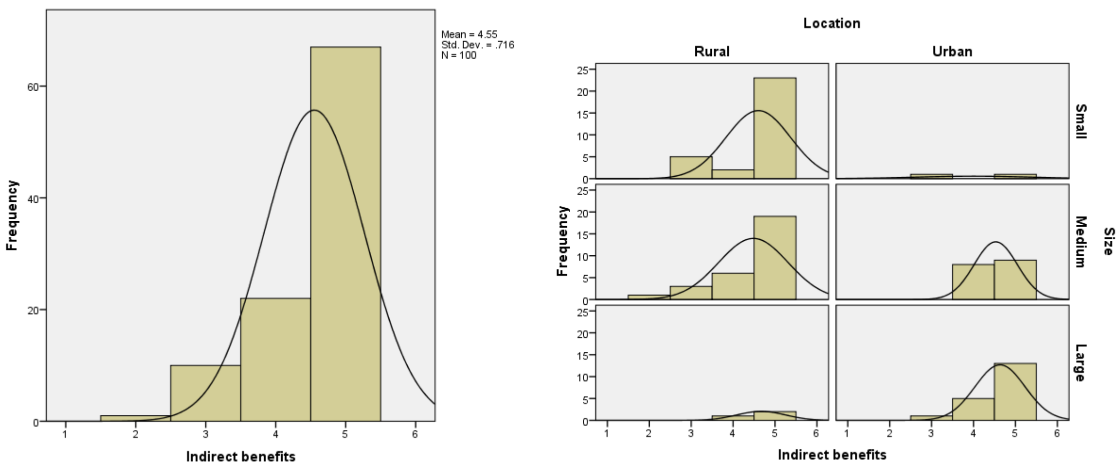


Figure 45: Indirect benefits descriptive statistics

4.4.5 The role of ERP systems

The analysis of the data revealed additional information regarding the role of ERP systems in the extent of adoption of SCMP. The critical role of ERP systems in the initial adoption and full exploitation of SCMP was initially verified as part of the two case studies that were performed in the qualitative phase of the research. The existence of an ERP system and the historical data contained within this system enabled the implementation of SCMP such as data segmentation, demand forecasting and inventory replenishment optimization processes. The availability of standard functionality and standard reporting tools within these systems were crucial to the successful implementation of SCMP. This supports the argument that the inter-departmental and multi-organizational nature of supply chains makes effective management very difficult for businesses that lack the right resources and highlights the crucial role of ERP systems in the creation and implementation of a more efficient supply chain process.

The quantitative phase and the data analysis also confirmed that ERP systems play a key role in several aspects of the creation and maintenance of superior SCM processes in hospitals. Significant correlations were found between the use of ERP systems and the adoption of SCMP as can be seen in the following correlation analysis.

		KPI Tracking	ERP System Usage
KPI Tracking	Pearson Correlation	1	,210*
	Sig. (2-tailed)		,036
	N	100	100
ERP System Usage	Pearson Correlation	,210*	1
	Sig. (2-tailed)	,036	
	N	100	100

*. Correlation is significant at the 0.05 level (2-tailed).

Table 20: Correlation between KPI tracking and reporting and ERP system usage

		Inventory replenishment optimization	ERP System Usage
Inventory replenishment optimization	Pearson Correlation	1	,288**
	Sig. (2-tailed)		,004
	N	100	100
ERP System Usage	Pearson Correlation	,288**	1
	Sig. (2-tailed)	,004	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Table 21: Correlation between inventory replenishment optimization and ERP system usage

		Data segmentation	ERP System Usage
Data segmentation	Pearson Correlation	1	,354**
	Sig. (2-tailed)		,000
	N	100	100
ERP System Usage	Pearson Correlation	,354**	1
	Sig. (2-tailed)	,000	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Table 22: Correlation between data segmentation and ERP system usage

		Demand forecasting	ERP System Usage
Demand forecasting	Pearson Correlation	1	,281**
	Sig. (2-tailed)		,005
	N	100	100
ERP System Usage	Pearson Correlation	,281**	1
	Sig. (2-tailed)	,005	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Table 23: Correlation between demand forecasting and ERP system usage

		Supplier evaluation	ERP System Usage
Supplier evaluation	Pearson Correlation	1	,144
	Sig. (2-tailed)		,153
	N	100	100
ERP System Usage	Pearson Correlation	,144	1
	Sig. (2-tailed)	,153	
	N	100	100

Table 24: Correlation between supplier evaluation and ERP system usage

		Web-based procurement	ERP System Usage
Web-based procurement	Pearson Correlation	1	,224*
	Sig. (2-tailed)		,025
	N	100	100
ERP System Usage	Pearson Correlation	,224*	1
	Sig. (2-tailed)	,025	
	N	100	100

*. Correlation is significant at the 0.05 level (2-tailed).

Table 25: Correlation between web-based procurement and ERP system usage

		Asset tracking	ERP System Usage
Asset tracking	Pearson Correlation	1	,296**
	Sig. (2-tailed)		,003
	N	100	100
ERP System Usage	Pearson Correlation	,296**	1
	Sig. (2-tailed)	,003	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Table 26: Correlation between asset tracking and ERP system usage

		Supplier integration	ERP System Usage
Supplier integration	Pearson Correlation	1	,256*
	Sig. (2-tailed)		,010
	N	100	100
ERP System Usage	Pearson Correlation	,256*	1
	Sig. (2-tailed)	,010	
	N	100	100

*. Correlation is significant at the 0.05 level (2-tailed).

Table 27: Correlation between supplier integration and ERP system usage

Overall, the results of the qualitative as well as the quantitative phase of the research confirmed that ERP systems offer (1) visibility on all aspects of the supply chain, (2) easier and more flexible ways to establish and alter the parameters within which a supply chain is required to operate, (3) the ability to monitor and execute supply chain activities in real-time, which is essential for staying competitive and ensuring cost-effective operations, and (4) superior information aggregation and organization to ensure that any undesirable variances throughout the supply chain are quickly identified and effectively addressed.

5 Discussion and implications

As healthcare settings are facing increasing cost pressures while being expected to uphold high standards of care, adopting and assimilating SCMP to improve their supply chain activities becomes imperative. However, despite the significance and urgency of operational efficiency improvements, they remain a relatively low researched topic within the healthcare context (Dobrzykowski et al., 2014). Furthermore, while there appears to be an increasing belief in the value of SCMP, healthcare managers claim they do not know the return they gain through their application. In an attempt to contribute towards filling these gaps, the present thesis aimed at extending the understanding of SCMP adoption in hospitals by identifying factors of influence and by assessing their impact on the hospitals' cost performance.

The results of the analysis empirically confirmed a significant relationship between SCMP adoption and hospital cost performance. This finding is of paramount importance because hospitals, like every other firm, need to show the business value derived from the application of SCMP and their enabling technologies and it has significant implications that will be discussed in the next sections. Furthermore, with respect to the major drivers for SCMP adoption in hospital supply chains, the study found support for the following four: (1) technological readiness, (2) organizational readiness, (3) hospital size, and (4) perceived benefits. While several research efforts have provided support for the impact of these factors on the adoption of single technologies in various other traditional sectors, the present thesis verified their link with the overall adoption of relevant SCMP within hospital supply chains, while highlight the healthcare sector's unique organizational, technological and environmental characteristics that influence these relationships.

The technological context of the SCMP adoption research framework was confirmed, as IT infrastructure and IT expertise, reflecting the hospitals technological readiness, were found to play a significant role. This implies that hospitals with an established, integrated technology infrastructure and skilled IT resources are better suited for SCMP adoption. The critical role of technological readiness was suggested by a variety of other studies in the past which investigated the adoption of specific technologies, such as EDI, RFID and e-procurement, in various business sectors, healthcare being among them (Wang et al., 2010; Zhu et al., 2003; Chwelos et al., 2001). The present thesis moved beyond this traditionally narrow single technology focus as it confirms the positive impact of technological readiness on the extent of overall SCMP adoption in hospital supply chains, encompassing all technologies relevant to SCM related processes in hospitals.

Similarly, the organizational context of the research framework found significant support, as the thesis provided empirical evidence on the key role of a hospital's organizational readiness in adopting SCMP in its supply chain processes and functions. The findings suggest that hospitals with a positive stance towards innovation and change, with a strong learning culture and with upper management that supports related initiatives by committing the necessary financial and organizational resources, are more likely to implement and fully exploit SCMP. This is consistent with other scholars' findings that highlight the direct impact of organizational context factors on the adoption of single technologies (Shao et al., 2016). Expanding the explanatory power of factors within the organizational context, the results of the present thesis highlight the amplified role of organizational readiness on the extent of overall SCMP adoption in hospitals.

Moreover, another factor within the organizational context that proved to significantly impact SCMP adoption, albeit to a lesser extent compared to the organizational readiness, is hospital size. Prior studies report findings that support insignificant correlations, positive correlations or even negative correlations between organizational size and technology adoption. The present thesis suggests that larger hospitals are more likely to adopt SCMP and expand their depth, a finding that can be attributed to economies of scale, which enhance the feasibility of adoption (Sultz and Young, 2014), and to the fact that larger hospitals tend to enjoy resource advantages (Rogers, 1995) as is the case for the Greek public healthcare sector.

