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BUSINESS ANALYTICS FOR HEALTHCARE COST OPTIMIZATION: A DATA-DRIVEN STUDY ON IMPROVING FINANCIAL SUSTAINABILITY IN HEALTHCARE SYSTEMS

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Abstract

High-tech medical technologies, chronic disease epidemics, and limited workforce and resources following the Covid-19 pandemic are driving up financial pressures on healthcare systems, particularly in this context of ageing populations. This has led to the focus on cost optimisation being one of the key points for the healthcare managers and policy makers. This article looks at business analytics's role in cost control and strengthening the financial sustainability of healthcare systems. This study is a secondary study, and adopts a desk based method of research with evidence drawn from international health expenditure reports, the academic literature, healthcare analytics studies, and policy documents and case examples of healthcare systems. The article looks at the key drivers behind the cost of the health care system, including hospital readmissions, emergency demand, workforce costs, long waiting times, inefficient resource use and procurement waste and sub-optimal preventive care. It discusses the advantages of descriptive analytics to improve cost visibility, the advantage of predictive analytics and anticipating demand and financial risk, and the potential contribution of prescriptive analytics to staffing, patient flow, procurement and resource allocation decisions. The discussion also includes the impact of analytics to minimize avoidable readmissions and maximize workforce and supply chain efficiency. The article shows that soundly based on data, well integrated systems, ethical governance, and personnel capability, business analytics can play a significant role in supporting financial sustainability, but only when there is a strong focus on patient outcomes.

INTRODUCTION

In today's healthcare landscape, the challenge of cost optimisation is a key strategic priority given that many healthcare systems are unable to sustain their financial burden (McLaughlin, 2022). As healthcare organisations struggle to meet the demand of an ageing population, the spread of chronic disease, costly medical technology, staffing needs, and the financial implications of COVID in the long term, they must now provide safe, timely and effective care. This is a challenging policy and management challenge – reducing cost can't just be about service reductions, as poorly planned cost reduction can negatively impact on patient safety, waiting times and health inequalities. Thus, cost optimisation in healthcare

is a process that needs to address the identification of waste, improving efficiency and the utilization of resources to the greatest possible clinical and financial benefit.

International expenditure figures are a good indication of the scale of the problem. WHO said it estimated global health spending at US$9 trillion in 2020, which is roughly 11% of global GDP, primarily due to pandemic-related changes in government spending on health (World Health Organization, 2022). This article is of special significance because of the Global Health Expenditure Database produced by WHO, which offers comparable health expenditure indicators for 195 countries, such as expenditure on the government (WHO, 2020) and expenditure on out-of-pocket financing and expenditure by household members. This indicates that the challenge of cost pressure on the health sector is not a local or even a national one but a global one that impacts publicly-funded, insurance-based and mixed health systems.

The OECD data also shows that expenditure on health has been keeping a strain on the economies of the countries. Healthcare expenditures in OECD countries are estimated to have accounted for 8.8% of GDP in 2019, 9.7% in 2021 and 9.2% in 2022 (OECD, 2023) see detail in appendix 1. The overall cost of health in per-person terms is almost USD 5,000 in OECD countries and USD 12,555 in the United States in 2022, with significant variations in cost intensity of health systems (OECD, 2023). The numbers indicate that simple increases in funding are not the answer to financial sustainability; the evidence-based management of resources, demand, workforce and care pathways in healthcare systems are additionally very important.

In this regard, business analytics is becoming increasingly relevant as it allows to make the clinical, financial, operational and patient flow data actionable. Descriptive analytics can provide insights on what is causing costs to increase, departments that have "unusual" spending behavior, and areas of inefficiency. Predictive analytics can predict demand, bed occupancy and workforce needs (Bertsimas et al., 2022), and it can predict risk of readmission and medicine use. But analytics is not all on its own. The quality of the data, integration with other systems, ethical governance, staff skills and the ability to maintain a balance between financial efficiency and patient results are all important to its value.

The objective of this article is to explore how the business analytics can facilitate healthcare cost optimisation, and enhance the financial sustainability of healthcare systems. Specifically, it identifies the major factors driving healthcare costs, explores the use of analytics to reduce wasteful cost of healthcare, offers an analysis of the use of predictive and prescriptive analytics for guiding financial planning and resource allocation, and critically discusses the challenges to implementation and suggests a data-driven framework to make healthcare economically sustainable.

