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Outcomes of managing healthcare services using the Theory of Constraints: Asystematic review

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ABSTRACT

Despite ever-increasing resources devoted to healthcare, lack of capacity and timeliness are still chronic problems worldwide. This systematic review aims to present an overview of the Theory of Constraints (TOC) implementations in healthcare services and their outcomes. We analysed 42 TOC implementations (15 full-text articles, 12 video proceedings, and 2 theses/disserations) from major scientific electronic databases and TOC International Certification Organization Conferences. All implementations reported positive outcomes, both tangible and intangible. The two main improvements reported by authors were in productivity (98%; n = 41) – more patients treated – and in the timeliness of care (83%; n = 35). Furthermore, the selected studies reported dramatic improvements: 50% mean reductions in patient waiting time; 38% reduction in patient length of stay; 43% mean increase in operating room productivity and 34% mean increase in throughput. TOC implementations attained positive results in all levels of the health and social care chain. Most TOC recommendations and changes showed almost immediate results and required little or no additional cost to implement. Evidence supports TOC as a promising solution for the chronic healthcare problem, improving quality and timeliness, both necessary conditions for providing effective healthcare.

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1. Introduction

Healthcare has evolved dramatically in the last century but managing it has become a conundrum. The 20th century was the stage of extremely relevant discoveries in medicine that affected health conditions all over the world, e.g., penicillin, the pacemaker. After those discoveries, we are living longer, and the population is growing. However, these improvements led to a higher and rising demand for healthcare services.

Medicine continues to evolve at an impressive rate, and so is its increasing costs. Healthcare consumes an average of 10% of a country's gross domestic product (GDP), and its costs are rising faster than economies are growing (Halim, 2019); in the USA this reached 18% of GDP in 2017 (Sisko et al., 2019). Despite this unprecedented investment in healthcare, lack of capacity and timeliness are still problems affecting every country, even the wealthier (World Health Organization, 2010, 2019). Long wait lists for appointments (Ryu & Lee, 2017), emergency departments crowding (Morley et al., 2018), shortage of hospital beds (Song & Ferris, 2018), and cancellation of elective surgeries (Al Talalwah & McIltrot, 2019) are some examples of chronic problems. The delay of care is a significant issue, a persistent and undesirable characteristic of current healthcare systems (Murray & Berwick, 2003; Ryu & Lee, 2017). When patients must wait for medical assistance, serious consequences happen (Corley, 2016; Ryu & Lee, 2017). Long waits before care delivery have emotional consequences (e.g., anxiety, despair) and contribute to worsening clinical conditions, developing avoidable complications, and even death. There are also financial consequences, treating patients in more advanced conditions requires more specialised care resources, which are more costly.

Healthcare services are under pressure to deliver better healthcare outcomes to an increasing population, with higher quality care, in less time, and at a stable (or lower) cost. However, current management methods are not providing an effective solution to this chronic problem. Traditional solutions to address this problem often require investment to add more capacity to the system, but without a proper analysis to improve throughput using existing resources, it has the potential to make the situation even worse (Han et al., 2007).

Over the last century, some disruptive management philosophies emerged and had considerably improved quality and reduced lead times of manufacturing and services. As a natural consequence, researchers

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The supplemental data for this article can be accessed here.

considered the adoption of these management philosophies in the healthcare environment to improve care delivery (Kim et al., 2006; Young et al., 2004). Potential solutions – like Lean and Six Sigma – provide limited benefits, and they both encounter the same problems: involve high investments and long implementation time (Chiarini & Bracci, 2013; D'Andreamatteo et al., 2015; Poksinska et al., 2017).

The Theory of Constraints (TOC) is also one of those disruptive management philosophies that emerged late in the last century. Originally developed by Dr Goldratt to solve manufacturing issues, TOC today is considered a holistic management philosophy that views every organisation as a system composed of many interacting resources. These interdependent resources work together towards achieving the system goal; however, at least one resource limits the capacity of the whole system; otherwise, its throughput would be infinite. This limiting resource is the constraint, and it is the most important resource of any organisation since it determines the performance of the whole system (Goldratt & Cox, 2004; E. M. Goldratt, 1999).

Acknowledging the existence of a constraint creates a whole new management paradigm. Instead of considering any new improvement idea anywhere as an improvement for the organisation, improvement efforts should focus on the constraint. If an organisation was able to identify and increase throughput at its constraint, more effectively exploit the constraint, or better subordinate other resources to the constraint, then the organisation would achieve more of its goal. For instance, if the organisation loses a minute at the constraint, this is a minute lost for the whole organisation; but if any other resource loses a minute, it will not dramatically affect the organisation because it has protective capacity to recover the flow (Goldratt & Cox, 2004). Furthermore, to assure overall performance, the organisation must plan and synchronise its productive flow according to the constraint and protect it from uncertainty. Since most healthcare academics and practitioners are unfamiliar with TOC, a brief overview is provided here with a more detailed description provided in the appendix for those interested.

1.1. TOC overview

In contrast to both the traditional management philosophy's and lean (reduce waste) philosophy's emphasis on cost reduction everywhere, TOC focuses on achieving the organisation goal (e.g., providing excellent and timely healthcare effectively). Its primary focus is on increasing throughput (the number of properly treated patients), although maintaining or reducing operating expenses are very common consequences. TOC also strives for a systems perspective of the environment examining all stakeholders' perspectives in searching for a win-win solution to satisfy the different stakeholders (the objective is to meet the stakeholders' necessary conditions without compromising the goal achievement). The organisation goal is achieved by implementing three processes of ongoing improvement (POOGI) to align, schedule and execute the organisation's processes to achieve its goal: 1. five focusing steps (5FS) (Cox et al., 2012; Goldratt & Cox, 2004); 2. buffer management (BM) (Cox et al., 2012; Goldratt, 1986); and 3. change question sequence (CQS) (Cox et al., 2012; Goldratt, 1994).

First, we define the organisation's goal and supporting measures. Next, we apply the 5 focusing steps (5FS) (Goldratt & Cox, 2004), which starts by step 1: identifying the constraint; then step 2: deciding how to exploit the constraint – how to make maximum use of its available capacity. Since all other resources have more capacity, the constraint governs both the throughput and inventory in the system, (step 3: non-constraint resources must work accordingly to support the previous decisions. If the constraint remains, now it is time to invest money, (step 4: elevating the constraint and eliminating it. However, this is a process of ongoing improvement (POOGI), thus step 5: we must not allow inertia to become the system's constraint, we must go back to step 1 and start again.

