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Healthcare Supply Chain modeling: a conceptual framework

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Abstract

This work describes and illustrates aspects of healthcare logistic network design and management and provide advances in theory about healthcare supply chain modeling according to System Dynamics paradigm, investigating internal feedback loops and decision-making delays that affect the behavior of the entire system. The conceptual discussion is empirically-derived by the authors and investigates relevant strategic issues affecting the design and development of the new Italian centralized logistic healthcare networks (called “Area Vasta” consortia) with the help of new IT/IS investments (such as RFID) and logistic hubs creation (to assure large economies of scales).

The study firstly presents an extensive literature review on RFID Technology innovation and diffusion in healthcare, on drugs distribution systems practices and on System Dynamics modeling in healthcare in order to support successive qualitative assumptions. Then it develops an “Healthcare logistic network Causal Loop Diagram” and provide discussions.

Keywords: Information Technology, Healthcare management, RFID technology, System Dynamics, Decision Making

INTRODUCTION

International Healthcare systems are under increasing pressure to reduce waste, eliminate unnecessary costs while improving the quality and consistency of the care they provide to patient. For this reason, Healthcare logistics / supply chain management is receiving high attention at National and International level from practitioners and academics. In the last decade the healthcare supply chain complexity increased exponentially due to the high variety in health services provided. According to the Statistical Office of the European Communities (Eurostat), by 2060, 30% of the population of the 27 EU countries will be over 65. This means that there would be only two persons of working age for every person aged 65 or more in 2060, compared with four persons to one today. The age-profiles for expenditures per head on long-term care show a similarly distinct pattern across Member States – there is little or no expenditure before old age, and then rapidly increasing levels of expenditure at higher ages (Figure 1).

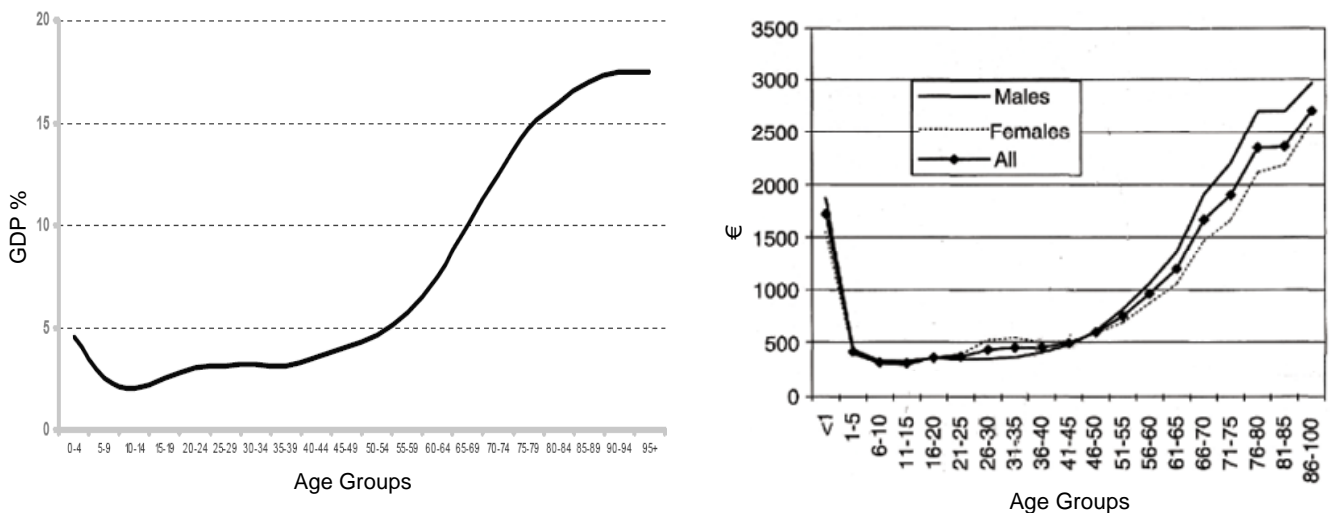


Fig. 1 Average EU healthcare expenditure per head by age group on the left and age profiles for public healthcare expenditure per head in Italy on the right (Sources: EPC, 2001 and World Health Report 2008).

Thus, the ageing of populations would be an important driver of health and long-term care expenditures in the coming decades. However, other factors also come into play in the determination of the evolution of the healthcare sector.

First of all the necessity of reducing adverse event (i.e. medical errors in drugs prescription and administration, in transfusion management and in the pre-analytical phase) risks and costs, while improving patient's safety. The lack of standardized identification procedures for patients and materials and of efficient health information systems has been underlined by the e-Health Conference in 2004. Moreover, there is an urgently need of reducing hospitalisation and improving disease management and treatment at the point of need, through more precise assessment of intermediate care services.

