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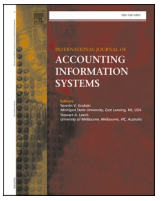

The paradoxes of the reengineering of information flows for management control: A case study in a public university hospital

Adelaide Ippolito [a,*], Marco Sorrentino [b], Luisa Guardato [c], Raffaele Marcello [d], Giuseppe Paolone [e]

[a] Università Telematica Pegaso, Department of Information Science and Technology, Centro Direzionale, Isola F2, Naples 80143, Italy
[b] Università Telematica Pegaso, Department of Management and Economics, Centro Direzionale, Isola F2, Naples 80143, Italy
[c] Health Data Analyst, Santec Spa, Via Enrico Capozzi, 45, 83100 Avellino, AV, Italy
[d] Università degli Studi di Salerno, Dipartimento di Scienze Aziendali – Management & Innovation (DISA-MIS), Via Giovanni Paolo II, 132 84084 Fisciano (SA), Italy
[e] Università Telematica Pegaso, Centro Direzionale, Isola F2, Naples 80143, Italy

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ABSTRACT

This study analyses the organisational reengineering processes developed following the adoption of an Enterprise Resource Planning (ERP) system in a public university hospital. Interestingly, a public university hospital was obliged to adhere to a regional ERP system owing to regulatory requirements. This caused the elimination of the pre-existing information flow architecture and the need for further reengineering. The analysis examines a case study in which reengineering information flow is conducted with ERP and business intelligence (BI) systems, highlighting the positive results. Using a data warehouse based on the ERP and BI systems allowed it to transform data into useful information, providing a global and detailed vision of the university hospital's performance through Key Performance Indicators (KPIs). Indeed, reengineering processes have made it possible to reorganise information flows consistent with the needs of new information systems.

1. Introduction

The complexity of organisations and the need to effectively integrate information flow to respond to market challenges with success, or at least adequate performance levels, have led to the development of new information technologies (data warehouse, business intelligence (BI), cloud, ERP, and other advanced technologies). These technologies can handle large quantities of economic and quality data effectively and efficiently in an organisation's framework while delivering tangible outputs regarding decision-making (Mathew and Pillai, 2015; Krause, 2015). The strength of these technologies lies in their ability to:

- provide an integrated overview of performance, allowing organisations to create a wide-ranging information system which fosters knowledge sharing (Adler-Milstein et al., 2019; Lehoux et al., 2019);
- provide reliable real-time performance measurement (Alfian et al., 2018).

* Corresponding author.
E-mail addresses: adelaide.ippolito@unipegaso.it (A. Ippolito), marco.sorrentino@unipegaso.it (M. Sorrentino), luisa.guardato@santec.it (L. Guardato), rmarcello@unisa.it (R. Marcello), giuseppe.paolone@unipegaso.it (G. Paolone).

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Scholars have highlighted the valid support new information technologies provide. These technologies can promote the integration of information flow in any organisation (Anguelov, 2021; Mariano-Melo and Ramírez-Correa, 2021) to optimise organisational (Uwizeyemungu and Raymond, 2012; Elbashir et al., 2021) and operational performance (Madapusi and D'Souza, 2012; Chae et al., 2014). The effects of such applications are determined in terms of information management costs (Zhang et al., 2022) and ensure information transparency (Al-Jabri and Roztocki, 2015), accurate control processes (Yamin and Sinkovics, 2007) and support for strategic decisions (Al-Mashari and Zairi, 2000; Appelbaum et al., 2017). Where control processes are concerned, these technologies ensure the diffusion of information flows at all levels within the company (Dechow et al., 2007) at the top management level, highlighting the effectiveness of these technologies, mostly for management control systems. The integration and dissemination of information flows is a critical aspect of organisations, given the nature of management control systems that operate as packages (Malmi and Brown, 2008; Abernethy and Chua, 1996; Flamholtz et al., 1985).

Malmi and Brown (2008, p. 287) stated, 'Organisations may have numerous controls present, and they all may be used to align individuals' activities with organisational goals'. Still, these controls constitute complex systems developed over the years for different information needs. This generates a real stratification of complementary control systems, which does not generate a single system (Malmi and Brown, 2008), but a package of balanced controls (Akroyd et al., 2019). Although these management control systems are characterised by their individuality and purpose, they are interconnected, and each constitutes part of a larger control system aimed at directing organisational actors' behaviours. Thus, the phenomena that affect a single control system reverberate over the entire package of management control systems (Chenhall, 2003). Management control systems as packages make integrating information flows critical, an integration that can be achieved owing to new information technologies.

Therefore, new information technologies ensure the integration of information flow and their diffusion, facilitating overcoming the limits connected to such information flows generated within a package of management control systems and not a system of holistic unitary control. Furthermore, the integration of information flow appears even more critical if we consider that the management control system, to be effective in directing people's behaviours, requires information in real-time and in predictive evaluation (Cokins, 2013), which support strategic decisions and measure and evaluate performance internally and externally (Ittner and Larcker, 2001; Nielsen, 2015) by using big data (Scapens, and Jazayeri, 2003; Davenport, 2006).

ERP and BI systems have the inherent potential to ensure the integration of information flow and the effectiveness of management control systems in organisations. Elbashir et al. (2021) underlined how new BI technologies and the integration of information systems can positively affect management control systems, allowing information integration into organisational processes with a significant performance impact. However, this potential can only be realised if the dynamic capabilities generated by new information technologies are adequately integrated into routines and processes to reconfigure activities and resources consistent with environmental needs. Moreover, the effectiveness of these dynamic capabilities is not automatically exploited in implementing such systems; many scholars have highlighted failures in implementing ERP and BI systems. Alsène (2007) highlighted that ERP systems do not automatically guarantee a contribution to the coordination and integration of company activities; planning, control, and strategic decision-making do not necessarily benefit from such systems (Appelbaum et al., 2017), Momoh et al. (2010) identified nine factors that can give rise to implementation failures in ERP systems. Elbashir et al. (2021) highlighted how integrating information systems *per se* is insufficient to ensure positive effects on management control and organisational performance. Granlund (2009, 2011) and Appelbaum et al. (2017) highlighted that the integration of information systems 'has failed to support the analysis, real-time customised reporting, and interpretation of information for planning, control, and strategic decision-making' (Elbashir et al., 2021, p. 1776). The key to solving critical issues lies in the ability to generate, at an organisational level, a profitable harmony between:

- New information technologies, such as ERP and BI, and the systems that comprise the organisation's management control system package (horizontal level of information flow integration),
- The management control systems package and broader decision-making support systems present in the organisation (vertical level of decision-making systems integration).

Effective organisational integration, horizontal and vertical, allows for the activation of the holistic integration potential of new information technologies. This will result in successful integration between the management control system package and this package and the wider decision-support mechanisms implemented in the organisation. Therefore, defining this integration is holistic because it operates at all organisational levels. The holistic integration described above specifically derives from the activation of the dynamic capabilities connected to the holistic integration potential of the new information technologies, as highlighted by Elbashir et al. (2021) for new information technologies and theorised by Teece et al. (1997) as 'the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments' (p. 516).