Remember that TOC has two other POOGI's. Buffer management (BM) is a mechanism used in both the planning and execution phases of TOC applications that controls the constraint's protection against uncertainty based on the amount of time or stock (in healthcare, e.g., patients or beds) remaining until it is idle. A simple colour-coding system similar to a traffic light's colours is used to determine when to take action. Green means everything is running smoothly, do what you are doing; yellow means an imminent threat to patient flow or constraint utilisation is approaching, plan accordingly to eliminate the threat; and red means enact the plan. This proactive control system eliminates most disruptions to the constraint and to patient flow.

The change question sequence (CQS) is comprised of five-interrelated questions that are answered with a set of logic diagrams (Cox et al., 2012; Goldratt, 1986, 1994). This POOGI provides a gap analysis of system characteristics (question 1: why change?), a logical analysis starting with the current system problems (called undesirable effects, UDEs in TOC terminology) and ending with the identification of the system's underlying core problem(s) and its assumptions (question 2: What to change?). Based on the causal network constructed in answering the preceding question, the search for and development of a holistic win-win solution to the system's core problem(s) and related problems is in response to question 3 (what to change to?). Answering question 4 (how to cause

the change?) results in the construction of an effective implementation plan. In answering question 5 (how to measure and sustain the change?), one establishes procedures for measuring and sustaining system results. The application of the 5FS to a healthcare environment is provided in the supplementary material as are more detailed applications of BM and CQS.

The adoption of TOC in business environments started in manufacturing and has spread to other areas, such as logistics, distribution, project management, and sales and marketing (Ronen, 2005). In 1998, Mabin and Balderstone (2003) conducted a literature review to assess the outcomes provided by TOC applications. This study involved 77 different companies across many different purposes (for-profit, not-for-profit, and government), industries, and sizes, including giant multinational corporations (e.g., Boeing and GM), military organisations (e.g., US Air Force), and even a small-town bakery. Their analysis of reported changes presented positive results, though many companies achieved with only partial implementations:

- Lead-time reduction of 69%;
- Cycle-times reduction of 66%;
- Due-date-performance improvement of 60%;
- Inventory levels reduction of 50%;
- Revenue increase of 60% (excluding one outlier, a 600% increase at Lucent Technologies achieved within one year).

These significant results support the investigation of TOC as a potentially effective solution for the chronic healthcare problem. However, the application of TOC still has few case studies published in refereed academic journals (Mabin & Mirzaei, 2016; Ronen, 2005), particularly in healthcare. Since academic papers do not entirely reflect the adoption of TOC in healthcare yet, answers to this subject may be covered in grey literature.

The widely accepted definition of grey literature is known as "that which is produced on all levels of governmental, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers" (Auger, 1998). Examples of grey literature include conference abstracts and proceedings, research reports, dissertations, government documents, personal correspondence, among others. The inclusion of grey literature in systematic reviews is not as common as it should be, because of the cost in time and resources needed to search for it. However, including grey literature is a valuable and recommended practice, since it helps to reduce the publication lag time between a manuscript submission and its publication, and enriches the findings of a study (Paez, 2017; Shamseer et al., 2015).

A typical path in conducting research is to move from the grey literature to the academic literature. A degree-seeking candidate conducts and defends a thesis or dissertation (reviewed by an examining committee). Then, she submits and presents an updated version of the research as a presentation at a conference (and again receives critiques from reviewers and the audience). Finally, she submits the "improved" research to an academic journal for formal peer review and publication.

Therefore, to minimise the publication bias and provide a more balanced view of the evidence, we decided to include in this systematic review a major source of TOC knowledge: the annual conference video proceedings of the Theory of Constraints International Certification Organization (TOCICO) Conferences (2004–2020). The TOCICO is a global not-for-profit certification organisation for TOC practitioners, consultants, and academics formed to develop and administer certification standards, and facilitate the exchange of the latest developments in the TOC body of knowledge (TOCICO, 2018).

Our motivation for this systematic review is twofold. First, to assess the adoption of TOC as a potentially effective solution for the chronic healthcare problem. Second, to gather existing TOC academic literature, and expand it with TOC experts' knowledge available in grey literature.

The aim of this systematic review is to present an overview of TOC implementations in healthcare services and their effects. To this end, the proposed study will answer the following four questions:

(1) What are the outcomes of applying the TOC in healthcare services?
(2) What is the diffusion of TOC in healthcare so far (e.g., primary care or hospital, public or private practice)?
(3) Are there common problems – also called undesirable effects (UDEs) in TOC terminology – faced by healthcare services and was TOC able to address all of them?
(4) What are the methods and tools commonly used to apply TOC in healthcare services?

The first question aims to give a preliminary answer to whether TOC has improved healthcare services. This question tries to describe the outcomes achieved after implementing TOC in a healthcare service considering a wide range of effects, for instance, the number of surgeries performed, provider utilisation, the waiting time (direct and indirect) of patients for an appointment, the number of patients treated, the length of stay (LOS) in a hospital, the financial results, the quality or timeliness of healthcare, the patient no-show rate, etc.

The second question presents the details of the healthcare services where TOC implementations occurred. This question intends to reveal to what extent TOC has been implemented in healthcare. For

that purpose, we described the country of the implementation, level of care (e.g., primary care), nature of service (e.g., for profit, government), its setting (e.g., hospital, clinic), and a brief service description (e.g., operating room, emergency department).

Question three aims to unveil whether healthcare services face common or unique UDEs and core problems and if TOC was able to address them. In cases of successful outcomes, can these case studies help to provide a generic template to guide other healthcare organisations around the globe facing the same problems in their search for a successful path of improvement?

The last question aims to present the methods and tools used to support the implementations. In addition to the three POOGI, TOC has a number of other methods and tools (such as throughput accounting, critical chain project management) used in other organisations to improve performance. To what extent are these tools used in healthcare?

2. Methods

This systematic review followed the guidelines proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Shamseer et al., 2015), with some exceptions detailed below. We imposed these exceptions to take account of the variety of research approaches and consequent methodologies, as well as different traditions of research (social sciences and health sciences).