Background and Context of Healthcare Cost Pressures

Rising Healthcare Expenditure

There has been a global rise in the cost of healthcare over the years as health systems are treating more older patients, more chronic conditions, and more complex conditions that demand the use of advanced medicines, diagnostics and specialist care. According to OECD evidence, significant differences do exist in spending intensity across countries: In 2022, the United States spent nearly two-and-a-half times the OECD average of nearly USD 5,000 per person on health care services (OECD, 2023b). This means that spending more does not necessarily provide greater cost efficiency; it can also be due to administrative complexity, high prices and service provision fragmentation.

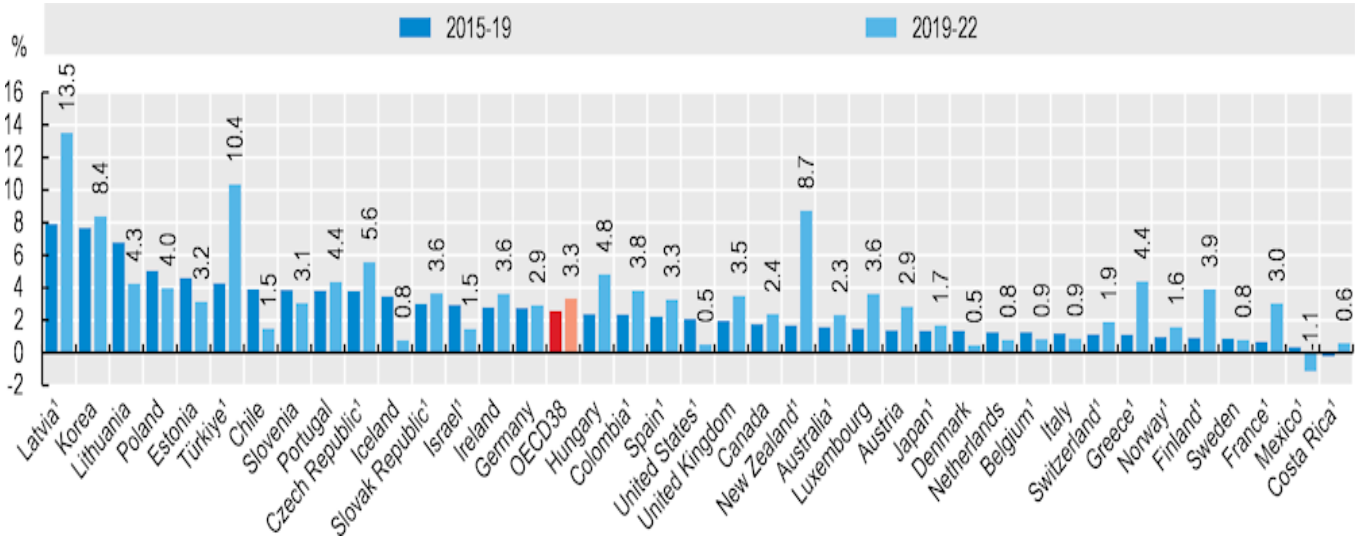

Figure 1: Average annual growth in per capita health expenditure

Source: (OECD, 2023b)

This is a difficult issue for governments to deal with when expenses increase as access, quality and affordability are all to be taken into account with the policy of healthcare. WHO data revealed that real per-capita health expenditure actually decreased in 2022 from 2021 after the initial COVID-19 pandemic surge, and also decreased by domestic public expenditure per person across income groups in 2022 compared to 2021 (WHO, 2023). This indicates that many systems were in a weaker fiscal position than before the pandemic and cost optimisation is needed now more than ever.

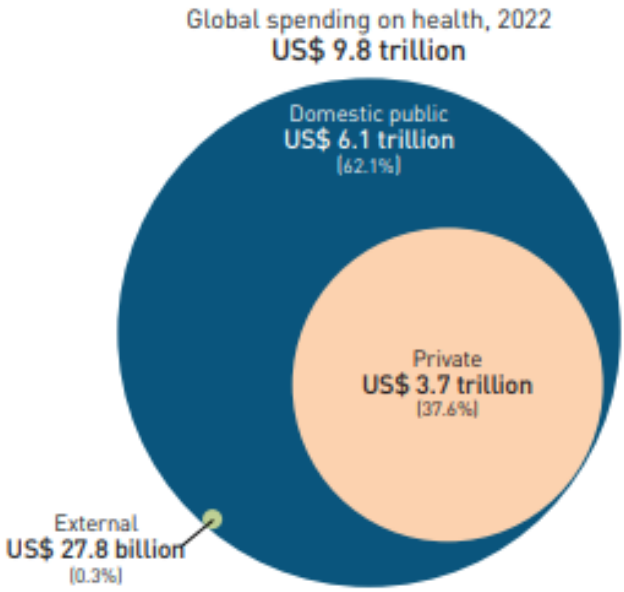

Figure 2:Global spending on health was US$ 9.8 trillion in 2022

Source: (WHO, 2023)

Main Healthcare Cost Drivers

Most of the drivers of healthcare cost relate to both growth of demand and ineffective system design. Older patients tend to be more demanding in terms of medicines, diagnostics and repeated hospital visits, as well as their needs for longer-term care, leading to higher expenditure. Chronic diseases, like diabetes, cardiovascular disease and respiratory illness, also cause ongoing costs as they are diseases that need to be monitored, medicated and diagnosed by specialists for a lifetime. Evidence from the OECD indicates that there are still a significant number of avoidable hospital admissions, particularly for chronic diseases which are often treatable with better primary health care.