This study presents how management control can fully develop its potential by developing customised and real-time reports for the decision-making needs of healthcare organisations. The concrete integration of information systems derived from the effective reengineering of information flow and implementing a BI system was made necessary by the new ERP system.

Therefore, this study analyses the organisational reengineering processes developed following an ERP system, considering a specific situation that is given very little consideration in the literature, a public university hospital. This organisation is already equipped with an ERP system, obliged to adhere to a different regional ERP system owing to regional government requirements, eliminating the pre-existing architecture of information flows and the need to redevelop reengineering processes. The analysis was conducted by examining a descriptive case study over which the researchers had no influence (Yin, 2003), as they acted as observers and not actors in reengineering information flows and adopting a BI system.

The case study of a public university hospital underlines how significant deficiencies emerged from evaluating the efficiency of the

pre-existing information flow architecture of the hospital, invalidating management control. Therefore, with the new ERP system, it became necessary to reengineer the information flow in harmony with this ERP system, as widely noted in the literature, and to implement a BI system to improve the information for decision-making purposes. Notably, the information flow reengineering process allowed ERP implementation to be integrated with BI to create a widespread management control system at the departments into which the public university hospital was organised, involving the heads of these departments. This case study offers healthcare professionals and policymakers fundamental lessons on the organisation and management of information flow.

2. Literature review

Management control must integrate the various information flows generated by the management control systems that constitute the control package and the support systems for prompt decision-making. This integration is vital for management control, as information flows must permeate the entire organisation, from routine activities to strategic decision-making processes.

This integration can be ensured through an ERP system. However, implementing an ERP while ensuring the material integration of the flow generated by various management control systems, *per se,* cannot achieve the potential for integrating information flows that make management control effective. Therefore, it is necessary to guarantee conditions for activating dynamic capabilities which allow for integrating information flows from potential to concrete.

The conditions for activating dynamic capabilities can be ensured through the correct implementation of ERP and BI systems; the latter allows monitoring and analysing large amounts of available data and representing them through intuitive interfaces that facilitate decision-making. The correct implementation of ERP systems can be guaranteed by ensuring consistency between these technologies and information flows. Martins and Santos (2021) highlighted that the effectiveness of ERP systems depends on the systems' tuning with company culture, organisational structure and how work activities are carried out, linked to reengineering processes. The package, in the organisation, allows management control to activate its potential, creating an information system with multiple purposes and dimensions capable of permeating the entire organisation, from simple routines to complex decision-making systems aimed at mere control and learning.

The literature review, therefore, analyses the main scientific works that have focused on the critical aspects highlighted by the research objectives of this study, namely, the reengineering of information flow in ERP and BI systems.

2.1. The reengineering of information flows and business intelligence as critical issues in the implementation of an ERP system

Performance management in healthcare organisations calls for technological innovations that have characterised information systems in recent years (Alohali et al., 2020; Benevento et al., 2021), which are data-driven technologies that enable reliable, real-time performance verification (Wager et al., 2021). Therefore, in a world increasingly dominated by automation and the data-driven approach, modern performance management systems progressively require complementarity between ERP and BI systems (Ranjan, 2008; Peters et al., 2016), even though new-generation ERP systems already include BI functionalities that allow managers to set performance indicators and customised measurement parameters according to the organisational structure and established corporate objectives (Davenport, 2006; Chaudhuri et al., 2011). In this regard, the data-driven approach must become a real data-driven culture; as Perdana et al. (2022) state, 'firms must also ensure their business processes generate high-quality data; they must also avoid data silos and strive to have a data-driven culture' (p. 100548). Implementing an ERP system (Momoh et al., 2010) and its interaction with the BI are the most critical factors (Elbashir et al., 2008) for effective performance measurement. In particular, while the ERP system connects information processes to optimise resource management, the BI system allows an even deeper analysis. It represents the processes in a usable and easy-to-interpret format.

Bradford and Florin (2003), using references to the diffusion of innovations theory, pointed out how the successful implementation of an ERP system in an organisation is linked to three attitudes towards innovation. Even though this study does not adopt the theoretical approach of these authors, the following characteristics are useful for theoretical analysis:

1. Innovative characteristics, including technical compatibility with pre-existing IT systems, perceived complexity within the entity of its implementation, and the reengineering of processes.
2. Organisational characteristics include support from top management, consensus on organisational objectives, and staff training programs.
3. Environmental characteristics include competitive pressure.

Implementing an ERP system with BI functions in a company requires a review of the organisation of staff working methods and information flow to allow 'the distribution of management control information to both operational and strategic level managers' (Elbashir et al., 2021). While many factors influence the effectiveness of an ERP system (Momoh et al., 2010), the reengineering of information flow and their interaction with BI is certainly the most critical (Elbashir et al., 2008) to use and exploit the opportunities inherent in such systems. However, notably, the reengineering of information flow is the basis for reengineering business processes; information flow reflects the processes to which they are connected.

Information flow must capture process complexity while allowing for improvement (Davenport, 1998; Peters et al., 2018). Furthermore, design management must be dynamic rather than static, *inter alia* new information arriving late or the need to review processes to improve their efficiency (Pektas and Pultar, 2005), and the fact that an ERP system is an infrastructure and not a simple software package (Lee and Lee, 2000; Kumar et al., 2003; Shehab et al., 2004) must be considered. Therefore, the ERP infrastructure

influences the logic of the processes that are going to be designed and not the contrary, although Shehab et al. (2004) highlight how 'the solution can be a compromise between complete process redesign and massive software modification' (p. 375).

The literature analysis on ERP systems in the healthcare sector reveals a significant emphasis on the complexity of healthcare organisations owing to the presence of multiple and diverse information flows, including (i) clinical, (ii) administrative, (iii) outsourced, and (iv) radio diagnostic activities (Agarwal and Garg, 2012; Garefalakis et al., 2016). However, little consideration has been given to the reengineering of information flows with the ERP system, although many authors have highlighted how an ERP system is costly and demanding because of the time it takes to achieve effective adoption, meaning that implementation can fail (Al-Mashari and Al-Mudimigh, 2003; Chiarini et al., 2018). A recurrent issue in the ERP systems is the need to make clinical information available to doctors (Adwan et al., 2013) and motivate and train staff to adopt the new system (Garg and Agarwal, 2014; Abukhader, 2015; Almajali and Tarhini, 2016), the latter problem is particularly acute in healthcare organisations given the different staff, which 'includes a large spectrum of professionals that can be characterised by possessing expertise, power, and autonomy' (Agarwal and Garg, 2012, p. 159) and who could resist change.