In conclusion, sustainable delivery of quality healthcare at affordable cost is a major challenge for European healthcare systems for a variety of reasons such as: (a) demographic change and increasing

prevalence of chronic diseases (old age people); (b) inefficiencies, inadequate safety standards and quality control; (c) demanding citizens who require best-quality care and cover for the use of latest diagnostics and treatments. This calls for changes in the way healthcare service is delivered, the way healthcare partners are linked and mutually correlated one to each other and the way logistic flows and processes are managed and transferred between partners in a network-oriented system. The development of new advanced healthcare logistic models and tools is the primary key to implement these changes and obtain a reduction in future healthcare expenditure without compromising quality of care. Thus, European healthcare sector is asking to the scientific research to provide advances in theory about healthcare logistic network modelling and controlling, going through a complete re-thinking process of inventory management and resources planning criteria based on the new "Healthcare Logistic Network" paradigm. To reach this purpose, it's urgently a re-design of the whole healthcare logistic structure by an holistic point of view and "Network Oriented", investigating with innovative approaches all information, materials and resources flows inside the network, logistic services required and transaction costs associated in order to define the best logistic network architecture (i.e. the best centralization degree of resources).

PURPOSE OF THE PRESENT STUDY

Italian healthcare sector is urgently asking for improvements and complete re-thinking of logistic structures, services and procedures. We can only remind that about 300 million Euros are spent, each year, for hospital inventory management in our country (Assologistica Conference, 2009). For this reason, a complete re-design of the national healthcare logistic structure is required and need to be supported by logisticians knowledge and experiences, rather than form political or cultural paradigms. This work investigates the challenge described above, working towards the analysis and qualitative dynamic modelling of advanced healthcare supply network, highly centralized and provided with distribution hubs. Here is developed an “Healthcare Logistic Network Causal Loop Diagram” -empirically derived by the authors and accurately supported by state of the art analysis- investigating most relevant internal feedback loops and decision-making process that affect the development of the so-called Italian “Area Vasta” consortia.

The main purpose of this study is to investigate supply network structure interactions, all benefits and risks associated to different centralization level and logistic network structures.

One aspect arose from the literature review (next paragraph) is that RFID technology is necessary to decrease drastically adverse events in critical processes like drugs administration, drugs distribution and prescription. At the same time, a logistic network structure and assets centralization are required to arise economies of scale and consequently reduce healthcare public expenditure. At the same time the risk connected to the creation of a centralized hub need to be assessed. The study firstly presents an extensive literature review on RFID Technology application in healthcare, Drugs Distribution Systems and System Dynamics application in healthcare sector (§3). Then it develops a new Causal Loop Diagram for describe an Area Vasta consortium growing process, and present its conceptual discussion (§4). It finally discuss conclusion and future steps of this research.

STATE OF ART

The extensive effort in the literature review reported following indicate the importance of linking Radio Frequency monitoring and controlling with Drugs Management Policies and other healthcare

logistic activities in order to drastically reduce Adverse Events. At the same time, it discusses System Dynamics modeling in healthcare, showing a lack of qualitative and quantitative models useful to assist both logisticians during Supply Chain design and optimization and both healthcare managers decision making.

Information technology and RFID in healthcare

In order to increase systems performances in the healthcare process (i.e. the Drug Distribution Process) and improve patient safety, the areas of intervention for information technologies are human errors and human violations. To minimize the impact of human fallibility in the safety critical environment of the healthcare system, it is important to design process that addresses the positive control of patient safety critical data (CEN, 2000). The procedures of identification of patient and Patient Related Objectives is the unique intervention point with the highest potential for minimizing the risk of human errors and for maximizing the performance of the health informatics systems (CEN, 2000).

The commission of the European communities on e-Health (2004) underlines the double need of identify a person unambiguously and reach the interoperability of electronic health records. The First working document of CEN report in health informatics (2000) underlines that Automatic Data Capture (ADC) technologies (i.e. technologies that enter data directly into a computer system, a programmable logic controller without the need of a keyboard, such as magnetic, biometric, optical, electromagnetic) could lower to a minimal value human errors, providing a faster, more accurate, reliable, repeatable way to collect data, i.e. to perform the Minimum Object Set (MOS) identification and the Minimum Data Set (MDS) retrieval. RFDC technology is common for manufacturing, warehousing, distribution and logistics management and it is in use also in hospitals for tracking pharmaceutical and medical suppliers. Stroetman (2006) outlines that research needed to solve problems with privacy and confidentiality of patient data and that improving patient safety through ICT is not only a technical issue but a holistic approach incl. organisational & political factors is needed. Recent studies point out that RFID technologies in EU Community are actually