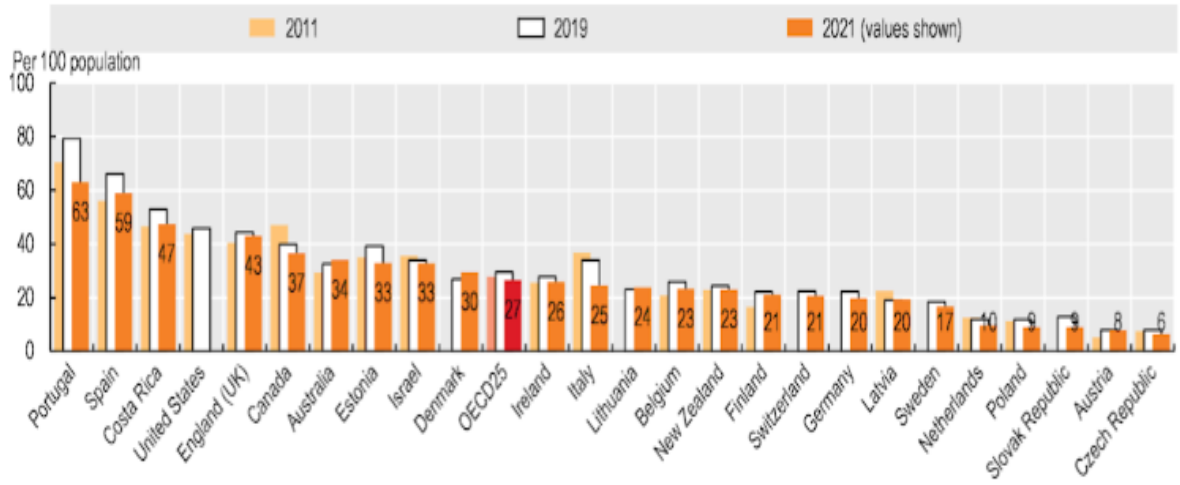

Figure 3:Number of visits to emergency departments per 100 population, 2011, 2019 and 2021
Source: (OECD, 2023c)

Additional costs are being incurred due to the pressure on beds, staff and urgent care created by hospital readmissions and ED overcrowding and long waiting times. In addition, OECD points out that early discharge may be associated with high rehospitalisation costs, and late discharge is an inefficient use of available hospital services (OECD, 2023). Extra financial pressures include administration costs, duplicate testing, inefficient buying, and the cost of the medicines and lack of staff. So cost is not just a patient demand issue, it is also a lack of coordination, poor prevention and inefficient resource allocation issue.

Financial Sustainability in Healthcare

Financial viability is the ability to continue to provide access to high quality care without running out of money or putting patients' ability to pay a strain on public finances. OECD statistics reflect the fact that health spending accounted for approximately 15% of governments' overall expenditure in the 2021 fiscal year across OECD countries (OECD, 2023d), providing a sense of the importance health spending receives in comparison with other government spending, like education, housing and social protection. But simply cutting back on services is not sustainable. Effective health financing includes ways to ensure higher service coverage and financial protection, ensuring that people receive health services they need without incurring unaffordable costs (World Health Organization, 2019).