The role of the third pillar of technology adoption, the environmental context, could not be confirmed in the thesis. Neither the influence of government policies, nor the influence of business partners proved to have a significant impact on SCMP adoption in Greek public hospitals. Public hospitals in Greece operate under a tight regulatory framework, however no indications could be found that healthcare related governmental policies and legislation prioritize or even acknowledge the importance of SCMP adoption. An exception to this rule are the governmental policies launched towards the use of e-procurement technologies, mainly due to negative publicity resulting from high drug and medical supplies purchasing prices compared to other EU countries in spite of the country's severe financial crisis. However, these initiatives proved to be fragmentary and inconclusive. The second environmental factor, the influence of business partners, could not be confirmed either. This might be attributable to lack of trust and collaboration between hospitals and their suppliers. Contrary to other industries, where suppliers are considered true partners within the supply chain, rather than just vendors, the healthcare sector lags behind in recognizing their critical contribution to the ongoing and sustainable success of a business. Another possible reason could be that several SCMP are not necessarily relying on business partner involvement. Unlike supplier integration and web based procurement, which can be considered business partner intensive, other SCMP clusters largely rely on a hospital's internal expertise and willingness to apply and utilize existing technologies for the benefit of improving SCM processes. Thus, the thesis fails to provide support for the role of business partners in a hospital's SCMP adoption.

The fourth contextual factor of the research model, the perceived benefits component, was confirmed, as the study's results indicate significant positive impact of expected direct and indirect benefits on SCMP adoption. This is in line with findings of other scholars who argue that expected benefits can provide motivation for SCMP implementation and expansion, because employee appreciation of new technologies' relative advantage influences the extent of their implementation (Lin and Lin, 2008; Gibbs and Kraemer, 2004). Apparently, this also holds true for hospitals albeit their complex decision making process which involves many stakeholders with different priorities.

Regarding the Greek healthcare sector in particular, the results indicate that despite the severe financial crisis and the resulting difficulties, certain public hospitals are leading the way to higher productivity and efficiency by adopting high levels of SCMP in their supply chain processes. They are demonstrating that determining factors such as knowledgeable and motivated employees, skilled IT professionals, positive attitude towards change and supportive upper management can compensate for limited financial resources, raising the bar for less productive hospitals.

5.1 Scholarly implications

From a theoretical standpoint, the thesis aimed at developing a holistic framework to enhance understanding of the contextual drivers of SCMP within the downstream element of the healthcare supply chain, ultimately driving improvements in operational cost performance. In this context, it offered several important insights and theoretical contributions. Firstly, it is one of the few studies that empirically examine hospital SCMP using a business performance lens. Despite increasing regulatory pressures for healthcare providers to improve the efficiency and effectiveness of their operational practices, specifically their supply chains, there has been a dearth of empirical work within this domain (Chen, 2013). In order to contribute towards filling this gap, this thesis aimed at advancing the current understanding of the contextual factors driving the adoption of SCMP and their performance outcomes in hospitals.

Secondly, although SCMP are considered key factors driving supply chain and overall organizational performance, there has been a lack of research that has employed an appropriate theoretical lens to empirically test such relationships. Therefore, responding to calls for more theory-driven empirical research on supply chain management (Chen, 2013), this thesis examines SCMP and their impact by developing and applying a conceptual framework that approaches SCMP adoption and the resulting cost performance via the established theoretical lens of the TOE theory along with the theory of perceived benefits. The proposed synthesized framework attempts to address weaknesses of technology adoption models that have been identified by scholars and differs from other frameworks as it a) expands existing models by adding new constructs, b) incorporates both organizational characteristics and personal beliefs components, c) includes elements of organizational performance and d) is adapted to the healthcare context. The results of the data analysis lend support for this synthesized TOE-based framework in explaining the determinants of SCMP adoption in hospital supply chains and their impact on cost performance.

Additionally, the thesis contributes significantly to the body of SCM and technology adoption research by expanding the knowledge frontier and introducing an integrated approach that goes beyond the traditional orientation on single technologies. Previous studies examine determinants of adoption by concentrating mostly on specific technologies and vary their research goals by focusing on different business sectors and different countries. In order to facilitate richer analysis, an integrated view is taken, (1) by investigating the full spectrum of technologies used to enable and support SCMP, and (2) by evaluating their aggregated impact on performance. The adoption of specific technologies, although important and linked to performance improvements as demonstrated in many cross country and cross industry studies, cannot lead to reaping the full benefits if it remains isolated. Adopting EDI technology in transacting with business partners, as an example, has obvious benefits, however how can it be fully exploited and assist in reaching an organization's business goals, if it is not supplemented by optimum replenishment strategies, improved accuracy in demand forecasting, data segmentation and supplier evaluation? Thus, the answer in realizing the full benefits of SCMP may lie in following an integrative approach in their implementation. Embracing this point of view, the focus is placed on a comprehensive set of SCMP applied in conjunction with their underlying technologies. Hence, the thesis advocates a shift in this research domain as to embrace a more holistic view of technology adoption in order to better understand how performance can be improved, thereby enriching the literature on the business value of SCM.

Another distinct aspect differentiating the present thesis from the majority of technology adoption studies, is that it emphasizes on the extent of adoption, rather than treating adoption as a dichotomous variable. The thesis claims that simply knowing whether a SCMP has been implemented decreases the informative value of studying its effects, as there can be major variations on how extensively it is used. Hence, this thesis contributes to the literature in this line of research by exploring the factors associated with both the adoption of SCMP and the extent of their usage and encourages other researchers to look beyond the mere adoption of a technology by digging deeper into its evolutionary process and its outcomes.

Moreover, the large spectrum and depth of SCMP evidenced in hospital supply chain processes and their evidenced impact on cost performance mitigates concerns that have been voiced regarding their transferability from other business sectors to healthcare delivery settings. Many of the problems associated with rising healthcare costs can be addressed through simple supply chain concepts that have been around for years and are widely used in other industries. To mention one example of SCMP adaptation to the healthcare context, the classic tool of ABC analysis, used to categorize materials in order to differentiate inventory management policies, can evolve to ABC-VED analysis in order to incorporate the healthcare specific component of clinical criticality of items (with VED representing vital, essential and desired items). Thus, it is asserted that the uniqueness and complexity of the healthcare supply chain should not be used as an excuse to justify the low extent and delay of SCMP adoption compared to other business sectors. SCMP are transferable to hospital supply chains; thus, it is rather a matter of acknowledging their value and ensuring that the right conditions are in place to enable and support their adoption and full exploitation.

5.2 Managerial implications

With respect to practitioners, and hospital supply chain stakeholders in particular, a major contribution of the thesis is that it provides empirical evidence of the cost benefits resulting from SCMP adoption. Although there seems to be a general consensus about the added value SCMP can have for health care organizations, it is based largely on assertion rather than demonstration (Shi and Yu, 2013). Making this added value more explicit by performance metrics as well as the conditions under which this added value emerges is without doubt one of the main challenges research on supply chain management in a healthcare context is facing (De Vries and Huijsman, 2011).

Aiming to address this challenge, the present thesis developed a holistic framework that investigated the determinants of SCMP adoption and empirically demonstrated their significant relationship with hospital cost performance, which is highly relevant for both OM theory and practice. The evidenced impact on organizational-level performance brings attention to this less explored area of study and reinforces the role of SCM as a strategic asset. The findings of the thesis are important because hospital managers, like managers of other organizations, need to show the value derived from the application of SCMP and the underlying technology investments. They imply that the issue of rising supply costs in hospitals, which comprise a large percentage of the total cost of care, can be counteracted by implementing a full array of SCMP in their supply chains. Thus, hospital management can better justify the investment in SCMP and their enabling technologies, which is often neglected as it competes with investment in clinical technologies.

From a practical perspective, the research findings have several other implications for supply chain executives, hospital top management, inventory managers, procurement managers, financial managers, pharmacists and healthcare practitioners. While some organizations have realized the importance of implementing SCMP, they often do not know exactly what to implement, due to a lack of understanding of what constitutes a comprehensive set of these practices (Gorane and Kant, 2017). It is especially important to identify the applicable SCMP in healthcare settings, as they operate in a highly unique and complex environment, requiring business practices be carefully tailored to fit with targeted outcomes and within given organizational contexts. Drawing on this necessity, the thesis identifies SCMP applicable to hospital supply chain operations and classifies them into suitable clusters. Following a holistic approach, all relevant practices supporting supply chain processes and the extent of their adoption were investigated. The findings suggest that healthcare managers should develop congruent operations strategies rather than concentrate on single decision areas and technologies as a key to improving a hospital's efficiency and performance. They should approach their supply chain with an integrated view, encouraging collaboration between the organization's functional areas involved as well as with external partners, and ensuring that these entities do not act as silos, which causes data and information important for efficient business operations to be fragmented. Hence, a key contribution of the thesis is that it shifts the focus of SCMP from functional to integrative encouraging hospital executives to view them as a strategic asset that can be leveraged to meet operational and financial performance imperatives.

In order to fully exploit the aforementioned opportunities, the thesis offers useful insights on technological and organizational aspects that need to be considered. One major area of focus for managers charged with achieving superior results is the hospital's technological readiness. Investments in IT infrastructure need to be sought, in order for the hospitals to be equipped with adequate hardware and powerful software applications, which act as a key enabler for the implementation of SCMP. Integration of systems and applications should be a priority, as it allows reaping the full benefits of this infrastructure. Equally important is the access to robust IT expertise as this goes hand in hand with the increasingly complex customization requirements of state of the art technological infrastructure. This can be achieved either by enhancing the knowledge of the existing IT personnel or by hiring new IT professionals with the required skill set, or even by outsourcing some of these functions to external specialists. These prerequisites for establishing technological readiness command a thorough understanding of the indispensable role of technology in SCMP adoption, as they are increasingly built around technologies.