2.1. Data sources, eligibility criteria and data extraction

This systematic review used three scientific databases and four grey literature databases. We performed an automated literature search on the scientific (academic) electronic databases – PubMed, Web of Science (WoS) and Scopus – to identify relevant articles published in peer-reviewed journals. We obtained an annotated bibliography (citations and abstracts) of TOCICO Conference video proceedings related to TOC applied in a healthcare environment. Moreover, we performed an automated literature search on a set of theses and dissertations electronic databases – The Networked Digital Library of Theses and Dissertations (NDLTD), Open Access Theses and Dissertations (OATD), and OpenThesis (OT) – to identify relevant studies unpublished in peer-reviewed journals.

TOCICO has its short-, and long-abstracts vetted by TOC experts and slides are reviewed and critiqued as a second stage of the review process. Other sources of TOC implementations are consultant websites, but we chose not to use these sources because they were not vetted. Likewise, we decided to include theses and dissertations because they are previously assessed by an academic committee and may contain knowledge unpublished in scientific journals (due to lead time between submission and publishing, and acceptance issues) (Paez, 2017).

This systematic review of TOC in healthcare included all relevant empirical studies, as described by Brandão de Souza (2009). In each selected study, the authors describe at least one actual implementation of TOC in a healthcare service, which must describe the application of TOC principles and methods to improve patient flow followed by its outcomes (regardless of geographical location, and languages of publication).

We excluded studies that did not meet the following criteria:

(1) Do not report at least one implementation of TOC in healthcare.
(2) No further details besides an abstract.
(3) Papers with no abstract available.
(4) Interviews, editorials, letters to the editor, simulations, books, tutorials, other systematic reviews, and theoretical papers. Here we consider theoretical papers those that focus on reflections and explanations on methodologies or specific issues within TOC in healthcare.
(5) Studies that report implementations of TOC combined with any other management methodology, such as Lean, Six-Sigma, or Total Quality Management. Exceptions for this are those cases where TOC was the leading methodology and a different methodology was used secondarily (e.g., to describe the process flows using a value stream mapping).
(6) Studies primarily focused on support services, such as information technology processes, meal delivery, and financial services in a healthcare environment.

Two researchers searched for relevant papers on electronic databases using a search strategy calibrated in Scopus database, which combines the terms described in Table 1 (searching article title, abstract and keywords).

We managed details of retrieved references in EndNote and used an online spreadsheet (Google Sheets). The two reviewers independently screened the titles and abstracts to assess which studies met the eligibility criteria.

We extracted data by using a standardised data extraction sheet (Google Sheets) directly from the included studies. Besides general study data (e.g., title, authors, year of publication, country where study was performed, publication source, and number of implementations described in each study), we collected information needed to perform the analysis minimising the risk of bias, and to answer each one of our four research questions.

Table 1. Search strategy including TOC terms and healthcare terms.

TOC terms	Healthcare terms
(1) "Theory of Constraints";	(10) "Health";
(2) "Buffer management";	(11) "Healthcare";
(3) "Five focusing steps";	(12) "Health care";
(4) "Constraints management";	(13) "Health system";
(5) "Management by constraints";	(14) "Patient flow";
(6) "Change question sequence";	(15) "Patient journey";
(7) "Goldratt";	(16) "Hospital";
(8) "Drum-Buffer-Rope";	(17) "Acute care";
(9) **(1 or 2 or 3 or 4 or 5 or 6 or 7 or 8).**	(18) "Primary care";
	(19) "Secondary care";
	(20) "Tertiary care";
	(21) "Rehabilitation";
	(22) "Home care";
	(23) "Community care";
	(24) "Critical pathways";
	(25) **(10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24).**
Search strategy:	**9 and 25**

The bias analysis consisted of 8 items. Each item captures a step of a TOC implementation and contains a statement and a 4-point scale (0-strongly disagree to 3-strongly agree). Whenever we were not able to classify an item given the content of the document, this item was not considered (up to a maximum of 2 unconsidered items allowed). The evaluation items are below (more information is available as supplementary material):

(1) Definition of the goal
(2) Definition of global performance measures
(3) Why change (Gap analysis and UDEs)
(4) Identification of the constraint
(5) Definition of how to exploit
(6) Subordination of everything else to support the constraint
(7) Elevation of the constraint
(8) Successfully established continuous improvement

In order to answer the four research questions, we performed a narrative synthesis of the case studies outcomes. Relevant data was extracted and presented in a tabular form and these findings were categorised and synthesised in a narrative summary. The narrative synthesis explores both the relationships and findings within and among the included studies.

3. Results

Based on the methods described in the previous section, we were able to identify 202 potentially relevant records by searching the scientific databases (last search on 2020–07-23), 64 records in the TOCICO database, and 206 theses/dissertations. We removed 94 duplicates and screened the titles and abstracts of 378 records; 19 articles, 18 videos, and 6 theses/dissertations remained. After performing a full-paper assessment and watching all available video proceedings (with respective presentation slides), we excluded 6 articles, 6 videos, and 4 theses/dissertations. We included 2 articles from the reference lists of scientific studies. The final list included 15 articles from the academic literature, 9 video proceedings, and 2 theses/dissertations. Figure 1 illustrates the flow of information through the different stages of this systematic review.

Overall, we analysed 42 implementations (cases). Those 15 full-text articles contributed with describing 22 implementations, while those 12 video proceedings described 24 implementations and 2 theses/dissertations described 4 implementations. Some articles (n = 4), video proceedings (n = 4), and theses/dissertations (n = 1) described more than 1 implementation (e.g., Knight et al. (2004) described 10 implementations). On the other hand, we could also identify a few implementations described in more than one record (e.g., 1 implementation described by 2 articles and 1 video proceeding, and 3 implementations described by 1 article and 1 video proceeding). Table 2 provides a summary of selected studies and bias analysis. Following a discussion of the bias analysis, the four research questions are answered.

3.1. Bias analysis

The evaluation system revealed that 83% of assessed implementations are classified as Excellent, 5% as Adequate, and 12% as Marginal. There was no Inadequate implementation among the full-text articles and video proceedings, none was therefore excluded.

All 12 video proceedings (100%) implementations achieved an Excellent classification, whereas 68% of article implementations achieved this classification. All theses/dissertations had an article (and no video proceeding) describing their respective implementations, and for this purpose, they were described together. Only 1 implementation achieved the highest possible score, an average of 3, and it was a video proceeding (Sierraalta-Arganguren, 2015).