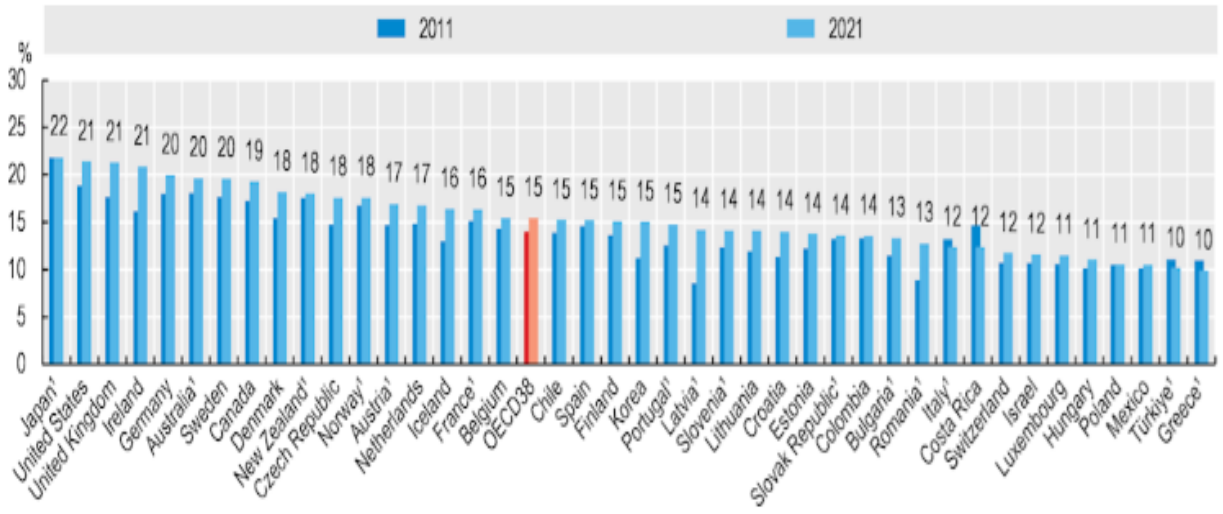

Figure 4: Health expenditure from public sources as a share of total government expenditure, 2011 and 2021

Source: (OECD, 2023d)

Cost optimisation is better than cost cutting in the stronger policy approach. The OECD report on wasteful spending in health care revealed that about one-fifth of health expenditure is ineffective in improving health, such as low-value care, operating waste and administrative inefficiency (OECD, 2023d). So financial sustainability should be based on eliminating waste, optimizing procurement, minimizing unnecessary admissions, and prioritizing resources on interventions that have a positive impact on the outcome and future value.

Literature Review

Business Analytics for Healthcare Cost Optimisation

Healthcare business analytics involves using data, statistical techniques, digital dashboards and models to aid in the decision making process in the clinical, operational and financial aspects. Plenty of examples can be found in the literature of increasing use of data in health care organizations from EHRs, claims systems, medication systems, lab systems, staffing systems and financial systems to evaluate performance and control costs. Sousa et al (2019) suggest that big data analytics can help in the management of healthcare by enabling the organisations to process the complex information about health and transform it to useful decisions. Cozzoli et al. (2022) also propose that healthcare analytics is not only a technical tool, but also a managerial approach which can help in planning, monitoring and controlling resources.

Business analytics is generally described with three types that are known as descriptive analytics, predictive and prescriptive analytics. According to KC, Scholtes and Terwiesch (2020), the descriptive analytics is the part of analytics that gets information about the past. This means data on costs, patient numbers, occupancy, average stay, departmental expenditure, among others, in healthcare. Predictive Analytics can predict what is likely to happen in the future, like the risk of readmission, the demand for the ED, the use of medicines and future bed needs. For cost optimisation, the literature indicates that analytics can be helpful as it helps to become visible about the waste. OECD lists some of the areas where it is possible to waste money in health systems, including providing low-value clinical care, inefficiency in health system operations, poor

health system procurement, administrative complexity and fraud (OECD, 2017). This reinforces the idea that there is no point in reducing services to optimise costs, it's about identifying unnecessary costs. Analytics can identify high-cost patients, avoid unnecessary diagnostic testing and repeated ER visits, inadequate appointment scheduling, delayed discharges, duplicated procedures and inefficient inventory. In this way analytical tools can be used to help with cost control, not for a general reduction in costs.

Analytics can also be used to drive financial sustainability by shifting from reaction to action in regard to cost reductions, which is known as cost management.Another benefit of analytics is that it can help financial managers make the transition from cost cutting to cost management, making it more proactive. (Zamil and Mojumder, 2022) Healthcare organisations can use dashboards and forecasting models to provide comparisons between departments, cost per patient pathway, demand forecasting and a correlation between spending and patient outcomes. This helps to make value-based care more possible since it is not just about cutting down on costs, but cutting them out to get better results with the resources spent.

Some important limitations of the literature, however, are revealed. However, E Lewis et al. (2023) point out that EHRs can be inconsistent, incomplete and not comparable, and so, the quality of the data can lead to inaccurate forecasts or unfair performance measures. Another of these issues is algorithmic bias. If created and trained on biased and incomplete datasets, inequality can be reproduced in healthcare algorithms, according to Chen et al. (2023). This is dangerous in cost minimisation as the financial models can inadvertently put at a disadvantage vulnerable patients. Thus, analytics should be transparent, subject to regular audits and clinical judgment should be applied to them.