Another key finding of the thesis is the elevated role of a hospital's organizational readiness, which has an even greater impact on SCMP adoption than technological readiness. Efforts to increase technological readiness will yield the expected results only if they are embedded within a learning and continuous improvement culture in the organization. Therefore, hospital executives should promote a pro innovation culture by encouraging suggestions for improvement, supporting learning processes, promoting current employees training programs, cultivating solution-seeking mentality and practicing fast decision making, fostering trust and respect in employees. They might convene frequent problem-solving and information-sharing sessions (formal and ad hoc) to reinforce transparency and collaboration between functional areas of the organization. Upper management support has been found to play a key direct role in SCMP adoption, suggesting managers should secure adequate financial and organizational resources, launch related initiatives, actively support the implementation projects and clear the way by removing barriers. Personnel attitude towards change is another component of organizational readiness, therefore hospital executives need to promote the positive impact of SCMP on the processes and tasks performed by the hospital's employees, alleviate possible concerns and provide incentives to personnel actively involved in their implementation. Finally, hospital size constitutes an additional factor within the organizational pillar that affects SCMP adoption, suggesting there is no one-size-fits-all approach. The aforementioned efforts are more likely to be fruitful if adapted to the different organizational contexts and the specific conditions met in small and in large hospitals.

Furthermore, findings indicate that hospital managers should not rely on external factors to positively impact SCMP adoption. Business partners and governmental policies might be influential on the adoption of a specific subset of SCMP, however no significant impact on the extent of their overall adoption could be confirmed. This should motivate hospital managers and suppliers to fill this gap by fostering relationships of collaboration and trust, which has been shown to be positively linked with supply chain performance and can be enabled through knowledge exchange (Chen et al., 2013).

Additionally, the important role of perceived direct and indirect benefits suggests that technology vendors should make greater and more targeted marketing efforts to let hospitals appreciate the benefits of SCMP adoption. The government as a major public health stakeholder, top management of healthcare institutions and the research community should engage in coordinated actions towards increasing awareness on SCMP. Greater understanding of their potential benefits and their positive impact on hospital performance, as well as greater knowledge of the technologies involved, may lead to faster, wider and deeper SCMP adoption.

Lastly, as empirically demonstrated that the adoption of SCMP leads to improved cost performance, it is important that practitioners are provided with guidance on how to successfully implement these practices in their hospitals. While this goes beyond the scope of the thesis, the readers' interest should be spurred by offering directions that should be applicable to the Greek healthcare sector. As part of the research conducted it was determined that SCMP practices have been adopted in many instances, however a catalyst is needed in order for them to be fully exploited. Based on the insights gained, introducing personnel accountability as well as supply chain related performance measures and linking such performance with a rewards systems would be pivotal to the implementation of these practices, and therefore encourage future research in this direction.

In conclusion, the present thesis advocates that the time has come for hospital executives to view SCM as a strategic asset and make supply chain an integral, not ancillary part, of their organization. The thesis' powerful insights on the adoption, assimilation and impact of hospitals' SCMP, and its important implications for theory and practice, exemplify the value and essentiality of SCM related research in the healthcare sector.

6 Limitations and future research

While this thesis makes important contributions to OM and SCM literature, it does not come without limitations, thus offering opportunities for further research. Difficulties in gathering data for Greek hospitals despite major efforts are the cause for some of these limitations. Although the largest fraction of public expenditure in the Greek healthcare sector is directed towards hospital care, no centralized systematic data collection on important qualitative and quantitative KPIs is taking place. Many hospitals were reluctant to provide data that could be used for benchmarking purposes as they are part of the Greek public sector, which is known for its inherent inefficiencies. Data collection was often slowed down by bureaucratic, extremely time consuming procedures or was not possible at all due to unavailability of data of interest, such as hospital case mix indices and data related to quality of care. The case mix index (CMI), a relative value assigned to a diagnosis-related group (DRG), reflects the diversity and clinical complexity of cases treated in a hospital, and would enable a more detailed level of cost performance evaluation by including case mix adjusted costs in the calculations. Moreover, availability of data related to hospital quality performance would facilitate the investigation of their relationship to SCMP. This would allow to confirm that SCMP adoption in a hospital's supply chain positively impacts quality of care. This continues to be the primary goal of public hospitals due to their mission criticality and their non-profit character, even in the case of the Greek public healthcare sector, which continues to operate in midst of a severe financial crisis. Nevertheless, the data collection process generated some important networking facets, which will hopefully assist in overcoming bureaucratic hurdles more easily in future research projects.

A further limitation resulted from the sparse availability of private hospital data. It was initially envisioned to assess the hypothesized model using a private vs. public control variable to examine potential differentiations; however, private hospitals proved to be very hesitant to providing related data. In order to overcome this issue, a different data collection strategy for private hospitals should be designed in a follow-up research phase. Their inclusion will expand the research model by allowing the inclusion of competitive pressure as an additional component within the environmental context. Furthermore, it will allow the inclusion of hospital ownership as a meaningful control variable into the model as the existence of empirically established relationships with other focal variables of the study are anticipated (Bernerth and Aguinis, 2016). Moreover, a second phase will equip the present research with a longitudinal dimension, as its current cross-sectional character constitutes a definite limitation, especially considering that the fit between SCMP and cost performance is a gradual process.

Furthermore, testing the model and the associated hypotheses using data collected from Greek public hospitals may limit the generalizability of the findings. The Greek public sector operates in an environment of resilient economic recession and is influenced by frequent shifts in the direction of governmental policies. Therefore, the findings should be cautiously extended to other contexts and the model should be tested in hospitals of other countries for potential variations in the results.

Finally, as in every research study examining relationships among variables, endogeneity and common method bias limitations cannot be ruled out completely. Potential informant bias and random errors are drawbacks common to survey research as the measures for some of the study's constructs are subjective (Schmidt and Hunter, 2014). A high effort was placed in dealing with these issues upfront during the conceptualization of the research framework and the methodology design. Additionally, it was attempted to assess their potential effects as part of the post hoc data analysis by performing suitable tests. As a result, a thesis of convincing robustness was presented that will spur further interest in exploring the business value of SCMP adoption and will hopefully encourage future OM scholars to leverage its findings to investigate additional SCM aspects within the healthcare sector.

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Appendices

Appendix A – Survey questionnaire

Survey on Hospital Supply Chain Management Practices (SCMP)	Hospital ID	

Please respond to all questions below based on the instructions sheet provided

The hospital is: Public ☐ Private ☐

Name of the hospital: ______________________________________

Size of the hospital (in number of beds):__________________________

Your role in the hospital:___________________________________

Years of experience in this function:____________________________

Your level of education:____________________________________

We thank you for your valuable time!!!

	SECTION A (please reply to all questions!!!)	1 (Not at all) to 5 (To full extent)				
		1	2	3	4	5
1	**The Hospital is monitoring SCM related Key Performance Indicators** (e.g. average inventory values, service levels, inventory turnover, range of coverage, on time deliveries)	☐	☐	☐	☐	☐
2	**The hospital has adopted SCMP for Inventory Replenishment** (e.g. MRP, reorder point (min/max) planning, EOQ, safety stock)	☐	☐	☐	☐	☐
3	**The hospital has adopted practices for SCM related data standardization and classification;** (e.g. use of standardized material coding, ABC Analysis, VED Analysis (Vital/Essential/Desired))	☐	☐	☐	☐	☐
4	**The hospital has adopted SCMP for demand management and forecasting** (e.g. forecasting tools to predict demand based on historical data and prognosis models)	☐	☐	☐	☐	☐
5	**The hospital has adopted systematic Supplier Evaluation practices** (Supplier evaluation based on criteria such as pricing, on time deliveries, compliance with quality standards)	☐	☐	☐	☐	☐
6	**The hospital has adopted e-Procurement practices** (such as e-Purchasing, e-Auctions, e-RFx, e-Catalogues)	☐	☐	☐	☐	☐
7	**The hospital has adopted SCM related automatic identification and data capture practices** (e.g. Barcodes, RFIDs))	☐	☐	☐	☐	☐
8	**The hospital has adopted supplier collaboration practices** (e.g. EDI (Electronic Data Interchange), VMI (Vendor Managed Inventory), consignment stocks)	☐	☐	☐	☐	☐

Please add any comment that you would like to share regarding the survey: ____________________