In an ERP system, BI allows for managing all data flows, transforming them into useful knowledge depicted comprehensibly for decision-making using performance indicators within the organisation and its environment (Lönnqvist and Pirttimäki, 2006; Ortega et al., 2011; Elbashir et al., 2021). The transformation of data into information and knowledge is not a process which can automatically be effective. BI involves entering data from different sources into a data warehouse and subsequently extracting them to create functional meanings, including interpretation, description, knowledge sharing, and prediction (Watson and Wixom, 2007). However, the data warehouse or connected data marts are not a magician's hat that makes it possible to satisfy all a company's needs and knowledge requirements. The effectiveness of the extraction process depends significantly on soft conditions, such as the data quality and the ability to make queries, and also on hard conditions, such as the alignment between the BI and other IT systems (Lönnqvist and Pirttimäki, 2006; Watson and Wixom, 2007; Ortega et al., 2011; Reinking et al., 2020).

Scholars have highlighted that the adoption of BI systems in the healthcare sector is still low for reasons mainly linked to the 'need to meet the legislated and perceived requirements of security and privacy when dealing with clinical information' (Ali-Ozkan and Ouda, 2019, p. 1; see also Agrawal et al., 2002). However, other reasons exist for resisting BI systems in the healthcare sector. Foshay and Kuziemsky (2014) pointed out that the full adoption of BI systems in healthcare organisations is hindered by those working in the organisation and the compatibility of these systems with operational processes and pre-existing technology. Analysing and solving the issues preventing the full implementation of BI is necessary in the healthcare sector so that these systems can work at their full capacity, supporting the decision-making process of all spheres of healthcare organisations (Kao et al., 2016) while ensuring their profitability in terms of the investment (Muriana et al., 2017).

System integration between ERP and BI affects management control and organisational performance throughout the entity at all levels. Management control and accounting systems influence information systems by identifying the phenomena to be detected and represented correctly. However, information systems generate information and monitor and control functions that extend throughout the organisation and are not limited to the management control department, influencing its activities (Dechow et al., 2007). The influence on management control activities is linked to 'management control is becoming increasingly involved with managing technology' (Dechow et al., 2007, p. 46), which also influences the skills that operators must have. However, the widespread dissemination of information throughout the organisation allows for monitoring and controlling performance in departments other than the management control department (Scapens and Jazayeri, 2003; Quattrone and Hopper, 2005). However, this means the absorptive capacities are spread throughout the organisation (Elbashir et al., 2011). Therefore, the management control department may prioritise data considered for decision-making and loses its function as a data producer; strategic information. System integration between ERP and BI also impacts organisational performance. However, the effect that is immediately apparent is the availability of real-time data, with the consequent elimination of redundant and duplicate data (Watson and Wixom, 2007); the effect is holistic since the creation and dissemination of information at the operational and strategic levels enables integrated coordination and activity control, and widespread knowledge system (Wang and Wang, 2008; Muhammad et al., 2014).

3. Case study and methodology

3.1. Institutional background

The Italian Regional Public Health Service, taken as a whole, belongs to flexible planning systems or umbrella strategies (Mintzberg and Waters, 1985), where only general objectives are defined at the regional level. Public health organisations must make strategic choices consistent with these regional objectives. This setup exists when the environment is complex, varied, and uncontrollable and underscores the vision shared by executive leaders (the strategy is desired and decided in general terms but not in detail). However, the freedom to interpret this vision must be controlled to ensure the right course is followed.

Campania is located in southern Italy, experiencing economic hardship for many years because the regional government has been on a high level of debt. This has affected the public health sector, and the Campania Regional Health System has had to operate under a commissioner appointed at the national level for many years because of excessive debt. This continuous indebtedness affecting the public health sector has led regional governments to implement systems to monitor healthcare organisations and the efficiency of their management. Furthermore, the regional authorities acknowledged the need to implement an information system capable of correctly allocating direct costs and defining shared cost-recovery drivers; to implement an analytical accounting system providing management decision support to the region's different public health organisations and providing homogeneous, reliable data to the Ministerial Committees. Therefore, the government of the Campania Region standardised the information systems operating in the single public

healthcare organisations within the region to guarantee the availability of economic, managerial, and production data from healthcare structures to support planning activities and control the healthcare system at the regional level. This situation is not new in countries with public health care systems, as Kraljić et al. (2013) and Handayani et al. (2013) highlighted.

As part of the budget harmonisation process established under Legislative Decree 118/2011, the Campania Region strategically created a Management and Accounting Information System to develop an integrated monitoring and control system based on management and accounting data.

3.2. The case-study protocol

This research analysed a descriptive case study (Yin, 2003). The case study protocol envisaged carrying out a) in-depth interviews with the main parties involved in the process of reengineering information flows, b) gathering data regarding the information flows before and after the reengineering process, c) directly observing the functioning of the information system after reengineering the information flows, and d) in-depth interviews with administrative and the clinical department heads as users of the information system (Table 1). The case study protocols were conducted from May to June 2021.

The researchers conducted in-depth interviews with representatives of the hospital's directorate, the information systems service, and the management control service to get a clearer picture before and after the information flow reengineering process. This allowed researchers to accurately analyse the critical issues that emerged and the solutions applied to overcome them. Therefore, in-depth interviews were conducted with the staff of the IT company, which provided the information system and supported the hospital in implementing the new ERP and BI systems.

Subsequently, the researchers observed the architecture of the new information flow directly, studying its performance during normal hospital activities; this was conducted with the support of the information systems service and the company which provided the information system. Finally, the researchers conducted in-depth interviews with the managers of the different services and clinical departments (Table 1) to determine their satisfaction and ease of use with the new information system, particularly as a support system for providing data and information.

The in-depth interviews of the various actors follow the management control system and decision-making discretion in the performances achieved. The hospital directorate is responsible for strategic decisions made within the limits of the general objectives defined by the region; therefore, they define the information that the management control system must guarantee. Every quarter, the hospital directorate must communicate with the regional government and the Ministry of Health information on the economy, production of services, and health performance achieved, for which the management control system assumes a critical role since it provides information support for decision-making processes. However, the management control service must ensure effective integration of information flows to guarantee reliable and timely information. Moreover, the heads of the clinical department and administrative service managers have reduced strategic discretion. Still, they must monitor the performance of their departments to verify if these performances align with the objectives of the directorate.

Furthermore, two visits were made to the management control service, each lasting approximately one hour, to observe the functioning of the information system directly. During these visits, we acquired a list of key performance indicators.

4. Findings

4.1. The reengineering of information flows conducted by the public university hospital

Analysing and reengineering public university hospital information flows generated a preventive analysis of the strengths and weaknesses of the information system to identify the critical issues and consider them in the reengineering process.

From the analysis, it emerged that public university hospitals faced the following critical issues:

a) A highly fragmented monitoring system which only considered the performance indicators required by regional and national regulations (e.g. appropriateness, essential healthcare levels, referred to using the Italian acronym LEA, waiting lists, etc.) which, in the absence of an evaluative integration of all the results, was not suitable for steering strategic choices;

Table 1
In-depth interviews by researchers.