involved in pilot projects for healthcare, but this adoption is proceeding more cautiously than for other industries. (Evans et al., 2005) . Historically the technological transfer to healthcare provider industry is very slow and also for RFID technologies the pattern of diffusion is the same. A technology in healthcare has to get the right trade-off among patient safety, quality of care and financial constraints (very different, especially in Europe, from a conventional firm). Actually in pilot projects and in earlier applications of RFID in healthcare, five functional areas are involved (Ingeholm et al., 2006):

- 1) *Asset management*: active RFID can be used linked to an asset such as a wheelchair or a defibrillator. The advantages of this application are: cost reduction by increasing asset visibility, reduction of losses and thefts, improvement of inventory control.
- 2) *Patient safety at point of care*: bar-coding technology has been widely used to reduce human error in drugs administration and in blood transfusion management (Roark, 2004). Nowadays this activities are done with the support of passive RFID, which does not require line of sight, but a passive tag and handheld reader. The technological support to drugs administration and blood transfusion management will improve using active tags.
- 3) *Workflow optimization*: active RFID systems can be used to retrieve identification and location information about tagged entities in real time. Then it is possible, monitoring tagged staff, equipment and patients, to map the entire workflow of processes of a healthcare organization.
- 4) *Increased security*: another relevant application is the possibility to control the access to dangerous zones inside a structure. For example if for a person an exposure to x-radiation is not allowed, with RFID technology, it is possible to create a system of alert in proximity to critical boundaries.
- 5) *Electronic pedigree for pharmaceuticals*. As The Food and Drug Administration (FDA) (2004) sustains, endorsing the concept of Electronic Product Code(EPC)/RFID solution, this type of technology permits to “increase the safety of medications consumers receive by

creating the capacity to track and trace a drug from the manufacturer all the way to the pharmacy” .

Obviously the first pilot projects have met also obstacles in the application of this technology in healthcare area. In particular, (Ingeholm et al., 2006) they are:

Cost: this is the most relevant problem for the application of RFID technology in healthcare industry. This problem can be discussed along two dimensions: The cost of the tags and the investment for implementation (e.g.: changing processes, training people) are very relevant, It's difficult to quantify benefits. In facts it is not easy evaluating efficiencies in a care workflow and process and it is hard measuring cost reduction such as decreased medical errors. Furthermore the problem of cost is emphasized by the comparison with the bar-coding technology. This complementary technology present costs much lower: for example if a passive tag cost 0.4 \$ (20 \$ for an active tag), the cost of a bar-coding label is 0.001\$ per unit.

Standardization: from a technological point of view the most import obstacle for the application of RFID technology is standardization. The standardization process has been complicated by the emergence of competing standards from International Standardization Organisation (ISO) and EPCglobal/GS1 which are driven by divergent interests. Nowadays, in the earlier projects, this obstacle is not very dangerous because RFID applications operate in a closed-loop environment. In the future the need for interoperability of RFID system across an enterprise will make the challenge for standardization essential.

Data processing and integration: one of the most advantage of RFID than competing technologies is the possibility to create a large amount of data. In this sense the management of the data becomes critical and, because of RFID is not a stand-alone technology, it will be critical the choice of supporting technology.

To summarize the applications of RFID in healthcare it is useful analyzing Table 3, where it is presented a recent classification of particular uses.

Application	Description	Percentage on total RFID applications
Blood	Transfusion error prevention	4 %
Pharmaceuticals	Anti-counterfeiting drugs administration	13 %
People Tagging	Patients for error prevention tagged and followed by staff for location/alarm	16 %
Other	Surgery, Cards, key fobs, pendants and badges for secure access, health records and payment.	41 %

Table 1: Table modified by “RFID in Healthcare 2006-2016” (Harrop and Das, 2006)

To understand which are the most important pilot projects about the application of RFID in healthcare, it can be used a study of Castro et al. (2007) .