Methodology

Research Methodology

The type of design that was used in this study was secondary research or desk-based study as it involved studying the available data, reports and literature rather than collecting primary data from participants (Hofman et al, 2018). This design is appropriate for analysing the optimisation of healthcare costs as the topic demands information from large-scale health expenditure data sets, international reports and previous academic research(Nasim, Masood, et al., 2023). The study relies on sources like Global Health Expenditure Database by WHO, OECD health expenditure reports, peer-reviewed journal articles, healthcare analytics studies, cost-management literature from hospitals and policy reports, as well as case examples of healthcare systems around the world. This method will enable the article to highlight and analyze the cost pressure and solutions based on analytics in different healthcare settings.

Method of Analysis

The study adopts a thematic analysis method of literature to reveal the commonalities among the previous studies around healthcare cost optimisation and business analytics (Liu et al., 2023). Academic papers, policy reports and healthcare analytics papers are reviewed to categorise the outcomes into the following themes: increasing cost drivers, reducing readmissions, forecasting demand, planning staff, procurement efficiency, data quality and financial sustainability. Its advantage is that it enables the article to structure a large number of findings into analytical categories, instead of just a series of isolated findings. A comparative cost analysis is also conducted based on published data from such reports as WHO, OECD, etc. This allows for a comparison of spending patterns in healthcare, public expenditure pressure and cost variation in healthcare systems. Furthermore, a conceptual model is created to demonstrate the potential of different Descriptive, Predictive and Prescriptive Analytics to facilitate the visibility of costs, forecasting, resource allocation and long-term financial sustainability (Serag, 2021). Last but not least, there is a critical evaluation of the analytics applications. This involves not just a discussion of the value of analytics but also challenges like substandard data quality, disjointed systems, algorithmic bias, privacy issues, and employee resistance.

Analysis and Discussion

Descriptive Analytics for Cost Visibility

The first step in optimising healthcare costs is descriptive analytics – as hospitals can't manage costs if they do not know where they are going. The descriptive dashboards can be used to monitor such things as department expenditure, cost per patient, cost per procedure, medicine usage, staff overtime, bed occupancy, length of stay and readmission trends (Rishi Reddy Kothinti, 2022). This is crucial as a number of hospital expenses are often spread throughout the systems including finance, pharmacy, staffing, EHRs and more. If taken as a whole, these data can help managers determine if high spending is a result of clinical complexity or inefficiency.

The OECD evidence indicates that average length of stay is a recognised measure of the efficiency of hospital care, and that reducing the length of stay can lead to an improvement in cost per discharge and transition of care from high cost hospital to lower cost post-acute care, where clinically appropriate. However, extended length of stay might reflect inadequate care coordination, or delayed discharge (OECD, 2023c). Descriptive analytics can then be used to identify any cost differences across departments. Most importantly, descriptive analytics can be helpful, but it is not very useful. It helps to clarify the trends of the past, but not to forecast future demand or suggest the right course of action. Hence, it needs to be used along with predictive and prescriptive analytics to bolster cost control.

Predictive Analytics for Demand and Cost Forecasting

Predictive analytics (Ali et al., 2025) can help with healthcare cost optimisation, as it can help to predict the future needs, capacity stress and costs of healthcare services based on historical data and real-time data (Nasim, Yousaf, et al., 2023). Predictive models can be used by hospitals to forecast patient admissions, demand in the emergency department, seasonal disease trends, bed occupancy, need for intensive care, demand for medicine and staffing. This can cost the hospital money due to overcrowding, staff overtime, additional agency staff, delayed discharge, and inefficient bed use, if there is poor demand planning.

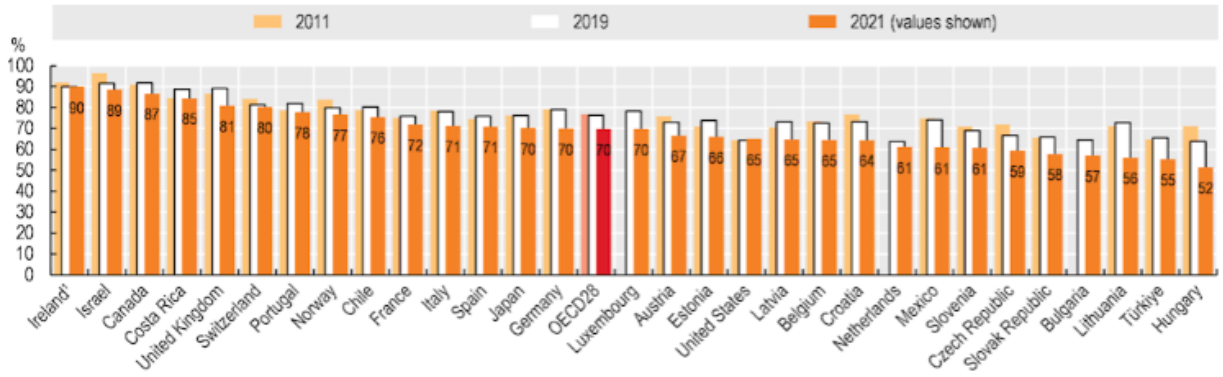

Figure 5:Occupancy rate of curative acute care beds, 2011, 2019 and 2021

Source: (OECD, 2023e)