Department/Service	Experts interviewed	Duration of each interview
Directorate	General Manager	Approximately 30 min
	Health Director	Approximately 30 min
	Managing Director	Approximately 30 min
Information Systems Service	Service Manager	Approximately 40 min
	Two service operators	Approximately 40 min
Management Control Service	Service Manager	Approximately 40 min
	Three service operators	Approximately 40 min
Staff of the IT company	Two service operators	Approximately 40 min
Clinical departments	11 Heads of clinical departments	Approximately 30 min
Administrative services	2 Service managers	Approximately 40 min

b) The fragmented information systems are not connected to collect data for indicators such as Quani, Diamante, SGP-CUP, AREAS (replaced by SIAC), Perseweb, Winsap, Cineca, Iriswin, and ADT-WEB;
c) The lack of a dedicated team to work on periodic monitoring of performance indicators and conducting the consequent critical evaluations of the results obtained;

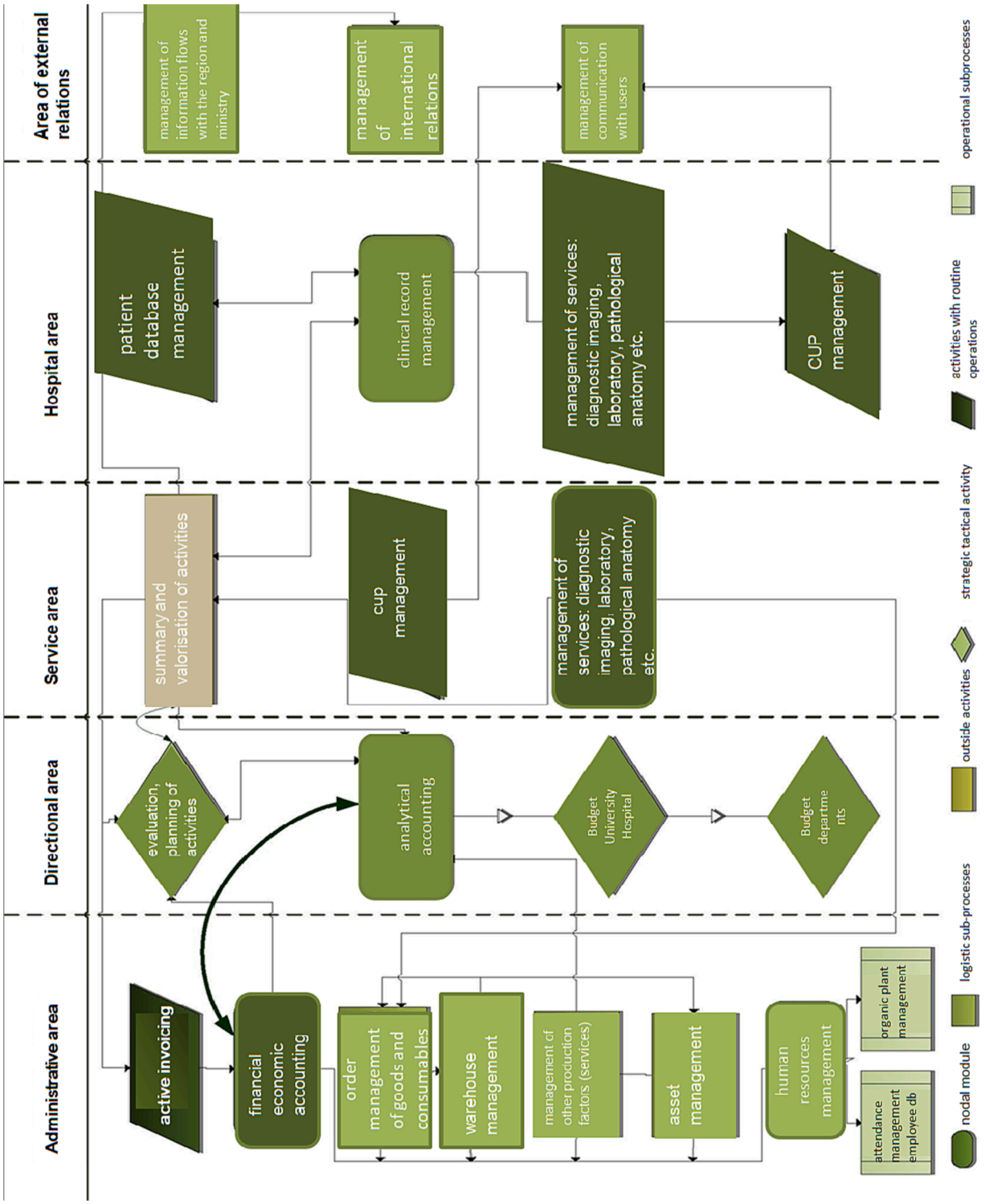

Fig. 1. The mapping of architecture and information flows.

d) Transitory, discontinuous involvement of the Heads of Departments or Heads of UOC/UOSD/Programs in analysing unsatisfactory performance as the main 'producers' of the outcome of healthcare activities.

The availability and reliability of data from the public university hospital represented a problem common to very complex or highly structured organisations due to vertical decision-making hierarchies or the interoperability of horizontal operating units. Therefore, planning and managing data assets proved difficult. The volume of data should be managed while managing inefficient data synthesis as it could jeopardise data production and their required characteristics: completeness, homogeneity, and usability.

The analysis and reengineering of information flow aimed to build a data warehouse system that would allow data integration from the different areas identified within the public university hospital and to build multidimensional indicators to monitor the management system and other economic and performance-related aspects over time. The data warehouse must ensure the aggregation and standardisation of data from external sources and management information systems, providing the necessary support for planning, management control, and decision-making. The key is to provide a holistic overview of the information assets while interacting with pre-existing applications in the organization. The data warehouse provides transversal views of the organization's activities at every level giving top management quick, complete, and effective information to make better operational and strategic decisions.

Therefore, the data warehouse integrates all data produced by various information systems.

To construct the data warehouse objectively and systematically, becoming fully acquainted with the existing situation within the public university hospital is important to understand all the active information flows, define the area of interest for each one producing data, and the compliance requirements in terms of the information to be submitted to the applicable authorities. It is necessary to map the information flows. Comprehensive mapping of the existing data model in a public university hospital was crucial to study the computer systems and the logic and structures of database construction.

The collected data allowed us to interpret and classify all decision-making processes in the public university hospital, analyse the relationships and correlations between them, and observe their behaviour within the value chain and organisational structure (*Decisional Analysis Process*). As gaining knowledge of information and workflows was conducted, the needs of the operators and management regarding how the data is to be summarised to produce useful information also emerged (*Requirement Engineering Process*).

The knowledge acquired during the flow analysis process made it possible to ascertain that the management applications used were designed such that each program was only aware of the information flow of its direct interest; hence, there was fragmentation and redundancy in the data assets. Therefore, the Data Warehouse Repository responded to the need to ensure the integration of various information flows.