Characteristics of the application	Author	Organization
Tracking of medical assets using an RFID-based real-time locations system (RTLS) to locate assets seamlessly	Bacheldor (2006)	Harmon Hospital (USA)
Future implementation of RFID for bedside applications to reduce medical errors and track ambulatory patients at a new hospital	Li et al. (2006)	St. Luke’s Health System (USA)
Using RFID tags on surgical equipment to ensure that all tools used during an operation have been removed from the patient’s body	Li et al. (2006)	Cardinal Health Inc. (USA)
Using RFID to comply with Wal-Mart’s mandate and prevent drug theft and counterfeiting	Li et al. (2006)	Purdue Pharma (USA)
Using active RFID tags on nursing wards to track IV pumps and other high-value mobile equipment	O’ Connor (2006)	Hamilton Health Sciences (Canada)
Deploying a pilot RFID system to track medication to ensure that patients get the correct doses of the right drugs. Implementing the RFID system to improve the efficiency of the treatment process and enhance drug-handling safety	Wessel (2006)	Jena University Hospital (Germany)
Using active RFID tags to track surgical patients, providing hospital staff with real-time information about their status. Tracking of about 2,500 assets to improve their accessibility through the use of active RFID tags	Bacheldor (2007 a)	PinnacleHealth (USA)
Using RFID-enable passive wristbands to identify surgical patients and track their operations to improve patient care and safety. System allows medical staff to save an average of 4.3 minutes per patient in performing patient identification and verification process	Bacheldor (2007 b)	Chang-Gung Hospital (Taiwan)
Using ultra-wideband systems to track and locate medical assets. Future applications: patient tracking.	Bacheldor (2007 c)	Washington Hospital Center (USA)
Tracking of 130,000 work garments by using an RFID-based system, resulting in reduction of inventory space and labor costs.	O’Connor (2007)	St. Olav’s Hospital (Norway)

Table 2: Adapted by Castro et al. (2007)

Drug Distribution Systems

In any hospital, a drug distribution system is required to supply the medication prescribed for each inpatient. The drug distribution system includes all the processes that occur between the prescription of a drug and the administration of that drug to the patient. There are many varieties of drug distribution system in use throughout the world, but all have the same goal: to ensure that each dose of medication administered to each patient is exactly that which was intended by the prescriber. A measure of the quality of any drug distribution system is the incidence of medication errors, where a medication error is any discrepancy between the medication prescribed and that administered.

Currently there are 3 management models for drugs:

- 1) The traditional managing in which there is a central pharmacy store in every hospital that decide what and how to buy. This is the most spread system.
- 2) The centralized managing of drugs in a district or regional center (unique distributive center).
- 3) All physical managing and drugs movement is give to a third partner (Logistic Operator) whist the decision of how and what to order is in charge of the hospital pharmacy.

These 3 models are combined with 2 kind of drugs distribution systems inside the hospital ward: the ward stock distribution system (WSDS) and the unit dose dispensing system (UDDDS). Reasons for the move drug do unit dose drug distribution include shortages of nursing staff and desire to reduce risk, reduce costs and increase pharmacists' involvement with drug therapy (Negele, 1994).

The unit dose system may differ in form, depending on the specific needs of the organization.

However, the following distinctive elements are basic to all unit dose systems: medications are contained in single unit packages; they are dispensed in as ready-to-administer form as possible; and for most medications, not more than a 24-hour supply a of doses is delivered to or available at the patient-care area at any time (Summerfield et al, 1983) and (ASHP, 1980). Numerous studies concerning unit dose drug distribution systems have been published over the past several decades. These studies indicate categorically that unit dose systems, with respect to other drug distribution

methods, are (1) safer for the patient, (2) more efficient and economical for the organization, and (3) a more effective method of utilizing professional resources.

More specifically, the inherent advantages of unit dose systems over alternative distribution procedures are: reduction in the incidence of medication errors, decrease in the total cost of medication-related activities, more efficient usage of pharmacy and nursing personnel, allowing for more direct patient-care involvement by pharmacists and nurses, Improved overall drug control and drug use monitoring, more accurate patient billings for drugs, the elimination or minimization of drug credits, greater control by the pharmacist over pharmacy workload patterns and staff scheduling, a reduction in the size of drug inventories located in patient-care areas, greater adaptability to computerized and automated procedures. The American Society of Hospital Pharmacists considers the unit dose system to be an essential part of drug distribution and control in organized health-care settings in which drug therapy is an integral component of health-care delivery.

System Dynamics in healthcare

The current global economic crisis and recent world events highlight the need to better understand the interconnections of complex dynamic systems. Particularly in today's uncertain environment, the ability to see "the big picture" and apply powerful tools in meaningful ways can be extremely valuable across a wide range

of industries, functions, and areas of focus. In the face of growing uncertainties and increasing complexity associated with such large socio-technical systems, health and social care professionals need to use more systemic and systematic simulation approaches to learning about them (Royston et al., 1999). Discrete events simulation models (DES) have been applied concerning the handling of patients with stochastically-generated attributes. Anyway, System dynamics simulation modelling is well equipped for analysis healthcare complex problems (Sterman, 2000) while providing the benefit of simulation for policy planning and evaluation by considering the process of planning and monitoring health care from a "whole system" perspective (Wolstenholme, 1993).