OECD evidence indicates that the number of hospital beds and occupancy rates are among the most important indicators of health system capacity, and higher occupancy limits health system flexibility in response to surges in demand (OECD, 2023). Predictive analytics can also help with the budget, as it can foresee upcoming cost pressures before they turn into operational issues. But, if the predictions are not tied to effective interventions like follow-up care or care coordination, they will not lead to reductions in healthcare costs, argues Teo et al. (2021). Most importantly, predictive models rely on accurate past data. Inaccuracies can lower accuracy if

records are missing, coding errors, pandemics, strikes or policy changes occur. Forecasts need to be updated continuously and clinically reviewed, therefore.

Reducing Hospital Readmissions

When patients return to the hospital, it is an important cost driver and a sign that there are deficiencies in discharge planning and/or follow-up care or chronic disease management. According to AHRQ, there were approximately 3.3 million adult (age 30 and older) all-cause readmissions in 2011, with an estimated hospital cost of US$41.3 billion (HCUP, 2019). Congestive heart failure, septicemia and pneumonia were some of the biggest readmission events causing approximately US$4.3 billion under Medicare. This means that readmissions are not just a quality problem, they're also a financial sustainability problem.

Analytics can alleviate this burden by computing factors of age, diagnosis, previous admissions, medication history, comorbidities, social risk factors and discharge complexity before discharge to identify patient at high risk. For instance, machine-learning models have been developed to predict readmission risk early in hospitalisation to enable the timely intervention of timely support from clinicians before the patient leaves hospital (Zhao, Yoo and Naqvi, 2021). McQueary et al. (2024) introduced Py-holmes, a toolkit designed for causal testing in Python.This allows the focused interventions to be implemented in the hospital (e.g., medication review, follow-up calls, community nursing, and/or telehealth monitoring or earlier primary care referral). Most importantly, readmission analytics should not be a one-way street focused on avoiding penalties or cutting costs. It should integrate discharge planning so that there is a better continuity of care as poor discharge planning leads to both patient harm and financial waste.

Resource Allocation and Workforce Optimisation

Because labour is one of the biggest and most challenging costs in healthcare cost optimisation, workforce planning is a key part of that process. In 2021, 10.5% of employment in all OECD countries was in health and social care, reflecting the extent to which employment in healthcare systems is dependent on the workforce (OECD, 2023). Patient-to-staff ratio, absenteeism, workload pressure, bed occupancy, overtime and agency staff usage dashboards are all potential areas where analytics can assist hospitals to balance their staffing with their patients. This assists in better scheduling as managers are better able to determine areas of risk where they are under staffed and areas of over cost where they are over staffed. These issues are explored in real-world evidence from England.