In designing and implementing a general information system capable of producing information for an entire public university hospital, specific knowledge of the characteristics of each area and the integration requirements between them cannot be ignored. This allowed the integration of information systems in each area, making up the entire package of management control systems of the Public University Hospital. In particular, the ability to divide information flows into macro-areas facilitated the attempt to schematise

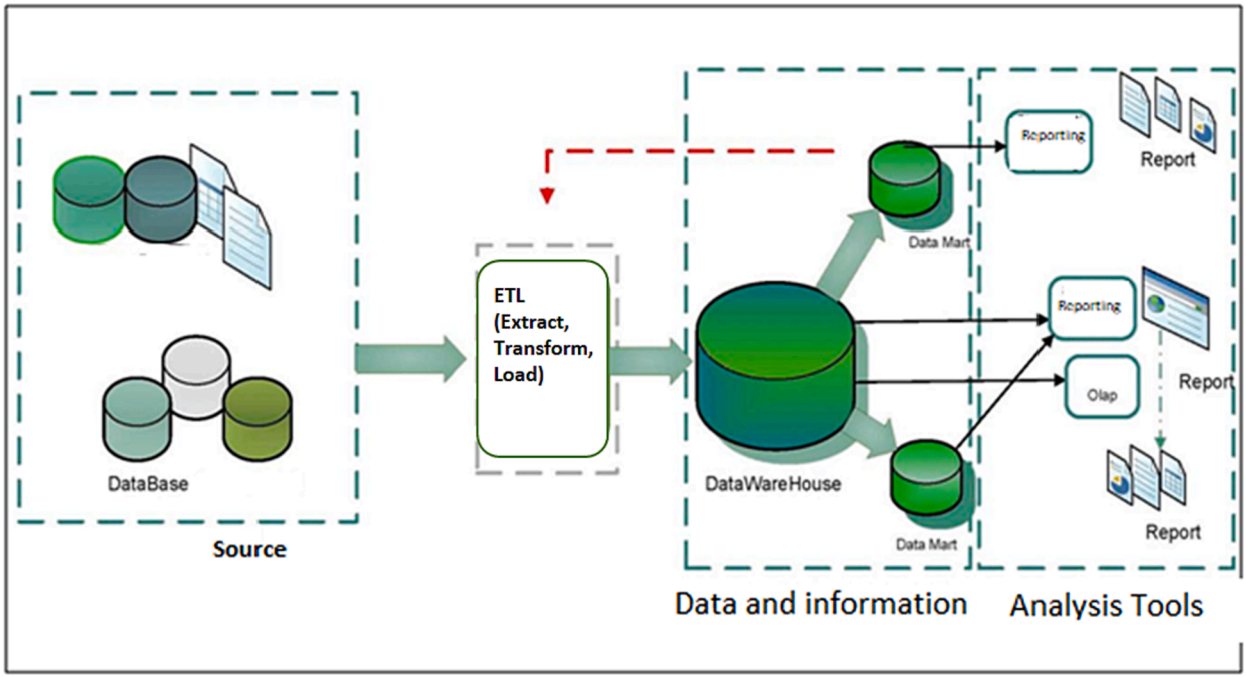

Fig. 2. The architecture of the data warehouse.

them to reproduce a 'functional' integration, in which it was possible to identify the following within each macro-area:

- various application modules corresponding to well-identified core activities;
- any sub-modules which refer to support activities;
- any parties external to the organisation;
- the information flows established between modules and subjects.

Some modules were considered nodal to the system, given that, owing to the amount and relevance of the information they collected and combined, they proved crucial in the circulation and integration of flows (Fig. 1). Other processes were logistical sub-projects or, they were external activities. Still, the mapping allowed us to highlight strategic activities and those connected to organisational routines. Therefore, mapping the processes highlight the nature of various information flows and their organisational roles.

The data warehouse of the public university hospital involved analysing multiple datasets to clear inconsistencies and obtain unique results at whatever level they were analysed. To achieve this, the data was literally 'restructured', i.e., copied into structures built specifically for the purpose. Hence, there is a need to build an environment where part of the data can be replicated for analysis, providing a structure that makes the extraction easier and faster.

Fig. 2 shows the architecture used in the construction of the data warehouse.

Fig. 2 highlights the steps followed to construct the information repository. Once the sources were identified, they were entered into the extract, transformed and loaded (ETL) system, which collected, processed, and transformed the data to make them suitable for loading into the data warehouse.

Two paths from the data sources to the data warehouse were followed according to the following requirements:

- building the Data Mart: creating database structures dedicated to specific information flows;
- creating simple and parametric reports and OLAP analyses using multidimensional cubes.

4.2. The role of BI in the construction of the public university hospital information flows

Creating a BI with the ERP system at a public university hospital enabled it to carry out multidimensional views (OLAP cubes) of data and reports with advanced organisational logic. The results obtained from creating the BI platform are summarised as follows:

- *The use of a single database:* particularly, it was necessary to ensure the integrated management of information to allow for
  - the use of uniform coding methods;
  - the pursuit of systematic homogeneity for all variables;
  - the use of the same units of measurement.
- *Access via browser:* It is necessary to have an Internet connection to consult the data on accessing the hospital intranet using appropriate credentials; leveraging specific services, including querying the data warehouse, was possible.
- *Access restricted to authorised users:* Almost all data collected by a healthcare entity can be defined as sensitive. Access may be guaranteed to authorised users, and security levels are differentiated according to the individual's role.
- *User-friendly environment:* The interface is intuitive and easy-to-use, even for inexperienced users.

Once access to the information within the data warehouse has been obtained, according to the reference group for restricted data access, the following features are available:

- *The possibility to vary the basic analyses, apply filters or modify the perspective:* Both the OLAP cubes and reports leave the user some freedom regarding the information viewed.
- *The possibility to print the results and export them in.pdf or Excel format* is another important property of this system.
- *Adequate update frequency*: The data in the warehouse are updated weekly; this decision was taken together with Management Control following the need to update the data to process useful information.
- *Eliminating waiting times in data processing:* This is a fundamental advantage deriving from using this system. To date, the 'waiting time' factor has been completely reduced; it is now a few seconds at the most.
- *Use of information sources, hardware and software systems that already exist or are easily available:* From the perspective of data, the existing sources are reorganised.
- *The possibility to create graphical representations automatically:* Both the OLAP and reporting display systems allow for customisable charts to be obtained automatically.

The features mentioned above make the system effective in managing data flows. It is important to emphasise that every OLAP analysis and advanced report visualising the data synthesis has considered the parties needing data consultation. For management control services and reporting analysis, the data are generally grouped by Cost Centre and Production Factor distributed over time; for healthcare professionals or for those who consult the data to carry out evaluations other than strategic ones, the data are grouped according to the relative structures; departments and functional areas distributed over time. It should be emphasised that the management control service has to monitor for strategic management; therefore, it can analyse economic and production data and strictly

health data, such as the average weight of DRGs. Health departments and functional areas are mainly interested in the health performance data of their organisational units; however, they also understand economic data and resource consumption. Initially, clinical unit managers did not pay attention to data other than health performance. However, this situation was resolved by linking part of the economic incentives of the annual evaluation to economic performance and resource consumption.