System dynamics modelling has been applied in different healthcare areas including: assessing public health risks, disease epidemiology including work in heart disease, diabetes and others (Hirsch and Homer, 2004; Homer and Milstein, 2004), Patient flows and managing waiting for hospital treatment (i.e. modelling performance of Accident and Emergency departments, Lane, Monefeldt and Rosenhead, 2000); Health capacity and delivery under natural disasters and terroristic acts (Hirsch, 2004); developing emergency health and social care (Royston, 1999), interactions between public health capacity and disease epidemiology (Homer and Milstein, 2004). General survey of this aspect can be found in Taylor and Lane (2000) so is stated only briefly here. This compartmentalized approach is engrained in the financial structures, intervention designs, and evaluation methods of most health organizations. Conventional analytic methods are generally unable to satisfactorily address situations in which population needs change over time, and in which risk factors, diseases, and health resources are in a continuous state of interactions and flux. Many public health interventions fall short of their goals because they are made in piecemeal fashion, rather than comprehensively and from a whole-system perspective. The gain of system dynamics approach is that considering aggregated variables encourages both a systemic view of the interactions of resources and information flows, and a more strategic perspective of the management of the system. The EU Community has stressed the importance of taking a "holistic" approach to improving health and health care and of having "joined-up policies". We see systems thinking in general and system dynamics in particular as a key tool to making the connections, because it can help groups gain a shared understanding as individual mental models are demolished or embraced. There is a lack of studies application of system dynamics modelling on Drug Distribution through logistic healthcare network. This study will propose a qualitative model to describe and investigate causal feedback loops inside an healthcare logistic network structure.

HEALTHCARE LOGISTIC NETWORK CAUSAL LOOP DIAGRAM

Recently, healthcare Italian organizations have been called to develop advanced integrated networks, defined "Area Vasta" Consortia, following geographical, historical and cultural criteria. Such healthcare logistic networks have the main scope to centralize strategic logistic activities (such as consumption analysis, market researches, materials/services procurement and management, assets distribution, resource planning, etc.) by the creation of a "logistic hub", which will be responsible of all logistics activities of all partners in the network. Examples are "AVEN" consortium (Area Vasta Emilia Nord) and "AVSE" consortium (Area Vasta Sud - Est Toscano) in Italy and, at European level, the well-known best practice ICS, The Catalan Institute of Health of Barcelona (Spain). Despite original ambitious objectives of new Area Vasta consortia: for example only for Veneto region it has been expected a reduction from about 90 fragmented warehouses to only 5 centralized hubs, providing a saving of 15 Million Euros per year, (Assologica Conference, 2009). Anyway, the current strategic design of such advanced future logistic networks is not supported by accurate studies and logistic model development and simulation, leading to high risks in terms of future networks solidity and processes safety. Moreover, how partners are linked one to each other and how big and centralized an Area Vasta logistic network will need to be (hospitals or other health structures are actually expected to be linked and grouped in different cluster following only cultural and geographical criteria) is actually not yet investigated. In same time also adequate outsourcing analysis of networks logistic activities need to be realized. Generally speaking, the current global economic crisis and recent world events highlight the need to better understand links and interconnections inside and between complex logistic networks. Particularly in today's uncertain environment, the ability to see "the big picture" and apply powerful tools in meaningful ways can be extremely valuable across a wide range of industries, functions, and areas of focus. In particular, health care professionals need to use more systemic and systematic modelling procedures and simulation approaches to learning about them (Royston et al., 1999) and to realize an evolutionary and efficient network strategy. Dynamic problem conceptualization with

Causal Loop Diagrams (CLDs) is an optimal way to lead concentration on decision points and performance measures (Lane, 2008). Rather than writing equations, CLD could be used to shape a qualitative discussion about feedbacks effects, in preparation fro quantitative formulation. However, some practitioners, suggests that qualitative analysis was sufficient (Coyle, 2000). Our research interest is studying the best development and growth criteria regarding future Italian logistic networks, investigating all costs and risk associated, by the creation of a qualitative Causal Loop Diagram of an healthcare logistic network. The model proposed following, is at this point, an exploratory one, not yet verified and refined through case study application but derived from author experiences, state of the art analysis and practical evidences.

The first step is to define the key system features and to create a high-level Causal Loop Diagram (CLD) that captures the key elements of the system in question including the major feedback loops. An overview of our models feedback structure is presented in Figure 2. The model focus is on feedback loops in order to analyse decision points that lead the development of an Area Vasta consortium and its growth (in number of healthcare partners involved in the same network consortium).