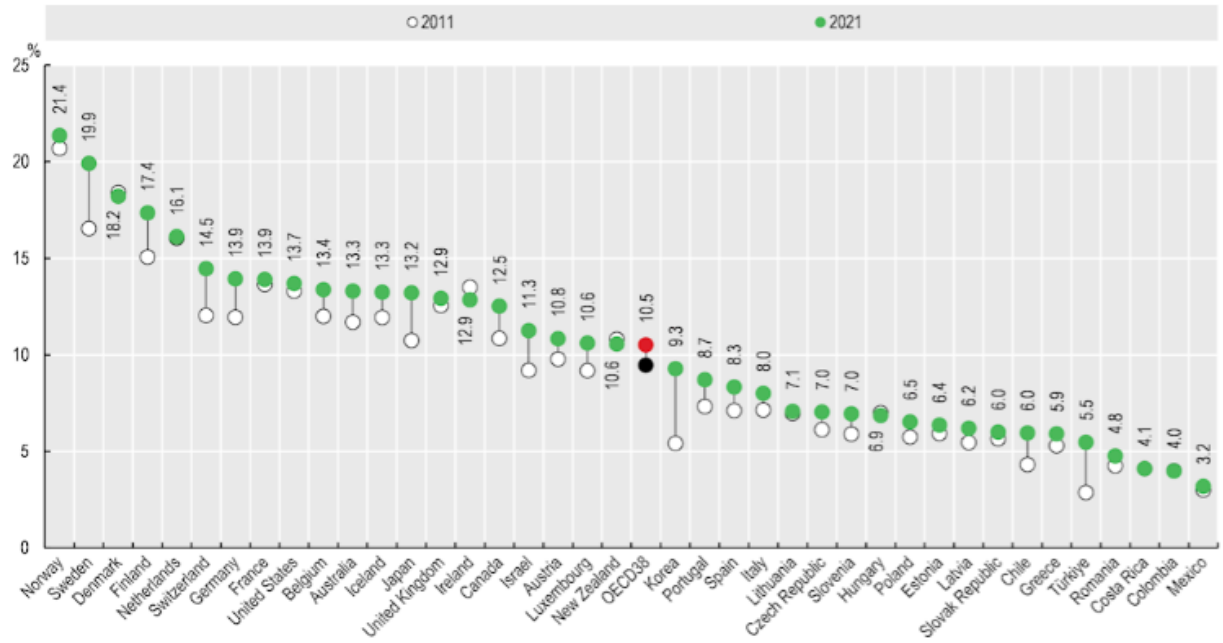

Figure 6: Employment in health and social work as a share of total employment, 2011 and 2021
Source: (OECD, 2023a)

Agency use puts pressure on trusts as agency spending has been shown to be higher than substantive and bank staff, which is why agency price caps were introduced by NHS England (England, 2019). The cost of NHS nursing agency staff in England has been shown to be directly linked to the workforce gap, as a total of more than £3 billion was spent on agency nursing staff between 2020 and 2023 in England, according to the Royal College of Nursing (RCN, 2020). Most importantly, analytics should not be used to merely slash employees. However, over-optimisation can have a negative impact on patient safety, burnout and retention. Efficient staffing with safe staffing, staff wellbeing and patient outcomes should be considered together in high quality workforce analytics.

Procurement, Inventory, and Supply Chain Analytics

Healthcare cost optimisation is critical for the healthcare sector, particularly in areas such as procurement and inventory management, where medicines, devices, consumables, and equipment make up a significant portion of the hospital's expenses. Medicines, appliances and medical devices represent a financial burden of £19.2 billion for NHS commissioners in England in 2022/23, an 8% rise on 2021/22 (Clews, 2023) and highlight the potential for the rapid growth of the cost of pharmaceutical and device spending. There is also a significant procurement of medical equipment and consumables as the NHS collectively spends approximately £8 billion a year on things such as gloves and paper products, to stents and prosthetic hips (Parliament.uk, 2023). Analytics could help to lower these costs by predicting medicine usage, monitoring expiry risk, detecting duplicated orders, comparing medicine prices from suppliers and tracking medicines of high cost devices. A supplier performance dashboard for instance can provide information on price variation, delivery delays, shortages, which can guide hospitals in negotiating better contracts and minimize emergency purchasing. Additionally, NHS Supply Chain's procurement calendar facilitates planning by enabling organisations to plan for opportunities to procure

within their cost improvement plans (NHS Supply Chain, 2023). One of the most important aspects of procurement analytics is the ability to rely on clean and standardized data. When the different levels of the inventory systems are not combined in the pharmacy, the manager will not be able to see the complete cost pathway. So, yes, analytics can boost procurement efficiency — but only with systems in place, accurate product coding and good governance.

Data-Driven Healthcare Cost Optimisation Framework

The analysis will be used to build a framework for understanding healthcare cost optimisation in an easy manner, using the concepts of data-driven models. To create cost visibility, hospitals must bring all of the data together from their electronic health records, financial systems, claims data, staffing records and procurement systems. Second, descriptive analytics should be employed to detect waste, cost variation, length-of-stay problems and inept departmental expenditure. Third, predictive analytics can predict patient demand, risk of re-admission, hospital pressure, medicine usage, and staffing needs, thereby avoiding unnecessary pressure on costs for the organisation. Fourth, prescriptive analytics can suggest more effective actions like enhanced staffing, procurement decisions and patient flow planning (Begum and Hasan, 2023). Last but by no means least, there is continuous performance monitoring – using KPIs – that connects financial efficiency to patient outcomes. The framework demonstrates that achieving financial sustainability relies not just on the reduction of cost but on the ability to use data to enhance value, safety and resource allocation.