4.3. The KPIs monitored by the public university hospital

In the public university hospital, using a data warehouse system (based on integrating an ERP and a BI system) speeds up management control activities, achieving results in a shorter time and obtaining reliable data. In particular, the entire area related to

Table 2
Key performance indicators identified by area.

Area	Key Performance Indicators
1. LEA + Thematic Objectives	Regular admissions of paediatric patients (<18) for asthma and gastroenteritis
	Regular admissions of adult patients (> = 18) for complications (short and long-term) from diabetes, COPD, and heart failure
	Diagnostic day-care
	Entry for medical treatment
	Ratio between admissions attributed to DRG at high risk of inadequacy (annexe B Pact for Health 2010–2012) and admissions attributed to DRG not at risk of inappropriateness in regular admissions
	Patients (65+) diagnosed with femoral neck fractures operated on within two days in a regular admissions procedure
	First-time caesarean section deliveries
	Admissions with medical DRG among those discharged from surgical wards
	Average length of hospital stay prior to surgery
	Discharge of regular admissions for acute cases with medical DRG and hospital stay beyond the threshold in older adults.
	Laparoscopic cholecystectomies performed in Day-Surgery and 0/1-day regular hospital stay
	Repeat admissions within 30 days for the same MDC.
2. PNE: Quality standard	AMI: Proportion of PTCA treated within two days
	Cholecystect. laparoscopy: Admissions with post-op hospital stay < 3 days
	Cholecystect. laparoscopy: % int. in departments with more than 90 annual int
3. Efficiency plan	Deviation of RO admissions compared to the expected result from PdE
	Difference in DH admissions compared to the expected result from PdE
4. Project Lines	Expenditure progress concerning the schedule
	Evaluation of outcomes
5. Appropriateness	Cases of pre-admissions within the established timeframe
	Waiting time between pre-admission and admission/surgery
	Average hospital stay performance index
	Case performance index over the threshold
	Preoperative MD for acute in RO for Surgical DRG
	SDO did not close RO
	Timeliness of delivery times for regular admissions
	Execution times of diagnostic and laboratory services
	Reporting times for diagnostic and laboratory performance
	Sdo with status IN THE DEPARTMENT and days of hospitalisation > 30
	Attractiveness
6. Staff	Incidence of medical and nursing staff costs on turnover.
	Incidence of non-medical administrative and technical personnel costs on turnover
	Absenteeism rate
	Medical staff for PL
	Nursing staff for PL
	Overall turnover rate
	Human Resources Assessment Indicator
	Overtime indicator
7. Waiting lists	Waiting times for admissions
	Outlier cases
	Cases cancelled
	Waiting times for outpatient services
8. Consumption monitoring (drugs + medical devices)	Drug consumption / Production value
	Device consumption / Production value
	Monitoring of drug consumption regarding the quantity and weight of hospitalisations
	Device consumption monitoring regarding the quantity and weight of admissions
9. Information flows	Timeliness of transmission
	Logical-formal correctness of the transmitted data
	Quality of production data
10. Didactics and Research	Average Impact Factor in the specialist area
	Number of trainees per doctor
	Number of undergraduates per doctor
	Number of publications per university doctor
	Total funds per publication

information flows has seen highly positive results from implementing the data warehouse.

The data warehouse system allows the hospital's directorate to count on a dashboard of reliable and real-time data useful for monitoring performance (many of which are only now monitored), constituting valid information support for decision-making processes, which have become less complex and more effective.

The integration of information flows of the management control systems constituting the package of controls has made the work of the Information Systems Service much more effective and efficient, obliged in the past to remedy unreliable information, and produced late because of the fragmentation of the various information systems. The heads of clinical departments expressed their appreciation for an information dashboard capable of providing information with intuitive interfaces. It is easy to analyse, allowing a clear understanding of the measure of the performances achieved.

The results changed the role of the management control department, which coordinates various information flows, such as the conductor of an orchestra, defining priority information and the characteristics that such information must feature on a case-by-case basis while also monitoring a *core* set of key performance indicators (KPIs) (Table 2). Furthermore, integrating the information flows of the control package created through the data warehouse system has made accountants more efficient; they often had to 'manually' build various reports by extracting data from various information systems.

The *core* set of performance indicators shown in Table 2 are collected and analysed by the management control department for different needs; indicators in Area 1 (Essential Levels of Healthcare and Thematic Objectives), Area 2 (Italian National Outcomes Programme), Area 5 (Appropriateness) and Area 7 (Waiting lists) capture performance in healthcare services they monitored to verify any deviations from the ministerial and regional targets. These performances are made available to the directorate, to allow the necessary strategic choices, and to the heads of the clinical departments to allow them to monitor performances. Indicators in Areas 3 (efficiency plan) and 9 (information flows) monitor the economic balances referred to in the efficiency and redevelopment plan drawn up by the regional government, which are made available to the directorate to check whether the efficiency conditions and obligations are being respected. Indicators in Areas 4 (project lines), 6 (staff), and 8 (consumption monitoring) monitor the costs related to the projects, health personnel, and consumption of health resources, which are made available to the directorate and the heads of the clinical departments to allow monitoring cost trends and corrective actions, especially for resources that have a greater impact on costs. Indicators in Area 10 (Didactics and Research) monitor didactic activities and research programs closely integrated with healthcare services and are made available to the heads of clinical departments to allow didactic activities and research programs.

The public university hospital can implement an efficient performance measurement system capable of providing real-time monitoring of achievements for the detected indicators; the conditions of efficiency achieved are connected to the following:

- The ability to increase management's awareness of the progress and potential, allowing them to guide it most efficiently, without the risk of pushing it beyond its limits or neglecting the opportunities to use those resources, which will finally be evident in the low added value or even non-use;
- The ability to exploit existing information assets at nearly zero cost, recover and import data trapped in company management systems, and display them clearly and concisely using graphs of various navigable tables;
- Greater effectiveness in fulfilling information debt obligations towards the Region and the Ministry of Health;
- The performance assessment at multiple levels, Directorates, Health Departments, and Operating Units;
- Monitoring the progress of the company's strategic plan;
- The ability to develop predictive and internal organisational models.

4.4. The transformation of data into information and their features

The public university hospital has an enormous volume of data in its information systems, which, thanks to an adequate BI system, has identified KPIs useful for a global and rapid vision of organisational trends and detailed data from which these KPIs are extracted in the same environment, thus making it possible to carry out deeper analysis with great detail.

The data warehouse system specially structured for data analysis in a public university hospital has made it possible to reduce the time-to-delivery, the time required to find the information necessary for decision-making. In a competitive context, decision-making rhythms are increasingly stringent; eliminating this increases the time available to analyse data and, therefore, make key decisions for growth. Knowledge of the performance indicators took time. Hence, the hospital directorate undertook actions to review behaviours, and there was little time to change performance.