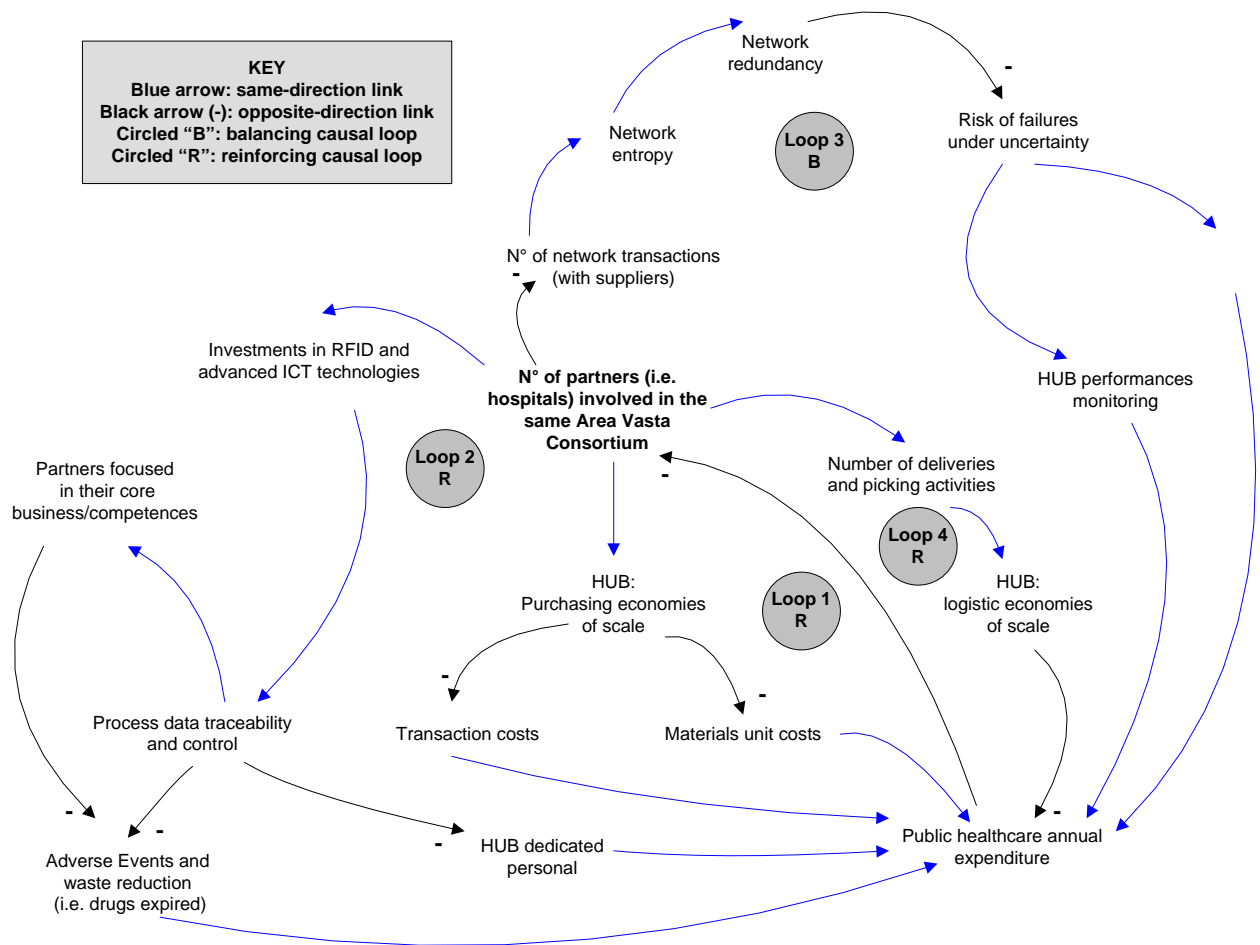


Fig. 2 Causal Loop Diagram investigating feedback loops in Italian “Area Vasta” consortia development and growing process.

The suppression of detail in the diagram is necessary to provide a strategic overview of the problem rather than wade through detail. This diagram aims to communicate strategic links and loops to be considered during an Area Vasta consortium planning and design, in order to achieve the final challenge of provide high healthcare services to patient at sustainable costs. It can be successfully use to draw healthcare stakeholders into thinking about all feedback loops present in the problem under study and all consequences to their choices.

In this diagram (Fig.2) there are a whole range of dependent variables and feedback loops that capture overall system behaviour.