3.2. Question 1: outcomes of applying the TOC in healthcare services

Before going deeper into the results of TOC implementations, we must consider the goal of the organisations involved in this study. Half of the articles (n = 8) and 2 video proceedings presented problems with the definition of their organisation's goal. Most of them did not mention the goal within the text, some did not clearly define the goal, and there was one article that the goal seemed to change along with the paper. However, an analysis of those that defined their goal shows 2 frequent characteristics: timeliness and quality of care.

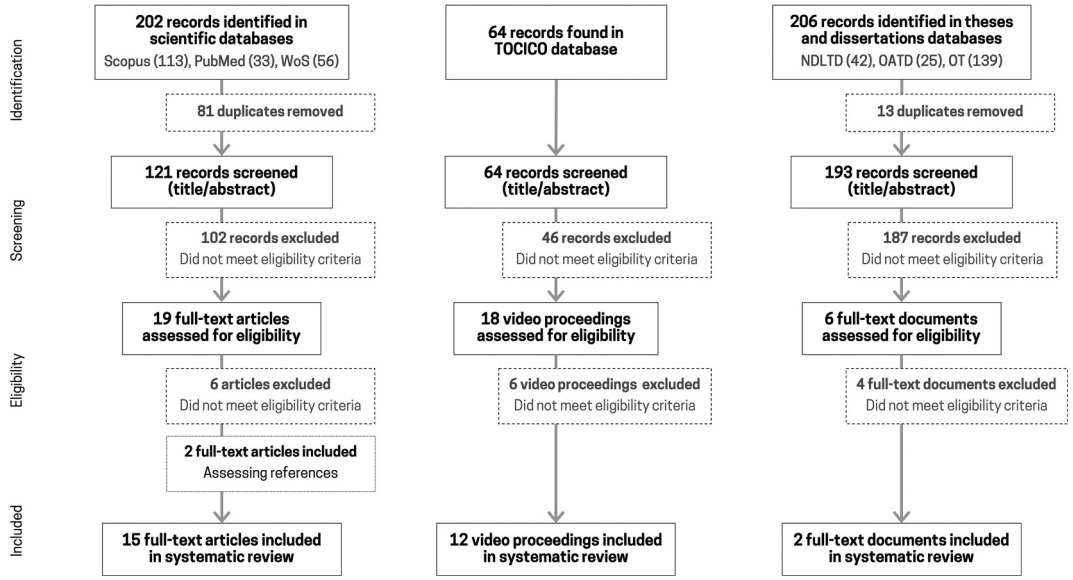

Figure 1. Flow of information through the different stages of this systematic review.

Table 2. Summary of participating studies. Includes publication source, number of implementations, bias analysis (bias score), health service details (e.g., country, setting), results, and UDEs.

Reference	Cases (n)	Bias score	Country	Nature of service	Setting	Service description	Continuous improvement	UDEs (n)	Addressed all UDEs?
Womack & Flowers, 1999	1	2.91	USA	Govt.	Health system	Government health system (U.S. Air Force)	YES	3	YES
Karvonen et al., 2004	1	1.90	FIN	Non-profit	Hospital	Cardiology and Cardiothoracic Departments (heart surgery)	NO	4	YES
Knight et al., 2004	10[a]	2.91	UK	Govt.	Hospital	- A&E - Discharge planning	YES	4	YES
Lubitsh et al., 2005; Lubitsh, 2002	3 [c]	1.30	UK	Govt.	Hospital	- Neurosurgery - Eyes (Ophthalmology) - ENT (Otolaryngology)	NO	3	Partially
Umble & Umble, 2006	3[a]	2.91	UK	Govt.	Hospital	A&E	YES	4	YES
Wadhwa, 2007	1	2.82	USA	For profit	Hospital	Oral & Maxillofacial Surgery	YES	1	YES
Gupta & Kline, 2008	1	2.36	USA	Non-profit	Clinic	Psychiatric rehabilitation	UNC	7	Partially
Paavola, 2008	1	2.30	FIN	Govt.	Hospital	Orthopaedics (particularly artificial-joint surgery)	UNC	3	Partially
Stratton & Knight, 2010	4	2.73	UK	Govt.	Hospital	- A&E - Discharge planning	YES	3	YES
Ronen & Pass, 2011	3	2.73	ISR	2 For profit, 1 non-profit	Hospital	Operating room	YES	N/A	N/A
Cox et al., 2014, Cox et al., 2016; Cox & Robinson, 2012	1[b]	2.91	USA	For profit	Clinic	Family medicine clinic	YES	7	YES
De Kiewiet, 2012	1	2.27	UK	Govt.	Hospital	Holistic implementation	YES	10	YES
Buwalda & Gijs, 2013	2	2.82	NLD	Non-profit	Hospital	- Internal Medicine - Pulmonology	YES	7	YES
Stratton & West, 2014	1	2.82	UK	Govt.	Hospital	Holistic implementation	YES	N/A	N/A
Gupta et al., 2015	1	2.18	USA	Non-profit	Clinic	Psychiatric rehabilitation	UNC	7	YES
Kimbrough et al., 2015	1	1.30	USA	Non-profit	Hospital	Operating room	NO	1	YES
Sierraalta-Arganguren, 2015	1	3.00	VEN	For profit	Hospital	Holistic implementation	YES	3	YES
Cattaneo & Bassani, 2016	1	2.27	ITA	Govt.	Hospital	Operating room	NO	9	YES
Taylor, 2016	3	2.64	USA	For profit	Hospital	- Cardiac ICU - Erlanger Children's Hospital - Autism Centre	UNC	115	YES
Groop et al., 2017; Groop, 2012	2 [c]	2.64	FIN	Govt.	Home care	Home care delivery system	UNC	8	YES
Gonçalves et al., 2018	1	1.00	BRA	Govt.	Hospital	Radiology department	NO	N/A	N/A
Mabin et al., 2018; Mabin, 2019, Mabin, 2020	1[d]	2.64	NZL	Govt.	Hospital	Chemotherapy clinic	NO	7	YES
Bacelar, 2019	1	2,70	BRA	For profit	Hospital	Ophthalmology	NO	3	YES

[a]Three implementations described in two different sources. [b] One implementation described in three different sources. [c] Described in an article and a thesis. [d] Described in an article and 2 TOCICO videos proceedings. UNC: Uncertain; N/A: Not available.