The data warehouse of the public university hospital is the central repository for information, as the place where all the different data sources converge, thus obtaining a system that unifies the various existing applications, allowing cross-analysis between information from the various management systems.

The data warehouse allowed the management control service to analyse trends with a significant historical depth (typically three or five years, but in many cases, even more than ten years). Furthermore, the data warehouse did not occur based on the system that powers it but for processing and analysing data. This means that, in the event of changes in the management system, the data warehouse can maintain its structure, acting as a glue between the two environments and maintaining the integrity of the pre- and post-migration information. This guarantees that the data reader has a stable environment, which is crucial when information is the basis for the decision-making process.

A fundamental aspect of constructing the data warehouse was the attention paid to cleaning the data; carrying out consistency and integrity checks on the information. The data warehouse reads data extensively during the night when there is low usage of machines. It can carry out multiple consistency checks before importing them, reporting any anomalies for correction directly on the source

systems. This approach has two advantages: on the one hand, it allows for a completely validated analysis environment according to the organisational rules defined by the users; on the other hand, it makes it possible to identify and correct any anomalies in the data within the management system that otherwise would never be detected. This aspect is even more important when multiple feeding systems exist, as cross-validation of information would otherwise be very difficult.

The data warehouse system implemented in the public university hospital provided summary and operational data. Data quality check was conducted at the highest level of detail, thus ensuring maximum consistency of the information presented, regardless of the depth at which it is presented.

4.5. Additional areas of the organisation that have been positively influenced by the implementation of the data warehouse

With the implementation of the data warehouse, the benefits in areas critical to the healthcare sector could be verified.

- *Risk and Asset Management*: Risk and Asset Management activities are an interesting application area, particularly for analysing and simulating portfolios and related risks and reporting.
- *Identification of fraud*: This application area can lead to significant resource savings. In managing a healthcare organisation with unique, integrated information assets, it is possible to have 'real' control over all processes, which includes envisaging cross-checks (e.g., on pharmaceutical prescriptions, inappropriate admission to hospital, etc.).
- *Clinical Decision Support System*: Decision Support System (DSS) is a technology that supports the management or physicians in making clinical decisions effectively and quickly. It must be emphasised that these support tools help doctors decide but do not replace the experience gained over the years.

The main advantage of the new information system from an organisational perspective is the significant reduction in 'time-to-delivery'. Table 3 presents the data extraction process for creating a budget sheet using the management systems before and after the data warehouse installation.

Table 3 shows that the reduction in time-to-delivery through a data warehouse system is more efficient than that in the original architecture. This efficiency impacts the different kinds of outputs produced in the hospital, such as quarterly reporting, performance assessment, measurement of results linked to the monitoring of Essential Healthcare Levels, and appropriateness. When this reduction in time-to-delivery is applied on a wider scale and to all the outputs within the system, a considerable amount of time is saved in quantitative terms, which can be used to analyse the results obtained more thoroughly.

The second advantage that can be measured quantitatively is increased data quality. A Key Quality Indicator (KQI) measures the benefits obtained: the proportion of 'OK' results concerning the total number of checks carried out, i.e., the percentage of cases in which the data is correct. The data checks performed by the management control service are listed in Table 4.

By measuring each KQI for each indicator, an increase in data quality of approximately 20 % compared to a traditional information system is observed.

5. Discussion

The case study highlights how a situation which could be rather confusing and uncertain for a public university hospital due to the decision made by the regional government in Campania to standardise information systems operating in individual public healthcare organisations is turned into an opportunity. The accurate reengineering of information flows allowed for integrating IT applications that previously operated independently and were fragmented, ensuring that the different management control systems comprising the control package worked in harmony. This is consistent with Bradford and Florin (2003), Momoh et al. (2010), and Elbashir et al. (2008); in particular, these studies have highlighted the critical role played by the reengineering of information flows in complex organisations such as healthcare. This integration process rendered these IT applications effective; it has created harmony between information systems and the organisation of information flows, activating dynamic capabilities and making the integration concrete and not purely formal, as theorised in general by Elbashir et al. (2021). Substantial and not purely formal integration of information

Table 3
Data extraction times for the creation of a budget sheet before and after the implementation of the data warehouse.

ID	No ERP SYSTEM		ERP SYSTEM	
Sequence	Activity	Time to delivery (hour)	Activity	Time to delivery (hour)
1	Extract data from ADT WEB	1	Extract data from DWH	1
2	Extract data from QUANI	1	Extract data from DWH	0
3	Extract data from OLIAM	1	Extract data from DWH	0
4	Extract data from CINECA	1	Extract data from DWH	0
5	Extract data from PERSWEB	1	Extract data from DWH	0
6	Extract data from IRISWIN	1	Extract data from DWH	0
7	Extract data from SGP-CUP	1	Extract data from DWH	0
8	Extract data from ELIOT	1	Extract data from DWH	0
9	Merge data	3	Extract data from DWH	0
	Total	**11**	**Total**	**1**

Table 4
The checks conducted on the data.

ID	Check
1	Does each data in the source system refer to active cost centres?
2	Are there monitored processes in which a historical reference is inconsistent with expectations? (Discharge dates in previous or future centuries)
3	Are all referrals between the date of admission and the date of discharge?
4	Is it possible to link financial compensation to all the staff in the system? Are any people on leave of absence still counted in the workforce?
5	Are all admissions counted in the ADT (Acceptance Discharge and patient Transfer) management system fully accounted for in the regional payment flows governing the (theoretical) economic remuneration?
6	Are all outpatient services in the system properly associated with formally correct prescription codes?

flows is necessary to transition complex organisations from a stratification of management control systems implemented over time to meet certain information needs, as Malmi and Brown (2008) highlighted. Therefore, several management control systems in the same organisational reality do not make them unitary and integrated, as do technological innovations, such as ERP and BI systems. They cannot make concrete the potential for integrating information flows that make management control effective. Thus, implementing ERP and BI systems in a complex organisation requires accurate reengineering of information flows.

With reengineering information flows linked to technological innovations, the public university hospital has developed a widespread monitoring and control system for individual departments and functional areas into which it is organised. Managers of these organisational structures can count on reliable and timely data on their performance, represented through interfaces that are intuitive and immediately useful, even for non-IT experts. As the literature indicates, the management control service coordinates information flows identified for monitoring and controlling (Dechow et al., 2007). Hence, the fragmented management control system can be overcome by adopting ERP and BI systems, which have the inherent potential to ensure the integration of information flows and the effectiveness of management control systems, allowing the transition from a package of control systems to a larger and higher-level system. ERP and BI systems were integrated in the analysed case, consistent with the different control systems' performance measurement and evaluation needs and packages (Malmi and Brown, 2008). It was connected to various management control areas developed over the years in healthcare organisations (Table 5). Table 5 shows the effective integration of information flows that influence the quality, timeliness, and accuracy of the information generated.