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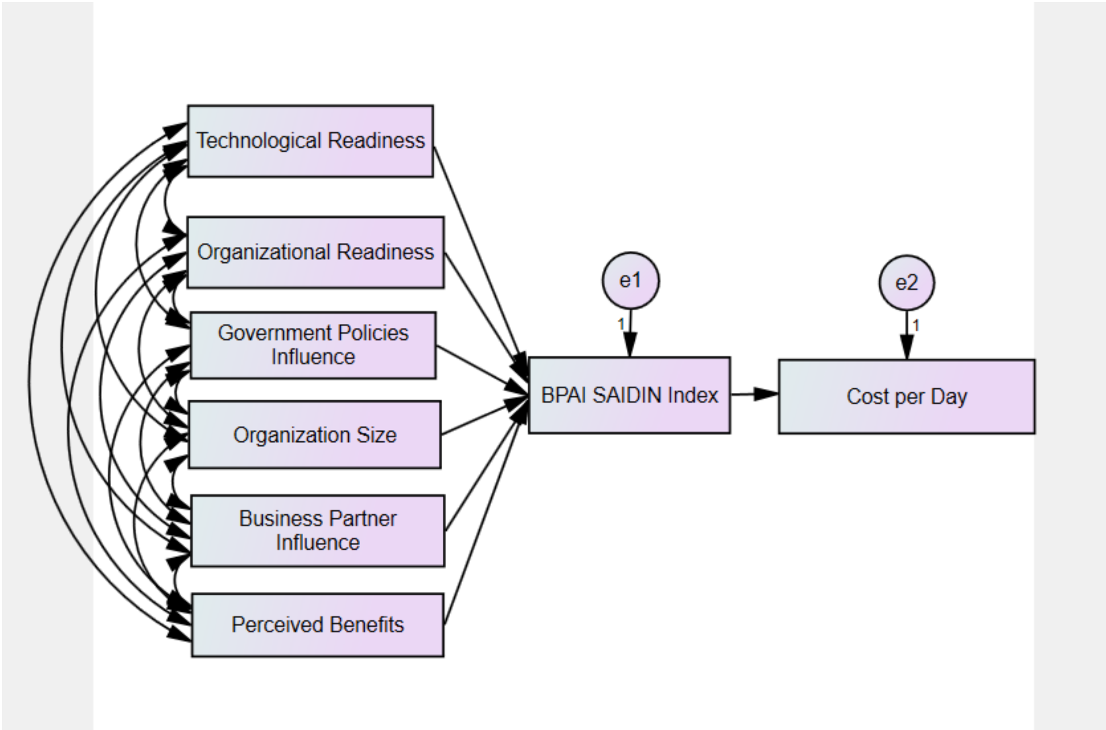
SECTION B (please reply to all questions!!!)		1 (Not at all) to 5 (Completely)				
		1	2	3	4	5
1	Do you personally believe that the adoption of SCMP reduces your hospital's supply chain costs?	☐	☐	☐	☐	☐
2	Do you personally believe that the adoption of SCMP improves your hospital's supply chain processes?	☐	☐	☐	☐	☐
3	Do you personally believe that the adoption of SCMPs improves your hospital's quality of care?	☐	☐	☐	☐	☐
4	Do you personally believe that the adoption of SCMP provides indirect benefits to your hospital (transparency, planning, coordination, decision making etc.)?	☐	☐	☐	☐	☐
5	Are your hospital's SW and HW resources sufficient to support the management of your supply chain?	☐	☐	☐	☐	☐
6	Do your hospital's employees have a positive attitude towards adoption of new technologies?	☐	☐	☐	☐	☐
7	Do your hospital's suppliers have the capability to support the adoption of SCMP?	☐	☐	☐	☐	☐
8	Is the level of internal IT systems integration adequate to support the hospital's business processes?	☐	☐	☐	☐	☐
9	Do your hospital's suppliers encourage you to adopt SCMP?	☐	☐	☐	☐	☐
10	Does the government mandate that your hospital adopts SCMP?	☐	☐	☐	☐	☐
11	Does senior management encourage and support the adoption of new technologies in your hospital?	☐	☐	☐	☐	☐
12	Are your hospital's employees knowledgeable regarding new technologies?	☐	☐	☐	☐	☐
13	Do your hospital's suppliers demand that you adopt SCMP?	☐	☐	☐	☐	☐
14	Do your hospital's IT systems enable integration with external systems?	☐	☐	☐	☐	☐
15	Does your hospital invest in the adoption of new technologies?	☐	☐	☐	☐	☐
16	Does the government support the adoption of SCMP in your hospital?	☐	☐	☐	☐	☐
17	Are your hospital's IT systems adaptable to new requirements?	☐	☐	☐	☐	☐
18	Do the employees of your hospital's IT department have adequate competencies to support new technologies?	☐	☐	☐	☐	☐
19	Does the government provide a sufficient legislative framework that enables your hospital to adopt SCMP?	☐	☐	☐	☐	☐
20	Do employees from different departments cooperate to improve the hospital's business processes?	☐	☐	☐	☐	☐
21	Are your hospital's employees receiving regular training?	☐	☐	☐	☐	☐
22	Does your hospital use an ERP system that fully exploits its capabilities?	☐	☐	☐	☐	☐
23	Are your hospital's suppliers willing to cooperate in order to improve supply chain processes?	☐	☐	☐	☐	☐
24	Does the government provide incentives for the adoption of SCMP in your hospital?	☐	☐	☐	☐	☐

Appendix B1 – AMOS structural model



Appendix B2 –AMOS structural model fit

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	30	6,646	6	,355	1,108
Saturated model	36	,000	0		
Independence model	8	196,934	28	,000	7,033

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	2,500	,984	,904	,164
Saturated model	,000	1,000		
Independence model	28,910	,590	,472	,459

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	,966	,843	,997	,982	,996
Saturated model	1,000		1,000		1,000
Independence model	,000	,000	,000	,000	,000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	,214	,207	,213
Saturated model	,000	,000	,000
Independence model	1,000	,000	,000

NCP

Model	NCP	LO 90	HI 90
Default model	,646	,000	11,283
Saturated model	,000	,000	,000
Independence model	168,934	128,126	217,233

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	,067	,007	,000	,114
Saturated model	,000	,000	,000	,000
Independence model	1,989	1,706	1,294	2,194

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	,033	,000	,138	,507
Independence model	,247	,215	,280	,000

AIC

Model	AIC	BCC	BIC	CAIC
Default model	66,646	72,646	144,801	174,801
Saturated model	72,000	79,200	165,786	201,786
Independence model	212,934	214,534	233,775	241,775

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	,673	,667	,781	,734
Saturated model	,727	,727	,727	,800
Independence model	2,151	1,739	2,639	2,167

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	188	251
Independence model	21	25

Appendix B3 –AMOS structural model estimates

Estimates (Group number 1 - Default model)

Scalar Estimates (Group number 1 - Default model)

Maximum Likelihood Estimates

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
BPSAIDIN	<---	M1GP	,261	,408	,640	,522	
BPSAIDIN	<---	M4OR	1,347	,495	2,721	,007	
BPSAIDIN	<---	M5BR	,510	,474	1,076	,282	
BPSAIDIN	<---	SIZE13	,737	,359	2,052	,040	
BPSAIDIN	<---	M2PB	,832	,408	2,040	,041	
BPSAIDIN	<---	M3IR	,980	,474	2,069	,039	
CostDay	<---	BPSAIDIN	-13,708	2,780	-4,931	***	

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
BPSAIDIN	<---	M1GP	,064
BPSAIDIN	<---	M4OR	,274
BPSAIDIN	<---	M5BR	,094
BPSAIDIN	<---	SIZE13	,164
BPSAIDIN	<---	M2PB	,173
BPSAIDIN	<---	M3IR	,222
CostDay	<---	BPSAIDIN	-,444

Covariances: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
M1GP	<-->	M3IR	,366	,078	4,704	***	
M3IR	<-->	M2PB	,056	,059	,955	,340	
M5BR	<-->	M3IR	,160	,054	2,952	,003	
M1GP	<-->	M2PB	,196	,066	2,977	,003	
M1GP	<-->	M5BR	,192	,059	3,259	,001	
M4OR	<-->	M2PB	,080	,053	1,514	,130	
M4OR	<-->	M5BR	,160	,049	3,249	,001	
M4OR	<-->	SIZE13	,064	,057	1,131	,258	
M5BR	<-->	SIZE13	,037	,051	,733	,464	
SIZE13	<-->	M2PB	-,031	,057	-,541	,588	
M5BR	<-->	M2PB	,127	,049	2,577	,010	
M1GP	<-->	SIZE13	,095	,068	1,403	,161	
M1GP	<-->	M4OR	,265	,067	3,951	***	
SIZE13	<-->	M3IR	,111	,064	1,746	,081	
M4OR	<-->	M3IR	,343	,067	5,127	***	

Correlations: (Group number 1 - Default model)

			Estimate
M1GP	<-->	M3IR	,537
M3IR	<-->	M2PB	,096
M5BR	<-->	M3IR	,311
M1GP	<-->	M2PB	,314
M1GP	<-->	M5BR	,347
M4OR	<-->	M2PB	,154
M4OR	<-->	M5BR	,346
M4OR	<-->	SIZE13	,114
M5BR	<-->	SIZE13	,074
SIZE13	<-->	M2PB	-,054
M5BR	<-->	M2PB	,268
M1GP	<-->	SIZE13	,142
M1GP	<-->	M4OR	,433
SIZE13	<-->	M3IR	,178
M4OR	<-->	M3IR	,601

Variances: (Group number 1 - Default model)

	Estimate	S.E.	C.R.	P	Label
M1GP	,734	,104	7,036	***	
M4OR	,512	,073	7,036	***	
M5BR	,419	,059	7,036	***	
SIZE13	,612	,087	7,036	***	
M3IR	,634	,090	7,036	***	
M2PB	,532	,076	7,036	***	
e1	7,460	1,060	7,036	***	
e2	9447,432	1342,799	7,036	***	

Squared Multiple Correlations: (Group number 1 - Default model)

	Estimate
BPSAIDIN	,396
CostDay	,197

Appendix B4 –AMOS structural model notes

Notes for Model (Default model)

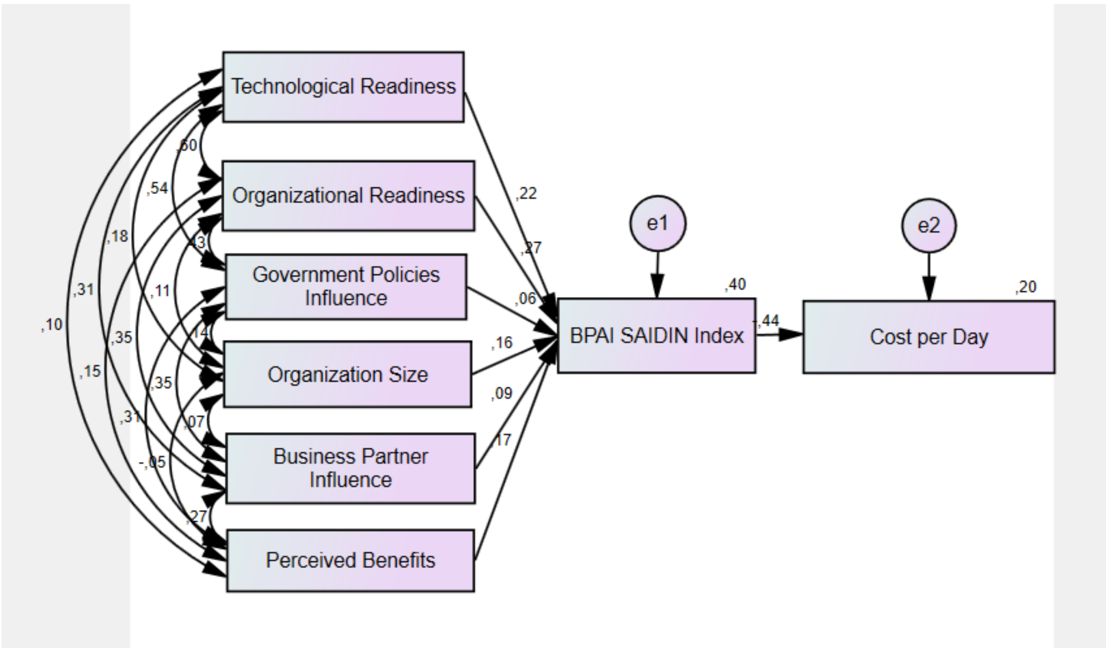
Computation of degrees of freedom (Default model)