All implementations reported positive outcomes, but they had different documented results, both tangible and intangible. Most of these outcomes did not require an additional cost and, in those that did it, the additional cost was little and always recovered in the very short-term. The two main positive outcomes

Table 3. Summary of groups of positive outcomes reported after implementing TOC.

Groups of positive outcomes	Reported cases (%)
Productivity	41 (98%)
Timeliness of care	35 (83%)
Quality of care	20 (48%)
Financial outcomes	12 (29%)
Staff satisfaction	12 (29%)

reported by authors were in productivity (98%; n = 41), which means more patients treated, and in the timeliness of care (83%; n = 35). Other positive results are related to quality of care (48%; n = 20), financial outcomes (29%; n = 12), and staff satisfaction (29%; n = 12). However, since we did not give a survey to the stakeholders of each implementation, these results may underestimate the impact of TOC. Table 3 contains a summary of groups of positive outcomes reported after implementing TOC.

Besides the overall positive outcomes, a few implementations also reported neutral results (7%; n = 3) (Gupta & Kline, 2008; Kimbrough et al., 2015; Lubitsh et al., 2005) – no significant change in a measurement – and one reported an UDE (2%). The authors described this UDE as "at times, the growth in the throughput caused congestion on the ward and especially in further treatment at health centres" (Paavola, 2008). This occurred because the number of operations per day increased by 50% and changeover times reduced from 54 minutes to 13 minutes – which potentially generated 700 USD k-$800 k savings for the Hospital District and caused a positive impact in staff motivation. The undesirable consequence was the next workstation got congested because of the additional throughput.

Furthermore, we assessed the performance outcomes reported after implementing TOC in healthcare services. The data available (Table 4) was analysed using exploratory data analysis methods, the same methods used by Mabin and Balderstone (2003).

3.2.1. Waiting time (mean reduction: 50%)

We considered the waiting time for appointments, exams, and procedures. Over half of the sample had reductions on waiting time equal or greater than 50%.

3.2.2. Length of stay (mean reduction: 38%)

The LOS included a rich collection of environments (e.g., whole hospitals, specific wards, an emergency department) in different countries. Many studies reported reductions of over 50%.

3.2.3. Accident and Emergency Department 4-hour target (mean improvement: 61%)

Studies from the UK assessed improvements in A&E (Accident and Emergency – equivalent to emergency department) – based on the percentage of patients seen and released within the 4-hour target. It did not allow us to merge these results into length of stay. Results varied between 45% and 73%.

3.2.4. Overtime (mean reduction: 93%)

Those studies that reported overtime achieved a mean reduction of 93%. The reduction of overtime varied between 63% and 100% (most of the cases).

3.2.5. No-show and late-cancellation rate (mean reduction: 72%)

Two implementations focused on reducing no-show and cancellation rate. One implementation was able to reduce those rates at 53%, the other reduced 90%.

3.2.6. Operating room productivity (mean improvement: 43%)

Implementations that focused to improve operating rooms were able to increase the number of surgeries varying from 5% (during peak hours, reducing in 8% after hours) to 100%. In many cases, the improvement continued after the study, which would increase this mean if we had considered this period.

3.2.7. Changeover time (mean reduction: 41%)

Few studies reported the changeover time between operations, but those who reported experienced a mean reduction of 41%.

3.2.8. Throughput (mean improvement: 34%)

The most frequently reported outcome; throughput in TOC is defined as the rate at which the system generates "goal units" (Cox et al., 2012). In this case, we considered throughput as the number of patients adequately processed and we assessed the difference in this measure after implementing TOC. The lowest improvement was a 5% increase in surgery during peak hours (described above), the highest was a 100% increase in cataract surgeries. Nearly half of the cases had an increase of 40% or more.

Almost all organisations had successfully achieved and sustained improvement, but many of them stagnated after that and did not report further improved outcomes. When it comes to continuous improvement, defining its sustainability is difficult since there is no clear definition and guidelines on how to assess it in past research. However, of those organisations that reported the sustainability of the solution (n = 34), 74% (n = 25) reported being successful in achieving and sustaining continuous improvement, i.e., were able to continue to improve beyond their initial improvement along time. The other 26% (n = 9) did not achieve or sustain continuous improvement. The remaining organisations (n = 8) did not provide follow-up on the achievement and sustainability of continuous improvement (uncertain).

Table 4. Summary of performance outcomes related after implementing TOC in healthcare services.

Reference	Waiting time	Length of stay	A&E [a]	Overtime	No show and cancellation rate	ORP	Changeover time	Throughput
Bacelar, 2019								64%
Buwalda & Gijs, 2013		−15% (Pulmonology) −28% (Internal Medicine)						
Cox & Robinson, 2012					−90%			40%
De Kiewiet, 2012	−50%			−100%				
Gonçalves et al., 2018	−27%							
Groop et al., 2017								12%
Gupta & Kline, 2008					−53%			
Gupta et al., 2015								15%[c] (daily attendance) 21% (group attendance) 15%[c] (caseload)
Karvonen et al., 2004	−50% (A1 group) −75% (A2 group)					40%		40%
Kimbrough et al., 2015						5%	−5%	5%
Knight et al., 2004		−58% ("short-stayers") −56% ("long-stayers")	45%[b] (Milton Keynes District) 73%[b] (Oxfordshire Radcliffe)					40%
Mabin et al., 2018	−87%			−63% (nurses) −100% (pharmacists) −100% (technicians) −100% (assistants)				
Paavola, 2008						50%	−76%	50%
Ronen & Pass, 2011	−41%					20% (case 1) 43% (case 2) 100% (case 3)		20% (case 1) 43% (case 2) 100% (case 3)
Sierraalta-Arganguren, 2015		−29%						
Stratton & Knight, 2010		−27%						
Stratton & West, 2014	−20%	−51%						
Umble & Umble, 2006			65%[a] (Oxfordshire Horton)					8%

[a]Difference (%) in the percentage of patients meeting the 4-hour target. [b] We did not use aggregate results from Umble and Umble (Umble & Umble, 2006) because Knight et al. (Knight et al., 2004) provided more recent results. [c] Value extracted from a chart. [d] ORP: operating rooms productivity.

3.3. Question 2: diffusion of TOC in healthcare

According to our findings, a typical TOC implementation in healthcare occurred in the Accident and Emergency Department of a United Kingdom (UK) public hospital. Nevertheless, TOC has been implemented in a diverse set of environments and countries.