Challenges and Limitations

While business analytics has great promise for optimizing health care costs, there are a number of practical, ethical and organizational challenges. The first big drawback is the quality of data. Resources for collecting healthcare data can be around various systems, including EHRs, finance-related systems, pharmacy systems, claims database and staffing systems (Trifirò, Sultana and Bate, 2018). Managers may not necessarily be able to view the whole cost pathway of a patient or department if these systems are not integrated. Inconsistent coding, lack of data, multiple data points in a single record, and outdated IT systems can lead to unreliable dashboards and forecasts. This can be especially dangerous when it comes to cost optimisation, as bad data can result in incorrect staffing, budgeting or patient prioritisation decisions.

Another barrier is privacy and ethics as healthcare information is sensitive. The main features of analytics projects that must safeguard patient data privacy involve anonymisation, secure data storage, consent management, adherence to data protection laws, etc. But with poor cybersecurity, financial and clinical information can be leaked, leading to loss of trust among consumers and patients (Patel et al., 2023). Models built on past data which contains unequal access to care may perpetuate those disparities. If, for example, vulnerable groups were underrepresented in previous data, they could be under-represented in the results of the high-risk scoring of their needs. Hence, it is essential that models are periodically audited for their fairness, accuracy and clinical relevance.

Still another drawback is resistance by staff. If clinicians and nurses feel that analytics primarily exist to drive budget reductions, performance or staff cuts (Harvey et al., 2018), then they are likely to feel distrust of analytics. This can also limit adoption, and undermine the effectiveness of the metrics. Therefore, training and clinical involvement, along with clear communication, is needed to make sure staff grasp how analytics is used to support decision making, not to replace it. So, business analytics shouldn't be seen as a quick and easy way to save money. It demands a long-term investment, cultural changes and a high level of joining up of financial efficiency and clinical quality. Its true benefit lies where cost optimisation is shown to enhance patient outcomes, rather than just cut costs.

Recommendations

Build integrated healthcare data systems

Clinical, financial, workforce and procurement data and patient outcomes should be unified in

one integrated analytics solution for healthcare organisations. This would enable the manager to view all the cost trajectory of care instead of analysing each department individually. The integration of EHR with financial and pharmaceutical information, for instance, could reveal if high cost is due to longer hospital stays, expensive drugs, repeated tests and late discharge. The impact in the real world is a more transparent visibility of costs and quicker decision making. This is crucial because OECD defines waste in three areas of clinical care, operations and governance, and hospitals require joined up data to be able to identify where waste is happening (OECD, 2017).

Focus analytics on high-cost pressure areas first

Hospitals should start analytics initiatives in the areas where it's most likely to save money and to improve patient outcomes including readmissions, emergency demand, length of stay, overtime for staff, procurement waste, and chronic disease management. This will make analytics more useful in that it will address a measurable issue instead of building generic dashboards with minimal impact. For instance, the rules for agency staffing by NHS England demonstrate how cost control of the workforce could help to lower financial pressures by incentivising providers to lower their agency costs and put substantive staffers and bank staff to better use (England, 2019). The practical takeaway is that hospitals can focus on analytics that will likely yield dollars that make a difference in their clinical operations.

Link cost optimisation with patient outcomes

Cost reduction should be measured along with patient safety, readmission rates, waiting times, mortality, patient satisfaction and equity of access. The information from analytics should be used to complement, not replace, clinical decisions. Cost avoidance is only one reason to use a readmission-risk model; it should also initiate a discharge plan, follow-up calls, medication review or community care. This is in line with WHO's perspective on health financing, which is to increase access to and financial protection from services, rather than lower spending. The practical impact is that analytics is used to improve value not just as a tool to cut costs and simplify resource usage (World Health Organization, 2019).

Conclusion

Strides in healthcare technology and the post-pandemic funding environment are adding to the financial strain on healthcare systems, which have been particularly stressed by the rising demand, increasing ageing population, chronic disease, staff shortages and cost of technology. This article demonstrated how business analytics can be beneficial in the healthcare cost optimisation process by enhancing the visibility of costs, forecasting demand, optimizing resources, managing readmissions, optimizing procurement and planning workforce. Descriptive analytics assists organisations to comprehend their previous spending patterns, uncover variation in costs and spot waste across departments. Predictive analytics enhances financial planning with prediction of future demand, bed pressure, Readmission Risk and staffing needs. Prescriptive analytics can also provide extra value by making more efficient choices regarding the utilisation of resources, care pathways and procurement. But analytics can't be the answer alone. Accurate data, integrated systems, ethical governance, cybersecurity, clinical participation and training of staff are key factors in its success. But, when analytics are deployed as an instrument for cost savings, they can have a negative impact on care quality and trust within the staff. Thus, business analytics can play a significant role in healthcare financial sustainability, but only as part of a broader health system improvement approach that emphasizes quality, equity, patient safety and system improvement over the long term.

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