Number of distinct sample moments:	36
Number of distinct parameters to be estimated:	30
Degrees of freedom (36 - 30):	6

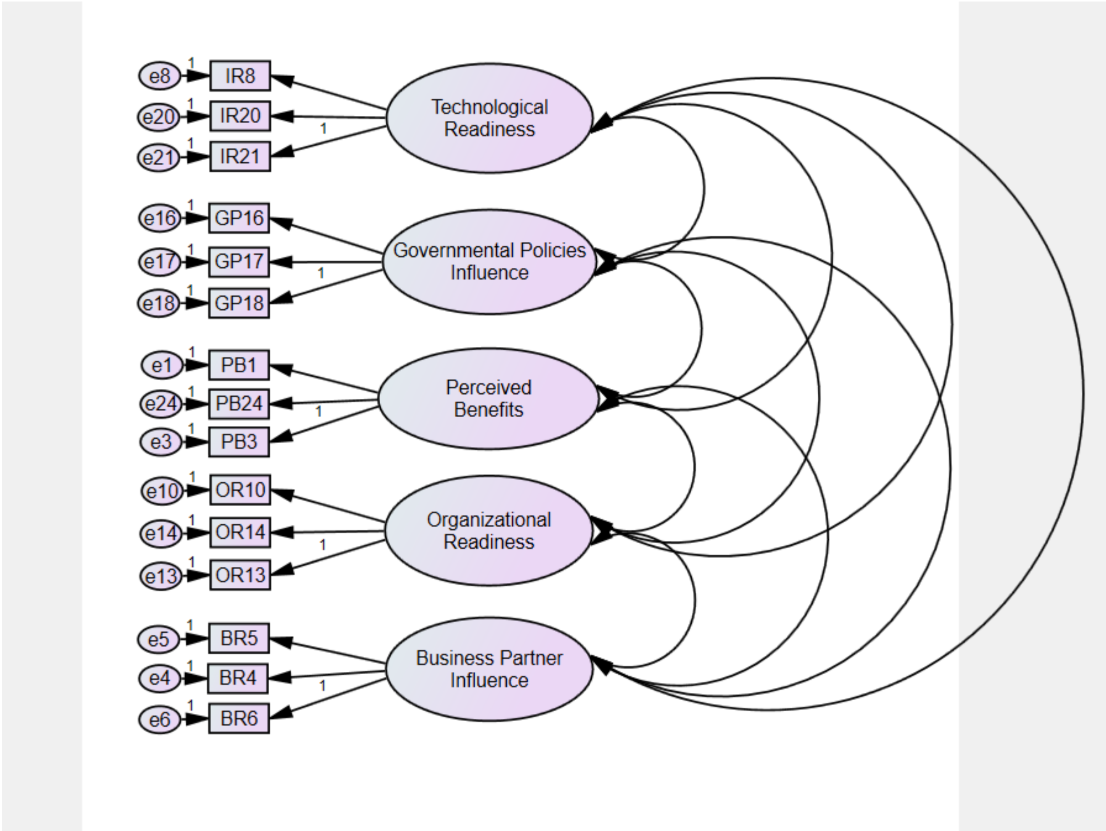
Result (Default model)

Minimum was achieved
Chi-square = 6,646
Degrees of freedom = 6
Probability level = ,355

Appendix B5 –AMOS structural model results (standardized)



Appendix B6 –AMOS measurement model



Appendix B7 –AMOS measurement model fit

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	40	83,758	80	,365	1,047
Saturated model	120	,000	0		
Independence model	15	617,281	105	,000	5,879

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	,058	,901	,851	,601
Saturated model	,000	1,000		
Independence model	,273	,443	,364	,388

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	,864	,822	,993	,990	,993
Saturated model	1,000		1,000		1,000
Independence model	,000	,000	,000	,000	,000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	,762	,659	,756
Saturated model	,000	,000	,000
Independence model	1,000	,000	,000

NCP

Model	NCP	LO 90	HI 90
Default model	3,758	,000	29,794
Saturated model	,000	,000	,000
Independence model	512,281	437,812	594,251

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	,846	,038	,000	,301
Saturated model	,000	,000	,000	,000
Independence model	6,235	5,175	4,422	6,003

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	,022	,000	,061	,852
Independence model	,222	,205	,239	,000

AIC

Model	AIC	BCC	BIC	CAIC
Default model	163,758	179,180	267,965	307,965
Saturated model	240,000	286,265	552,620	672,620
Independence model	647,281	653,064	686,358	701,358

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	1,654	1,616	1,917	1,810
Saturated model	2,424	2,424	2,424	2,892
Independence model	6,538	5,786	7,366	6,597

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	121	133
Independence model	21	23

Appendix B7 –AMOS measurement model estimates

Estimates (Group number 1 - Default model)

Scalar Estimates (Group number 1 - Default model)

Maximum Likelihood Estimates

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
PB24	<---	PerceivedBenefits	,589	,115	5,114	***	
OR14	<---	OrganizationalReadiness	1,034	,165	6,271	***	
IR20	<---	TechnologicalReadiness	1,019	,131	7,752	***	
GP18	<---	GovernmentalPoliciesInfluence	1,000				
GP17	<---	GovernmentalPoliciesInfluence	1,329	,181	7,328	***	
GP16	<---	GovernmentalPoliciesInfluence	1,363	,192	7,094	***	
PB1	<---	PerceivedBenefits	1,200	,208	5,763	***	
IR21	<---	TechnologicalReadiness	1,000				
IR8	<---	TechnologicalReadiness	,855	,119	7,163	***	
PB3	<---	PerceivedBenefits	1,000				
BR4	<---	BusinessPartnerInfluence	1,215	,268	4,534	***	
BR5	<---	BusinessPartnerInfluence	2,032	,435	4,669	***	
OR13	<---	OrganizationalReadiness	1,000				
OR10	<---	OrganizationalReadiness	,793	,171	4,624	***	
BR6	<---	BusinessPartnerInfluence	1,000				

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
PB24	<---	PerceivedBenefits	,593
OR14	<---	OrganizationalReadiness	,755
IR20	<---	TechnologicalReadiness	,804
GP18	<---	GovernmentalPoliciesInfluence	,683
GP17	<---	GovernmentalPoliciesInfluence	,885
GP16	<---	GovernmentalPoliciesInfluence	,823
PB1	<---	PerceivedBenefits	,841
IR21	<---	TechnologicalReadiness	,810
IR8	<---	TechnologicalReadiness	,732
PB3	<---	PerceivedBenefits	,721
BR4	<---	BusinessPartnerInfluence	,615
BR5	<---	BusinessPartnerInfluence	,855
OR13	<---	OrganizationalReadiness	,815
OR10	<---	OrganizationalReadiness	,516
BR6	<---	BusinessPartnerInfluence	,580

Covariances: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
OrganizationalReadiness	<-->	BusinessPartnerInfluence	,104	,046	2,245	,025	
PerceivedBenefits	<-->	BusinessPartnerInfluence	,125	,049	2,545	,011	
BusinessPartnerInfluence	<-->	GovernmentalPoliciesInfluence	,102	,041	2,473	,013	
BusinessPartnerInfluence	<-->	TechnologicalReadiness	,028	,047	,584	,559	
OrganizationalReadiness	<-->	TechnologicalReadiness	,360	,093	3,878	***	
PerceivedBenefits	<-->	OrganizationalReadiness	,043	,066	,648	,517	
PerceivedBenefits	<-->	GovernmentalPoliciesInfluence	,162	,063	2,554	,011	
OrganizationalReadiness	<-->	GovernmentalPoliciesInfluence	,248	,070	3,552	***	
PerceivedBenefits	<-->	TechnologicalReadiness	,024	,076	,320	,749	
GovernmentalPoliciesInfluence	<-->	TechnologicalReadiness	,322	,084	3,829	***	

Correlations: (Group number 1 - Default model)

			Estimate
OrganizationalReadiness	<-->	BusinessPartnerInfluence	,325
PerceivedBenefits	<-->	BusinessPartnerInfluence	,398
BusinessPartnerInfluence	<-->	GovernmentalPoliciesInfluence	,364
BusinessPartnerInfluence	<-->	TechnologicalReadiness	,073
OrganizationalReadiness	<-->	TechnologicalReadiness	,575
PerceivedBenefits	<-->	OrganizationalReadiness	,083
PerceivedBenefits	<-->	GovernmentalPoliciesInfluence	,352
OrganizationalReadiness	<-->	GovernmentalPoliciesInfluence	,532
PerceivedBenefits	<-->	TechnologicalReadiness	,039
GovernmentalPoliciesInfluence	<-->	TechnologicalReadiness	,585

Variances: (Group number 1 - Default model)