Most of TOC implementations occurred in the UK or in the United States (USA), 28 out of 41. Although the USA had more published studies (9 studies), the UK took the lead in the total number of implementations (19 implementations in 6 studies). Finland is represented with 3 articles that describe 4 implementations. Other countries described in a single article or proceedings are Israel (3 implementations), Brazil (2 implementations), Netherlands (2 implementations), Italy (1 implementation), New Zealand (1 implementation), and Venezuela (1 implementation).

Considering the levels of care, tertiary care (e.g., hospitalised patients, surgeries) were the most common, contributing 76% (n = 35). Implementations in primary care (e.g., family medicine clinic) and secondary (i.e. speciality care, e.g., ophthalmology, psychiatric rehabilitation) corresponded to 9%; (n = 4) and 15%; (n = 7), respectively. These numbers reflect the fact that hospitals are the most common setting of TOC implementations (86%; n = 36) followed by clinics (7%; n = 3), home care (5%; n = 2), and a health system (2%; n = 1). The same is true considering the nature of services, although there were representatives of all categories, government health services account for the most with 62% (n = 26), followed by for-profit (21%; n = 9), and not-for-profit (17%; n = 7).

The description of the services revealed the diversity of environments where TOC was implemented. Accident and Emergency Departments (33%; n = 14) and operating room (12%; n = 5) stood out as the most common environments. However, the list of services where TOC was implemented includes highly specialised services (e.g., neurosurgery and heart surgery), a government health system run by the U.S. Air Force, a chemotherapy clinic, a family medicine clinic, a home care delivery system, and discharge planning.

We can view the elements that compose the health and social care industry similar to a chain structure. Each link of this health and social care chain corresponds to a different service provided (e.g., general practitioner, inpatient care) and they are organised according to complexity level and need of care (e.g., general practitioner + speciality care + emergency). An overloaded link preventing patients to access treatment in a timely manner may result in an increased demand for the next link of the chain (higher complexity treatment) as the illness progresses. All implementations evaluated had an impact within their respective links of the health and social care chain. However, 57% (n = 24) of the implementations also had an impact between the links. That means the consequences of those 24 TOC implementations reverberated across the health and social care chain, indirectly improving other links (e.g., reducing the time between the emergency department and hospital admission).

While most of the studies analysed only applied TOC in specific environments. the TOCICO video proceedings contained 3 holistic implementations. These holistic implementations included one hospital (for-profit) in Venezuela (Sierraalta-Arganguren, 2015) and 2 hospitals in the UK (De Kiewiet, 2012; Stratton & West, 2014).

3.4. Question 3: common problems (UDEs) faced by healthcare services

The reported problem (the gap) that motivated implementing TOC was identified in each case study and arranged into 4 different categories. The most common problems experienced by healthcare services involved in this systematic review were (1) insufficient productivity (31%; n = 9), usually represented as a pressure to do more and be faster with existing or less resources; followed by (2) inadequate timeliness of care (21%; n = 6), usually patients had to wait for long periods for their treatment, both when scheduling appointments and procedures (indirect waiting) and once in the clinic/hospital (direct waiting); (3) financial problems (21%; n = 6), profits were low or non-existent; and (4) issues in quality of care (e.g., healthcare provided not as good as desired, consumer and provider low satisfaction or dissatisfaction, patients at risk of more complications) (18%; n = 5) complete the list. One article and two proceedings (11%) did not describe clearly the gap between where the organisation was and where it should be with respect to its goal (Buwalda & Gijs, 2013; Lubitsh et al., 2005; Ronen & Pass, 2011).

The median number of UDEs reported was 4, but we found a minimum of 1 (Kimbrough et al., 2015; Wadhwa, 2007) and a maximum of 115 (Taylor, 2016). The latter was a video proceeding that mentioned the existence of 111 UDEs in one of its implementations but did not described them. One article (Gonçalves et al., 2018) and two proceedings (Ronen & Pass, 2011; Stratton & West, 2014) did not report any UDE. All UDEs reported were analysed and arranged accordingly to their nature, resulting in 8 categories. The authors commonly reported more issues related to productivity (27%; n = 28), followed by financial outcomes (15%; n = 15) and market demand (12%; n = 12). Other UDEs reported were timeliness of care (11%; n = 11), lack of staff (10%; n = 10), logistics (10%; n = 10), staff satisfaction (8%; n = 8), and quality of care (6%; n = 6).

Since not all implementations described their UDEs, we considered only those 37 (88%) that did to assess whether they were able to address their UDEs. Most of the implementations (86%; n = 32) were able to address all their UDEs after TOC implementation, although a few implementations (12%; n = 5) could only partially address their UDEs (Gupta & Kline, 2008; Lubitsh et al., 2005; Paavola, 2008). Lubitsh et al. admitted that their results were biased due to a corporate merger being in process during the TOC implementation ("A frequently occurring complaint from staff was that the merger process was against the spirit of TOC and was undoing all the improvements which had come out of it.") (Lubitsh et al., 2005, p. 129).

3.5. Question 4: methods and tools used to apply TOC in healthcare services

The analysis of the TOC implementations sequence revealed many different approaches. The articles and video proceedings used 5 different TOC methods: 5FS, BM, thinking processes (TP), drum-buffer-rope (DBR), and CQS. The most used method reported was the 5FS, accounting for 76% (n = 32), followed by BM (60%; n = 25), TP (54%; n = 22), DBR (40%; n = 17), and CQS (17%; n = 7). Some implementations included more than 1 TOC method. Within the articles, 2 of them reported a maximum of 3 methods: Groop et al. (2012, 2017)) described the use of 5FS, CQS, and TP; while Cox, Robinson, and Maxwell (Cox et al., 2014, 2016) described the use of 5FS, TP, and BM. The latter implementation described the use of all 5 methods on a video proceeding (Cox & Robinson, 2012). More details about each of these TOC methods and their adoption in each study are available as supplementary material.

Among other methods adopted to support the TOC implementations, 4 of them stood out: documented flow analysis (76%; n = 31), TOC training (69%; n = 29), improvement meetings (67%; n = 28) – frequently called buffer management meetings or huddles –, and participation of a TOC champion (64%; n = 27). Articles describe other relevant methods, such as process flowcharting, semi-structured interviews, and non-participant observation, but none of these methods achieved an adoption level of 50%. All methods used are available in Table 5.