The most relevant feedback loops included are described below:

Loop1: Increasing the number of partners involved in a single consortium, purchasing economies of scale in the logistic hub of the network will grow and consequently, purchasing unit costs of materials (i.e. drugs and medical devices) will decrease and also transaction cost with suppliers, leading to a reduction in annual public expenditure of the healthcare national system. This will contribute to motivate the growth of the network, by adding new partners in the consortium. This loop is a “reinforcing causal loop”.

Loop2: Increasing the number of partners involved in a single consortium, investments in advanced Automated Data Capture Technologies (i.e. RFID) and in advanced ICT platforms will be always more justified in the new logistic hub created by the Area Vasta Consortium and in the same way, processes and all critical data will be traced in the whole supply network, assuring reduction both in Adverse Events (i.e. Adverse Drugs Events, this is well-motivated in the state of the art) and in waste (i.e. drugs expired in hospitals warehouses), conducting to a decrease of public expenditure and then an increment in network growth (more partners will be involved in the centralization process under study). This loop is a “reinforcing” one.

Loop3: By the centralization of logistic activities in Area Vasta network, increasing the number of partners integrated in the network, transaction with suppliers (managed by a single logistic hub) will drastically decrease (respect to the previous situation) and, as a consequence, links and flows in the new system will be drastically simplified, thanks to the hub presence. This concept is well-discussed in Network Analysis studies (Allesina et al, 2009 and Battini et al, 2007): the presence of an hub inside a network structure will decrease the network entropy and in the same way, it will decrease redundant flows and connections between partners. In other words, pruning away redundant connections is convenient when the risk of disrupting the remaining connections is low, that is, when the “external environment” is benign. Thus, a reduction in network redundancy will

increase risk of failures of the whole system, in particular under uncertain external environmental factors. So the network will need to be protected and constantly controlled and monitored through efficient performance monitoring and detailed risk assessment. These kind of activities will lead to an increment in healthcare annual expenditure and finally, it will slow down the consortium growing, creating strategic limits in network centralization. This is a “balancing causal loop”.

Loop4: Increasing the number of partners involved in a single consortium, deliveries and picking/handling activities in the network hub will increase, but new economies of scale will be reached and so the public annual expenditure reduced. This will lead to increase network growing, by the inclusion of new partners in the centralization process of logistic activities under consortium agreement. This loop is a “reinforcing” one.

CONCLUSION

The model developed in this study is at this point an exploratory one, not yet verified and refined through case study applications. Nonetheless, it helps the comprehension of dynamics impact of recent strategic logistic choices in Italian healthcare sector. All model assumptions are derived and justified from author experiences in Italian healthcare sector, state of the art analysis and practical evidences. The existence of the reinforcing and balancing loops depicted in the developed diagram suggests that the question of how best design a new “Area Vasta” consortium in our country is not a simple one. In fact the 4 loops shown in the diagram highlight that different benefit and risk will impact on such logistic networks creation and growing process. This problem needs to be investigated in depth, and the healthcare sector is demanding for new dynamic model, able to support Scenario Analysis and Decision Making process of healthcare stakeholders in the medium-long term anticipating and quantifying future network performances, costs, benefits and risks, according to alternative logistics configurations and level of integration between partners. This qualitative model doesn't mean to be exhaustive in its present form, but aims to lead policy insights

and a better understanding of the problem in question. Future steps will concern the quantification of all relations and variables identified, permitting a dynamic simulation of the model, which will be validated through real data collection and case studies development.

REFERENCES

Allesina S., Azzi A., Battini D., Regattieri A., (2008), Performance Measurement In Supply Chain: New Network Analysis And Entropic Indexes,. Int. Journal of Production Research, 2009, in press.

American Society of Hospital Pharmacists, 1980, ASHP technical assistance bulletin on hospital drug distribution and control. Am J Hosp Pharm; 37:1097–1103

Assologistica Conference "Libro Bianco per la logistica nella Sanità", Verona, January 2009)

Battini, Persona and Allesina, 2007, Towards a use of network analysis: quantifying the complexity of Supply Chain Networks, Int. Journal of electronic customer relationship management, vol. 1, pp. 75-90 ISSN: 1750-0664.

Bacheldor, B. , 2006, Harmon Hospital Implements RFID to Track Assets. Retrieved from <http://www.rfidjournal.com/article/articleview/2933/>

Bacheldor, B. , 2007a, Pinnacle Health Pushes Ahead with RFID. Retrieved from <http://www.rfidjournal.com/article/articleview/3026/1/1/>

Bacheldor, B. , 2007b, Taiwan's Chang-Gung Hospital Uses HF RFID to Track Surgery. Retrieved from <http://www.rfidjournal.com/article/articleview/2954/>

Bacheldor, B. , 2007c, Washington Hospital Center to Quadruple its RFID Expansion. Retrieved from <http://www.rfidjournal.com/article/articleview/3009/1/1/>

Castro , Fosso Wamba, 2007, An inside look at RFID technology, Journal of Technology Management and Innovation.