	Estimate	S.E.	C.R.	P	Label
PerceivedBenefits	,514	,144	3,573	***	
OrganizationalReadiness	,528	,126	4,201	***	
BusinessPartnerInfluence	,192	,070	2,753	,006	
GovernmentalPoliciesInfluence	,410	,112	3,665	***	
TechnologicalReadiness	,741	,165	4,487	***	
e21	,388	,087	4,457	***	
e20	,421	,092	4,563	***	
e8	,469	,085	5,506	***	
e18	,468	,076	6,154	***	
e17	,200	,061	3,303	***	
e16	,362	,078	4,673	***	
e3	,475	,100	4,733	***	
e24	,329	,055	6,034	***	
e1	,307	,113	2,718	,007	
e13	,267	,077	3,479	***	
e14	,426	,095	4,500	***	
e10	,916	,143	6,421	***	
e6	,381	,064	5,940	***	
e4	,468	,083	5,657	***	
e5	,291	,135	2,164	,030	

Matrices (Group number 1 - Default model)

Residual Covariances (Group number 1 - Default model)

	BR5	BR4	BR6	OR10	OR14	OR13	PB1	PB24	PB3	GP16	GP17	GP18	IR8	IR20	IR21
BR5	,000														
BR4	-,001	,000													
BR6	,013	-,032	,000												
OR10	-,043	-,121	,106	,000											
OR14	-,051	-,049	,146	,039	,000										
OR13	-,015	-,002	,096	,000	-,009	,000									
PB1	,009	,106	-,122	,137	-,051	-,073	,000								
PB24	,024	,029	-,030	,092	-,024	-,046	,009	,000							
PB3	-,038	,071	-,034	,184	,095	,068	,001	-,020	,000						
GP16	-,043	,089	-,014	-,089	-,060	,032	-,075	-,011	,107	,000					
GP17	,034	,050	,010	-,058	-,053	,020	-,025	-,004	,085	,005	,000				
GP18	-,114	-,040	-,048	-,046	,114	,071	-,063	-,020	,097	-,002	-,007	,000			
IR8	,060	,049	,073	-,059	,156	,051	-,040	-,027	,016	-,017	,040	,076	,000		
IR20	-,089	-,046	,069	-,015	,025	-,038	-,025	,020	,102	-,009	-,040	,073	-,025	,000	
IR21	,000	-,020	,019	,048	-,073	-,038	,014	,014	-,050	,018	-,028	,001	-,006	,022	,000

Standardized Residual Covariances (Group number 1 - Default model)

	BR5	BR4	BR6	OR10	OR14	OR13	PB1	PB24	PB3	GP16	GP17	GP18	IR8	IR20	IR21
BR5	,000														
BR4	-,013	,000													
BR6	,151	-,462	,000												
OR10	-,363	-1,234	1,246	,000											
OR14	-,477	-,562	1,910	,327	,000										
OR13	-,156	-,029	1,395	,003	-,088	,000									
PB1	,077	1,169	-1,536	1,188	-,501	-,790	,000								
PB24	,316	,468	-,554	1,155	-,339	-,725	,109	,000							
PB3	-,355	,810	-,445	1,651	,951	,766	,012	-,252	,000						
GP16	-,376	,943	-,168	-,726	-,538	,318	-,671	-,140	,990	,000					
GP17	,321	,590	,136	-,522	-,516	,217	-,242	-,051	,863	,038	,000				
GP18	-1,139	-,482	-,664	-,428	1,169	,805	-,645	-,291	1,017	-,020	-,069	,000			
IR8	,572	,564	,960	-,508	1,482	,532	-,386	-,379	,161	-,153	,385	,767	,000		
IR20	-,778	-,484	,830	-,123	,219	-,367	-,221	,261	,937	-,075	-,353	,674	-,196	,000	
IR21	,004	-,216	,230	,395	-,644	-,375	,131	,186	-,473	,150	-,256	,010	-,049	,161	,000

Appendix B8 –AMOS measurement model notes

Notes for Model (Default model)

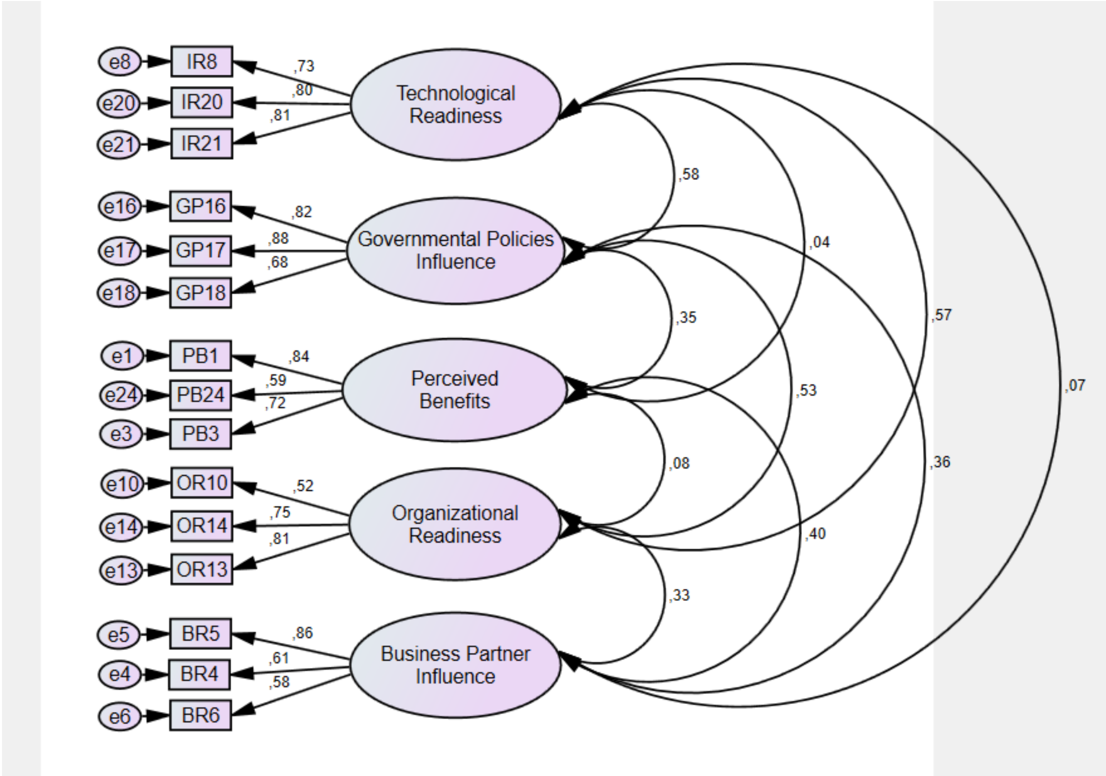
Computation of degrees of freedom (Default model)

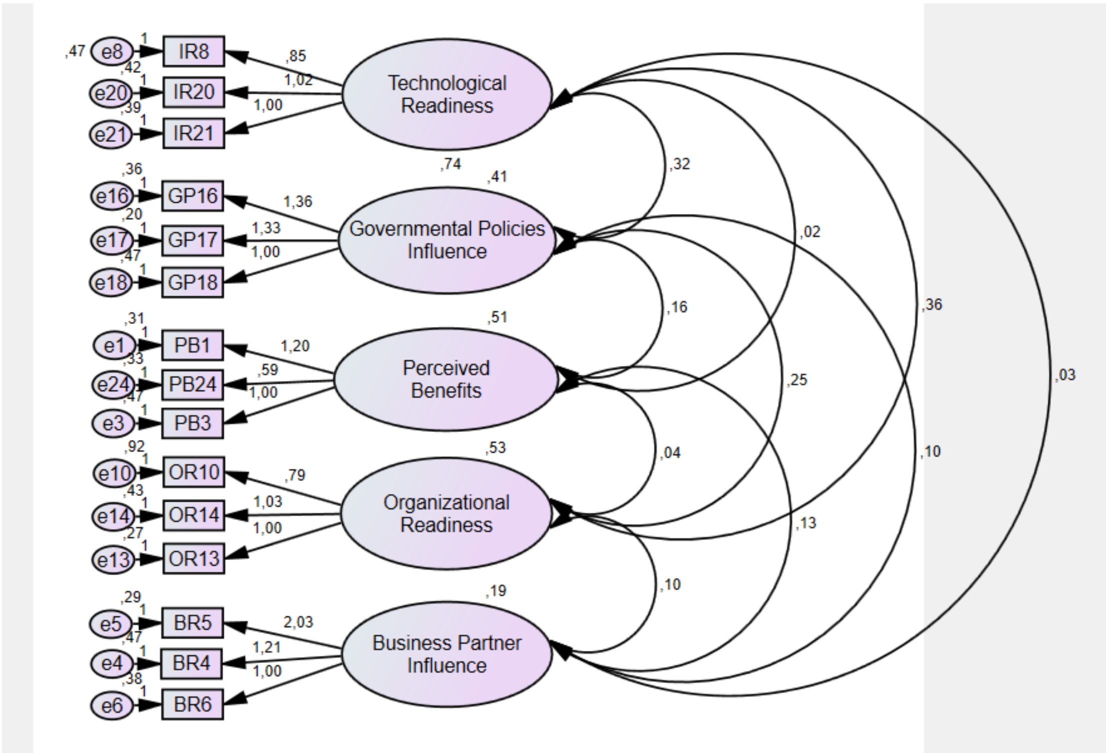
Number of distinct sample moments:	120
Number of distinct parameters to be estimated:	40
Degrees of freedom (120 - 40):	80

Result (Default model)