4. Discussion

Articles and video proceedings accounted for a similar number of implementations, 22 and 24, respectively. However, the video proceedings had only 12 studies included while there were 15 articles. Only 5 implementations were documented both in articles and in video proceedings. The number of video proceedings would have been even higher if we had included theoretical studies. While the video proceedings represent the grey literature, these results demonstrate the relevance and necessity of including these studies in this review. On the other hand, theses/dissertations accounted for a small sample in this study (n = 2), reporting 4 implementations (also described in articles) (Groop, 2012; Lubitsh, 2002). It demonstrates the need of more incentive for academic research on this subject.

Besides quantity, the quality of TOC implementations in academic studies is still lower than expected. Of course, there are good TOC implementations in academic papers. But, overall, our bias analysis revealed some gaps between academic and grey literature. Our framework assessed the implementations according to their adherence to TOC principles (and revealed when and where it was not achieved). Both academic and grey literature studies had well-described TOC implementations that achieved a high score, but academic studies had a lower mean score. Although the video proceedings provided rich details about the TOC tools and methods, many times they missed providing the implementation sequence. In contrast, academic studies provided a better

Table 5. Methods and tools used to apply TOC in healthcare services.

TOC Methods	YES		NO		Unclear	
5 Focusing Steps	32	76%	10	24%	0	0%
Buffer Management	25	60%	17	40%	0	0%
Thinking Processes	22	52%	20	48%	0	0%
Drum-Buffer-Rope	17	40%	25	60%	0	0%
Change Question Sequence	7	17%	35	83%	0	0%
Other methods	**YES**		**NO**		**Unclear**	
Documented flow analysis	31	74%	7	17%	4	10%
Training	29	69%	8	19%	5	12%
Improvement meetings	28	67%	7	17%	7	17%
TOC champion	27	64%	7	17%	8	19%
Process flowcharting*	12	29%	13	31%	17	40%
Semi-structured interviews	9	21%	26	62%	7	17%
Non-participant observation	8	19%	23	55%	11	26%
Questionnaires	2	5%	26	62%	14	33%
Prior simulation	1	2%	41	98%	0	0%

* Process flowcharting is very similar to documented flow analysis; we considered the former as a graphical representation of the latter.

description of the sequence. The fact that video proceedings were made to an audience familiar with TOC, whereas articles usually make no assumptions might help explain these differences to some extent.

Not surprisingly, most of the severe inconsistencies in applying TOC principles occurred in those studies that had the lowest score, including those studies that reported a few neutral results among their outcomes. Despite such shortcomings, all of them reported overall positive results. Some inconsistencies found involved skipping steps 2 (exploit) and 3 (subordinate) of the 5FS (Gonçalves et al., 2018), considering UDEs as bottlenecks (Kimbrough et al., 2015), staff not attending TOC committee meetings (Lubitsh, 2002; Lubitsh et al., 2005), and solutions based on cost accounting (Gupta & Kline, 2008), instead of throughput accounting. Throughput accounting is a management accounting method developed by Goldratt that evaluates the impact of any proposed local action on the system as a whole. Throughput accounting addresses the shortcomings of cost accounting on decision making (Budd, 2010).

4.1. Outcomes of applying the TOC in healthcare services

A relevant aspect of our findings is that all TOC implementations reported an overall positive outcome. Most implementations resulted in a dramatic improvement, particularly those that achieved higher scores in the bias analysis.

Most TOC recommendations and changes required little or no additional cost to implement and, whenever an investment was necessary, the return on investment (ROI) was usually immediate (or it pays off in the short-term) and much higher than the cost. Other methodologies, like Lean and Six-Sigma, usually demand more time, management attention, and financial resources (Blackmore & Kaplan, 2017; Chiarini & Bracci, 2013; D'Andreamatteo et al., 2015). Lean and Six Sigma implementations take much longer because they try to improve all processes of the system, lacking the focus to improve where it is needed the most. The benefits of combining the focusing mechanism of TOC with Lean and Six-Sigma tools for local improvement are huge. The successful combination of TOC with other methodologies already exist (Pirasteh & Farah, 2006), including in healthcare, as demonstrated by Wadhwa (2007).

On the light of the outcomes reported, one may question whether the improvement in some measurements, such as an increase in throughput or operations performed and a decrease in LOS, might jeopardise the quality of care delivered. Actually, the quality and timeliness of care increase for two reasons: (1) a TOC implementation alleviates the workload of qualified medical professionals (the constraint) so they can spend more time with patients performing high skill-level tasks; furthermore, (2) as throughput increases and waiting time decreases, healthcare organisations are able to deliver care to more patients on a timely manner, preventing the worsening of clinical conditions (Ryu & Lee, 2017). These two aspects are directly related to better value provided and lead to better healthcare outcomes (Porter & Lee, 2013).

Sustainability of results is also a relevant concern. Those cases that achieved higher scores were also associated with continuous improvement. Many implementations (61%; n = 25) were able to successfully achieve and sustain continuous improvement. However, any TOC implementation involves a change mindset to build a new paradigm within the organisational culture. For this reason, in order to achieve continuous improvement, one must adopt and continuously use TOC principles to manage.

Like Mabin and Balderstone (2003), we faced the same concern when assessing the performance outcomes reported after implementing TOC in healthcare services. The existence of so many apparent gaps in the data could indicate that those factors were not improved, or that only a few factors in each case improved. Likewise, there are many valid reasons for those omissions. Many healthcare services adopted TOC with a specific focus, such as to increase throughput, and may have failed to give attention to (or find a need to measure or report) effects outside this focus. Moreover, it was difficult to collect hard data, some studies only presented measurements after implementing TOC (e.g., "elevated enrolment capacity by 800 additional enrolees", "generated over 1.6 million additional revenue"). Many studies reported results that did not allow us to calculate (e.g., "daily number of operations has increased"). In many, if not all cases, the organisation was constantly fighting fires. Their role was to put out fires not to spend time documenting and measuring their problems.

The findings reported in this study become even more relevant when we realise that only 3 environments did a holistic implementation and only 1 environment reported the adoption of all TOC methods. The outcomes of all other 37 implementations resulted from applying some components of the overall TOC managerial philosophy. These results are only a partial demonstration of the power of TOC, corroborating results of a prior literature search of TOC applications (Mabin & Balderstone, 2003).