The quality and quantity of performances have also changed, and implementing a data warehouse system has allowed public university hospitals to transform data into useful information, providing a global and detailed vision of the performance of departments through KPIs. Wen et al. (2012) analysed how adequately the logical architecture of the data warehouse can provide relevant KPIs to improve the quality and speed of management and decision-making. Table 4 shows the increase in data quality achieved by the public university hospital and its considerable impact on the reliability and accuracy of the information produced. The same considerations were developed by Nasiri et al. (2015) to define a multidimensional data warehouse model. In this case study, the information is available promptly by reducing the 'time-to-delivery' (Santos and Bernardino, 2008; Bouaziz et al., 2016) to allow decisions in a short timeframe, useful in corrective actions. The example in Table 3 for data extraction time for creating a budget sheet before and after the data warehouse implementation indicates that considerable time was saved, which was also achieved concerning other information produced in the public university hospital. This is due to the integration of heterogeneous data sources, which, as Perdana et al. (2022) and Boufares and Hamdoun (2005) highlighted, requires considerable effort and the use of intelligent tools, and

Table 5
The evolution of management control areas from old to new logic.

Management Control Area	ERP/BI system	Old logic	New logic
Administrative Area	ERP system	- Very fragmented production and financial data. - Data generated late and often with errors. - Personnel management data available late and inaccurate	- Data integrated into an organic view - Data generated in a timely and accurate manner. - Personnel management data generated promptly and accurately
Directional Area	BI system	- Availability of unclear data, unable to highlight the relationships existing between them, with negative effects on decision-making processes	- Availability of data with clear and intuitive interfaces, able to detect the relationships between them, useful for decision-making processes
Service Area	ERP system	- Errors and delays in valuing activities. - Lack of integration between agendas for booking healthcare services - Absence of integration between the data flows of the different health services	- Proper valorisation of health activities. - Synchronisation between health service booking agendas. - Integration between the data flows of the different health services.
Hospital Area	ERP system/ BI system	- No integration between patient databases - Performance data interfaces not intelligible to clinicians. - Lack of integration between department-level health services management and their respective booking agendas	- Integration between patient databases. - Clear and understandable healthcare and performance data interfaces for clinicians. - Integration between department-level health services management and their respective booking agendas.
Area of external relations	ERP system	- Data generated late and with errors - Delays in communication flows with service users.	- Data generated in a timely and accurate manner. - Timely knowledge of the communicated needs of the users

the independence of source systems (Yu and Chen, 2009). The data warehouse was not based on the system that feeds it but based on the organisation's processes and the analyses to be carried out (Davenport, 1998; Böhnlein, and Ulbrich-vom Ende, 2000; Elbashir et al., 2008). Furthermore, the data entered in the data warehouse are carefully certified, which Rifaie et al. (2009) considered critical, and ensured using efficient maintenance (Javed and Rafique, 2006) to ensure maximum consistency of the information presented, regardless of the level of depth at which it is presented (Horng and Chen, 2001). Finally, it is necessary to consider the effect of a data warehouse on decision support systems, including clinical systems, to favour effective and timely clinical decisions (Ledbetter and Morgan, 2001; Palaniappan and Ling, 2008; Homaud and Opaid, 2014).

6. Conclusions

Through the case study, this study highlighted the effects of implementing an ERP system integrated with a BI system in a public healthcare organisation. In particular, the study considered the positive valence of an organisational reengineering process developed following an ERP system. However, it analysed a situation rarely considered in the literature; a public university hospital with an ERP system must adhere to a different regional ERP system due to regional government requirements.

In a public university hospital, reengineering information flows with a BI system gave rise to the implementation of a data warehouse which has had a highly positive impact on the availability of information for the organisation's management, healthcare workers, and administrative staff (Ramamurthy et al., 2008; Mettler and Vimarlund, 2009). The public university hospital developed key performance indicators that provide a general vision of the overall performance and specific individual details useful for analysis (Berler et al., 2005; Bergeron, 2017). However, the positive effects of the information system are a direct consequence of the effective integration of complex information flows, horizontally and vertically, constituting the package of controls in the organisation (Malmi and Brown, 2008). These technological innovations have significantly affected human resources. This is particularly significant for the middle management of university hospitals, as measuring results in real-time with an appropriate technology translated into progress towards management accountability, administration, and healthcare, to the extent that the publication of data linked to their work made the results timely, objective, clear, and transparent to the established targets.

The results allow us to make general considerations. Organisations, especially complex ones, manage a considerable amount of different data, making it difficult to generate information for decision-making. The difficulty of using data is often connected to a lack of integration of information flows derived from control systems that have stratified over time and are complementary. However, this does not cause a unitary control system (Malmi and Brown, 2008) but a balanced package of controls (Akroyd et al., 2019). Innovative technologies, such as ERP and BI systems, can resolve the criticalities connected to the absence of integration and favour implementing a management control system capable of harmoniously connecting various information flows with the wider decision support mechanisms. Nevertheless, innovative information technologies need to achieve rational analysis and reengineering of information flows (Elbashir et al., 2008; Elbashir et al., 2021) to allow these technologies to develop their effectiveness through the integration of information flows (Anguelov, 2021; Mariano-Melo and Ramírez-Correa, 2021). This integration of information flow generates a widespread system of performance monitoring and control at the organisational level, not relegated to the management control department alone but throughout the organisation (Scapens and Jazayeri, 2003; Quattrone and Hopper, 2005) and the absorptive capacities (Elbashir et al., 2011). In this regard, the case study shows how introducing technological innovations for measuring and monitoring performance resulted in actual cultural changes towards the targets to be achieved. In the past, a great deal of time was necessary to comprehend the results achieved collectively; with the inherent difficulties regarding any corrective action, the IT system has enabled continuous evaluation of the results achieved in the short term with the ability to intervene promptly with corrective action if medium-term results are not aligned with the long-term targets.

This case study has several practical implications for IT professionals and managers. For effective integration, information technology requires accurate analysis of the various information flows connected to the entire management control systems package, which must be followed by a reengineering process (Elbashir et al., 2008; Elbashir et al., 2021) for these technologies to develop effectiveness through the integration and governance of information flows (Anguelov, 2021; Mariano-Melo and Ramírez-Correa, 2021). Otherwise, implementing technological innovations will not integrate information flows, which will remain specific to the single management control system.

This research contributes to the literature by confirming that implementing efficient information systems in complex organisations is not simple or predictable. Effective adoption of ERP and BI systems requires an accurate evaluation of the organisation and its critical areas to reengineer information flows to create harmony between the new system, internal processes, and pre-existing technology (Peters et al., 2018). Finally, attention must be paid to ensuring that the new information system is accepted by the organisation's human resources (Adwan et al., 2013; Garg and Agarwal, 2014; Abukhader, 2015; Almajali and Tarhini, 2016).

The experience is limited because this study analysed a single healthcare organisation and not a plurality of cases. This would have verified and compared the specific reengineering processes related to the information flows created and the results obtained.

Future research could analyse experiences similar to the case study to verify in other complex organisations whether the change processes implemented are carried out in the same way as in the case study and with the same results, highlighting the critical factors connected to specific experiences.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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