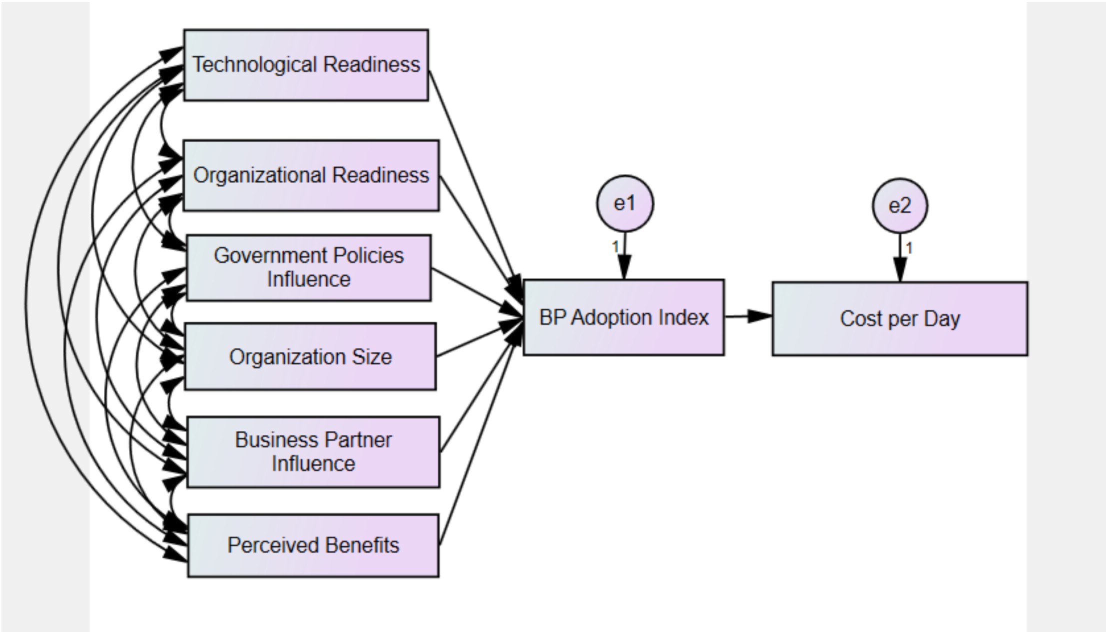
Minimum was achieved
Chi-square = 83,758
Degrees of freedom = 80
Probability level = ,365

Appendix B9 –AMOS measurement model results (standardized and non-standardized)





Appendix B10 – AMOS structural model w/o Saidin index logic



Appendix B11 – AMOS structural model notes w/o Saidin index logic

Notes for Model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments:	36
Number of distinct parameters to be estimated:	30
Degrees of freedom (36 - 30):	6

Result (Default model)

Minimum was achieved
Chi-square = 6,900
Degrees of freedom = 6
Probability level = ,330

Appendix B12 – AMOS structural model fit w/o Saidin index logic

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	30	6,900	6	,330	1,150
Saturated model	36	,000	0		
Independence model	8	205,069	28	,000	7,324

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	2,621	,983	,901	,164
Saturated model	,000	1,000		
Independence model	54,330	,583	,464	,453

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	,966	,843	,995	,976	,995
Saturated model	1,000		1,000		1,000
Independence model	,000	,000	,000	,000	,000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	,214	,207	,213
Saturated model	,000	,000	,000
Independence model	1,000	,000	,000

NCP

Model	NCP	LO 90	HI 90
Default model	,900	,000	11,728
Saturated model	,000	,000	,000
Independence model	177,069	135,283	226,345

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	,070	,009	,000	,118
Saturated model	,000	,000	,000	,000
Independence model	2,071	1,789	1,366	2,286

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	,039	,000	,141	,482
Independence model	,253	,221	,286	,000

AIC

Model	AIC	BCC	BIC	CAIC
Default model	66,900	72,900	145,055	175,055
Saturated model	72,000	79,200	165,786	201,786
Independence model	221,069	222,669	241,911	249,911

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	,676	,667	,785	,736
Saturated model	,727	,727	,727	,800
Independence model	2,233	1,811	2,731	2,249

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	181	242
Independence model	20	24

Appendix B13 – AMOS structural model estimates w/o Saidin index logic

Estimates (Group number 1 - Default model)

Scalar Estimates (Group number 1 - Default model)

Maximum Likelihood Estimates

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
BPALL	<---	M1GP	,499	,712	,701	,483	
BPALL	<---	M4OR	2,378	,864	2,753	,006	
BPALL	<---	M5BR	,576	,827	,696	,487	
BPALL	<---	SIZE13	1,366	,626	2,180	,029	
BPALL	<---	M2PB	1,780	,712	2,500	,012	
BPALL	<---	M3IR	1,921	,826	2,325	,020	
CostDay	<---	BPALL	-8,266	1,531	-5,398	***	

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
BPALL	<---	M1GP	,068
BPALL	<---	M4OR	,272
BPALL	<---	M5BR	,060
BPALL	<---	SIZE13	,171
BPALL	<---	M2PB	,207
BPALL	<---	M3IR	,244
CostDay	<---	BPALL	-,477

Covariances: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
M1GP	<-->	M3IR	,366	,078	4,704	***	
M3IR	<-->	M2PB	,056	,059	,955	,340	
M5BR	<-->	M3IR	,160	,054	2,952	,003	
M1GP	<-->	M2PB	,196	,066	2,977	,003	
M1GP	<-->	M5BR	,192	,059	3,259	,001	
M4OR	<-->	M2PB	,080	,053	1,514	,130	
M4OR	<-->	M5BR	,160	,049	3,249	,001	
M4OR	<-->	SIZE13	,064	,057	1,131	,258	
M5BR	<-->	SIZE13	,037	,051	,733	,464	
SIZE13	<-->	M2PB	-,031	,057	-,541	,588	
M5BR	<-->	M2PB	,127	,049	2,577	,010	
M1GP	<-->	SIZE13	,095	,068	1,403	,161	
M1GP	<-->	M4OR	,265	,067	3,951	***	
SIZE13	<-->	M3IR	,111	,064	1,746	,081	
M4OR	<-->	M3IR	,343	,067	5,127	***	

Correlations: (Group number 1 - Default model)

			Estimate
M1GP	<-->	M3IR	,537
M3IR	<-->	M2PB	,096
M5BR	<-->	M3IR	,311
M1GP	<-->	M2PB	,314
M1GP	<-->	M5BR	,347
M4OR	<-->	M2PB	,154
M4OR	<-->	M5BR	,346
M4OR	<-->	SIZE13	,114
M5BR	<-->	SIZE13	,074
SIZE13	<-->	M2PB	-,054
M5BR	<-->	M2PB	,268
M1GP	<-->	SIZE13	,142
M1GP	<-->	M4OR	,433
SIZE13	<-->	M3IR	,178
M4OR	<-->	M3IR	,601

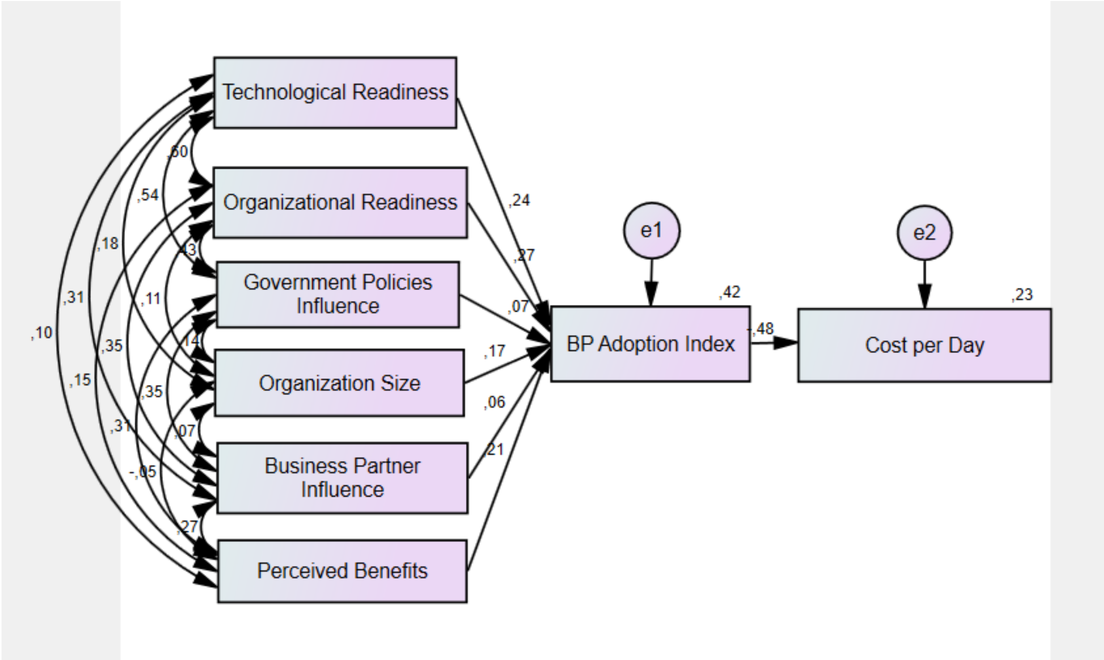
Variances: (Group number 1 - Default model)