4.2. Diffusion of TOC in healthcare

Mabin and Balderstone (2003) stated that a great number of other TOC applications have never been published (and many of them probably never will) because they provide a competitive advantage. The same may be true for TOC applications in healthcare services.

The mean performance outcomes reported after implementing TOC in healthcare services provide good evidence of the adoption of TOC as a potential effective solution for the chronic problems in most, if not every, healthcare environment. The set of studies included in this review, though small, demonstrates that TOC has already attained significant results in all levels of care and many links of the health and social care chain. There are successful examples from general practice (Cox & Robinson, 2012; Cox et al., 2014, 2016) to home care (Groop et al., 2017), described in 9 countries, on 4 continents. Furthermore, solutions proposed by Groop et al. (2017), or some variant of them, are now applied in at least 20% of the home care systems operating in Finland. At least 10 hospitals in the UK have already adopted TOC to support their practice (Knight et al., 2004). However, we only found a few cases in primary and speciality care.

4.3. Common problems (UDEs) faced by healthcare services

Shortage of hospital beds and workforce are frequently associated as common causes for lack of performance in healthcare services (Crisp & Chen, 2014; Song & Ferris, 2018). Nevertheless, TOC has proved with several successful cases its capacity to dramatically improve performance using the existing workforce; and, when necessary, usually hired an additional non-constraint, such as a medical assistant, at a reduced cost to leverage the constraint (the much expensive and scarce provider). Furthermore, the shortage of hospital beds did not present as a root cause, but as a symptom. As a matter of fact, the impressive mean reduction of 38% in LOS achieved by TOC also worked providing increased capacity to treat more patients within a given period of time using the same existing beds, as mentioned by Knight et al. (2004). Examples above and all other TOC outcomes show that healthcare services suffer from similar problems, but usually have a huge amount of protective capacity. These organisations are managing their resources and patient flow based on bad/outdated policies, which focus on improving local efficiency (not assessing its global impact on the organisation). Consequently, existing extra capacity is misused, which leads to undesirable outcomes (e.g., long waiting, increased LOS). TOC demonstrated that it is possible to uncover the hidden capacity and achieve breakthrough results with no or little investment.

4.4. Methods and tools used to apply TOC in healthcare services

The three POOGI offered by TOC have proven extremely valuable in healthcare. The path to improving healthcare systems and organisations is described in the 5FS. First, organisations must identify (step 1) where the constraint is currently and where the constraint should strategically be. Next, they need to uncover their hidden potential by making better use of existing resources (steps 2 and 3). Only after achieving their true potential should the organisations consider the need to invest in acquiring more capacity (step 4). But to continue improving, it is essential to remember step 5: do not let inertia become the system constraint.

Many times, however, a policy, procedure, rule, measure or behaviour is blocking patient flow (details explained in the supplementary material). In these cases, the TP and the CQS are quite useful in identifying and addressing these types of problems. Buffer management is extremely useful in hospital environments, where demand is uncertain (for example, in the emergency department where no appointment schedule exists) and where there are thousands of potential processes flows through the various hospital departments. DBR plays an important role once a patient process flow is then identified and frequently updated by the patient's physician (the drum) to ensure the patient receives appropriate and timely healthcare (Strear & Sirias, 2020). Knight's Pride and Joy (2014) provides numerous instances of the use of TOC in a healthcare environment. In an outpatient environment, buffer management is extremely useful in proactively managing the rapid treatment of acute patients, pulling patients forward in time to imminent vacant appointment slots, and monitoring overall and specific appointment types backlogs, as explained in a 2-article series where the authors used TOC to address appointment scheduling system design and execution problems (Cox, 2019; Cox & Boyd, 2018).

5. Limitations

Naturally, this work has some limitations and we would like to acknowledge them. First, the number of TOC implementations described in this study is small. Our dilemma in addressing this limitation was the traditional "Rigor versus Relevance" quandary. Do we wait another ten or more years so that enough published academic research is available to conduct statistical tests of significance OR do we conduct an exploratory investigate of what is available today in hopes that other researchers will move forward in learning more about TOC in healthcare and be on the forefront of developing new knowledge instead of the traditional role of academics of just reporting history? We choose the latter.

As an effort to address the above-mentioned limitation, we included grey literature sources, here represented as TOCICO video proceedings and academic theses. As previously stated, TOCICO is a not-for-

profit certification and knowledge development and dissemination organisation. Many members are certified in all aspects of TOC; others are on that journey. Most members are consultants and have led dozens to hundreds of TOC implementations. These presentations are vetted by the top TOC experts in the world. Presenters willingly share their successful and failed implementations in hopes of developing better solutions. Similarly, theses and dissertations are vetted by the students' examination committees.

A lesser limitation is that we tried to analyse each implementation separately, but many times a single article or video presentation reporting multiple cases treated them as one. Furthermore, this review only considered practical implementations directly related to patient flow. There are many other successful case studies in support services, such as logistic service of medical records in a hospital (Aguilar-Escobar et al., 2016), hospital inventory management (Wang et al., 2015), medical claims processing (Taylor & Sheffield, 2002), and developing technical reports for healthcare decision-makers (Patwardhan et al., 2006). These healthcare support-services TOC implementations differ little from TOC implementations in other services, so they provide no gain in TOC knowledge in healthcare.

5.1. Recommendations for future work

In the future, it would be of great value to science and management to have a systematic review that includes theoretical papers with proposed solutions, even though never implemented. Other recommendations are (1) a study revealing details of the most common TOC tools and methods used in the healthcare environments, (2) more studies about TOC in primary care and speciality care, (3) TOC combined with other methodologies, and (4) to develop generic templates of various applications based on the literature and successful case studies through theory building for use in implementing TOC in similar environments (theory testing). Cox and Boyd (2018) provided such a template for outpatient schedule design and Cox (2019) provided a template for outpatient schedule execution for testing and modification by other researchers.

6. Conclusion

Existing literature has revealed TOC as a potential effective solution to address the chronic healthcare problems. All documented healthcare services that implemented TOC achieved positive results, even those that only used some components or did a marginal implementation. Those organisations that adequately applied TOC were able to rapidly achieve breakthrough improvement, and with no or little investment. Furthermore, recent research shows that combining the focusing mechanism of TOC with other existing methodologies (e.g., Lean, Six-sigma) would provide larger benefits than using the other methodologies alone. TOC provided positive results in many different environments along the health and social care chain, and in many different countries, which leads one to believe they can be used to improve almost any healthcare environment.

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