CEN/TC 251/N00-032 First working document of CEN Report : Health Informatics - Safety procedures for identification of patient and related objects, 10-05-2000.

COM (2004) 356 final “e-Health - making healthcare better for European citizens: An action plan for a European e-Health Area”

Coyle G., 2000, Qualitative and quantitative modelling in system dynamics: Some research questions. System Dynamics Review, 16(33), 225-244

Evans, Nicholas D, 2005, ”The importance on Industry Parralels”, RFID Journal.

Fontan J. E., Maneglier V., Nguyen V. X., Loirat C., Brion F., 2003, Medication errors in hospitals: computerized unit dose drug dispensing system versus ward stock distribution system, Pharm World Science; 25(3): 112–117.

- Harrop P., and Das R. 2006, IDTechEx, "RFID in Healthcare 2006-2016"
- Hirsch G.B., 2004, Modeling the consequences of major incidents for health care systems. In: Kennedy M, Winch GW, Langer RS, Rowe JI, Yanni JM, eds. 22nd International System Dynamics Conference. Oxford, England: System Dynamics Society
- Hirsch G., Homer J., 2004, Modeling the dynamics of health care services for improved chronic illness management. In: Kennedy M, Winch GW, Langer RS, Rowe JI, Yanni JM, eds. 22nd International System Dynamics Conference. Oxford, England: System Dynamics Society
- Homer J., Milstein B., 2004, Optimal decision making in a dynamic model of community health. In: Proceedings of the 37th Annual Hawaii International Conference on System Sciences. Waikoloa, Hawaii: IEEE
- Ingeholm, In K. Mun, Seong K.Mun, RFID in healthcare, 2006. Journal of AHIMA, 56 – 66.
- Kamath B.N., Roy R., 2007, Capacity augmentation of a supply chain for a short lifecycle product: A system dynamics framework. European Journal of Operational Research, 179 (2), 334-351
- Lane D.C., 2008, The Emergence and Use of Diagramming in System Dynamics: A Critical Account - Systems Research and Behavioral Science - Syst. Res. 25, 3-23
- Li, S., Visich, J.K., Khumawala, B.M., Zhang, C., 2006, Radio Frequency Identification Technology: Applications, Technical Challenges and Strategies. Sensor Review, Vol. 26, No. 3, 193-202
- Negele HJ., 1994, Unit dose - ein neues Verteil - und Dokumentationssystem für Arzneimittel. Krankenhauspharmazie; 15:456-61.
- O'Connor, M., 2006, Toronto-Area Hospital Kicks Off Asset-Tracking Pilot. Retrieved from <http://www.rfidjournal.com/article/articleview/2848/1/1/>
- O'Connor, M., 2007, RFID Tidies Up Distribution of Hospital Scrubs. Retrieved from <http://www.rfidjournal.com/article/articleview/3022/1/1/>
- Persona A. , Battini D, Rafele C, (2008), Hospital Efficiency Management: the Just In Time And Kanban Technique, Int. Journal of healthcare technology and management, ISSN: 1368-2156. Vol.9 No.4 pp.373-391.
- Roark, D.C. , 2004, "Bar Codes and Drug Administration". American Journal of Nursing 104, no.1, 63-66
- Royston G., Dost A., Townshend J., Turner H., 1999, Using system dynamics to help develop and implement policies and programmes in health care in England. System Dynamics Rev.; 15: 293–313
- Sterman, J. D., 2000, Business dynamics: Systems thinking and modeling for a complex world. McGraw-Hill Higher Education, 982

Summerfield MR. 1983, Unit dose primer. Bethesda, MD: American Society of Hospital Pharmacists

Taxis K., Dean B., Barber N., 1999, Hospital drug distribution systems in the UK and Germany - a study of medication errors, *Pharm World Sci*; 21(1): 25-31.

US Food and Drug Administration, 2004, "FDA Announces New Initiative to protect the US Drug Supply through the use of Radiofrequency Identification Technology".

Wessel, R., 2006, German Hospital Expects RFID to Eradicate Drug Errors. Retrieved from <http://www.rfidjournal.com/article/articleview/2415/>

Wolstenholme, E. F. 1993. A case study in community care using systems thinking. *Journal of the Operational Research Society* 44: 925±93.