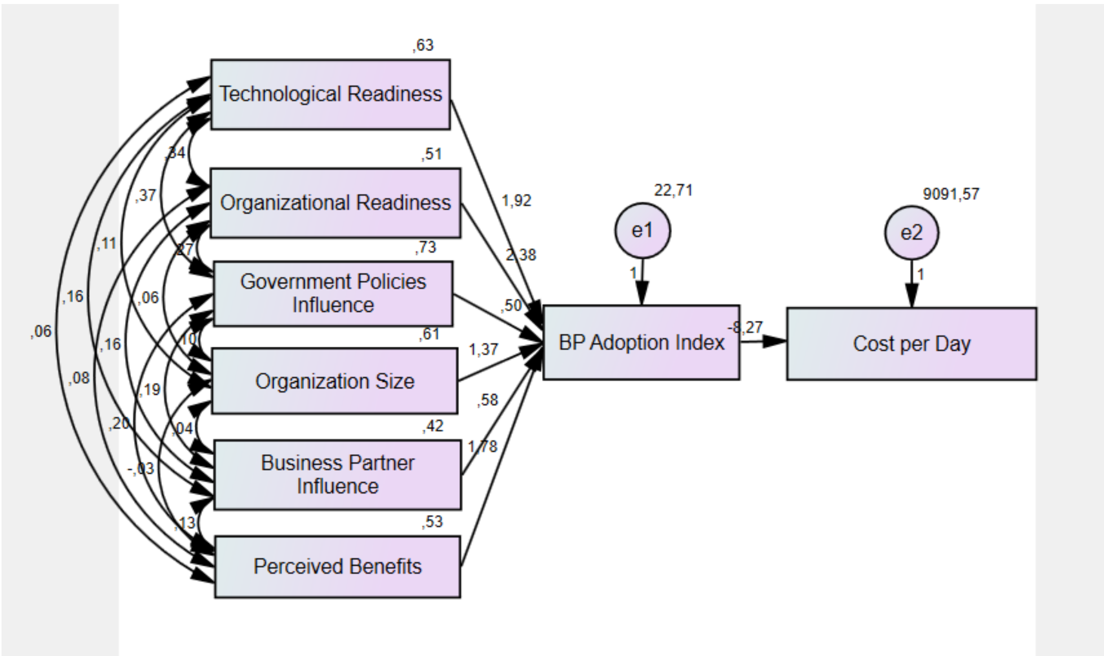
	Estimate	S.E.	C.R.	P	Label
M1GP	,734	,104	7,036	***	
M4OR	,512	,073	7,036	***	
M5BR	,419	,059	7,036	***	
SIZE13	,612	,087	7,036	***	
M3IR	,634	,090	7,036	***	
M2PB	,532	,076	7,036	***	
e1	22,710	3,228	7,036	***	
e2	9091,574	1292,220	7,036	***	

Squared Multiple Correlations: (Group number 1 - Default model)

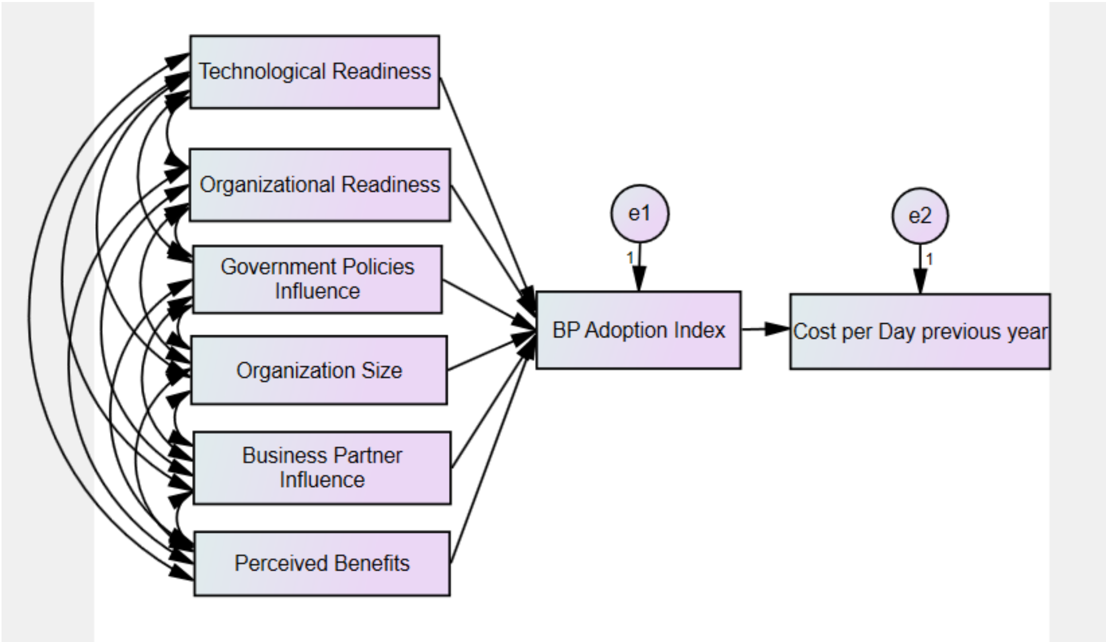
	Estimate
BPALL	,420
CostDay	,227

Appendix B14 – AMOS structural model results w/o Saidin index logic (standardized and non-standardized)





Appendix B15 – AMOS structural model with one year lagged cost per day values



Appendix B16 – AMOS structural model notes with one year lagged cost per day values

Notes for Model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments:	36
Number of distinct parameters to be estimated:	30
Degrees of freedom (36 - 30):	6

Result (Default model)

Minimum was achieved
Chi-square = 7,475
Degrees of freedom = 6
Probability level = ,279

Appendix B17 – AMOS structural model fit with one year lagged cost per day

values

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	30	7,475	6	,279	1,246
Saturated model	36	,000	0		
Independence model	8	198,050	28	,000	7,073

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	3,501	,982	,893	,164
Saturated model	,000	1,000		
Independence model	51,099	,594	,478	,462

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	,962	,824	,992	,960	,991
Saturated model	1,000		1,000		1,000
Independence model	,000	,000	,000	,000	,000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	,214	,206	,212
Saturated model	,000	,000	,000
Independence model	1,000	,000	,000

NCP

Model	NCP	LO 90	HI 90
Default model	1,475	,000	12,719
Saturated model	,000	,000	,000
Independence model	170,050	129,107	218,485

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	,076	,015	,000	,128
Saturated model	,000	,000	,000	,000
Independence model	2,001	1,718	1,304	2,207

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	,050	,000	,146	,427
Independence model	,248	,216	,281	,000

AIC

Model	AIC	BCC	BIC	CAIC
Default model	67,475	73,475	145,631	175,631
Saturated model	72,000	79,200	165,786	201,786
Independence model	214,050	215,650	234,891	242,891

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	,682	,667	,795	,742
Saturated model	,727	,727	,727	,800
Independence model	2,162	1,749	2,651	2,178

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	167	223
Independence model	21	25

Appendix B18 – AMOS structural model estimates with one year lagged cost per day values

Estimates (Group number 1 - Default model)

Scalar Estimates (Group number 1 - Default model)

Maximum Likelihood Estimates

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
BPALL	<---	M1GP	,499	,712	,701	,483	
BPALL	<---	M4OR	2,378	,864	2,753	,006	
BPALL	<---	M5BR	,576	,827	,696	,487	
BPALL	<---	SIZE13	1,366	,626	2,180	,029	
BPALL	<---	M2PB	1,780	,712	2,500	,012	
BPALL	<---	M3IR	1,921	,826	2,325	,020	
CostDayPrev	<---	BPALL	-7,777	1,753	-4,436	***	

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
BPALL	<---	M1GP	,068
BPALL	<---	M4OR	,272
BPALL	<---	M5BR	,060
BPALL	<---	SIZE13	,171
BPALL	<---	M2PB	,207
BPALL	<---	M3IR	,244
CostDayPrev	<---	BPALL	-,407

Covariances: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
M1GP	<-->	M3IR	,366	,078	4,704	***	
M3IR	<-->	M2PB	,056	,059	,955	,340	
M5BR	<-->	M3IR	,160	,054	2,952	,003	
M1GP	<-->	M2PB	,196	,066	2,977	,003	
M1GP	<-->	M5BR	,192	,059	3,259	,001	
M4OR	<-->	M2PB	,080	,053	1,514	,130	
M4OR	<-->	M5BR	,160	,049	3,249	,001	
M4OR	<-->	SIZE13	,064	,057	1,131	,258	
M5BR	<-->	SIZE13	,037	,051	,733	,464	
SIZE13	<-->	M2PB	-,031	,057	-,541	,588	
M5BR	<-->	M2PB	,127	,049	2,577	,010	
M1GP	<-->	SIZE13	,095	,068	1,403	,161	
M1GP	<-->	M4OR	,265	,067	3,951	***	
SIZE13	<-->	M3IR	,111	,064	1,746	,081	
M4OR	<-->	M3IR	,343	,067	5,127	***	

Correlations: (Group number 1 - Default model)

			Estimate
M1GP	<-->	M3IR	,537
M3IR	<-->	M2PB	,096
M5BR	<-->	M3IR	,311
M1GP	<-->	M2PB	,314
M1GP	<-->	M5BR	,347
M4OR	<-->	M2PB	,154
M4OR	<-->	M5BR	,346
M4OR	<-->	SIZE13	,114
M5BR	<-->	SIZE13	,074
SIZE13	<-->	M2PB	-,054
M5BR	<-->	M2PB	,268
M1GP	<-->	SIZE13	,142
M1GP	<-->	M4OR	,433
SIZE13	<-->	M3IR	,178
M4OR	<-->	M3IR	,601

Variances: (Group number 1 - Default model)

	Estimate	S.E.	C.R.	P	Label
M1GP	,734	,104	7,036	***	
M4OR	,512	,073	7,036	***	
M5BR	,419	,059	7,036	***	
SIZE13	,612	,087	7,036	***	
M3IR	,634	,090	7,036	***	
M2PB	,532	,076	7,036	***	
e1	22,710	3,228	7,036	***	
e2	11917,769	1693,918	7,036	***	

Squared Multiple Correlations: (Group number 1 - Default model)

	Estimate
BPALL	,420
CostDayPrev	,166

Appendix B19 – AMOS structural model results with one year lagged cost per day

values (standardized and non-standardized)