Article

A Theoretical Proposition for Spatial Data Infrastructure On-Going Improvement

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Abstract: The past three decades have seen technology become ubiquitous and impact on many fields academically and in professional practice. In geo-information, data acquisition and management have manifested through technologies such as global positioning systems, remote sensing, geographical information systems, unmanned aerial vehicles and improved photogrammetric processes. With all these improved technological capabilities, geospatial data collection, processing and dissemination have become possible in greater proportions. To reap from this technological boom, the geospatial information community has come up with a pervasive and network enabling concept called spatial data infrastructure (SDI). Over the years, several countries have embraced the SDI concept to shape policy, build and share geospatial information resources. Some levels of successes have been reported in number of developed countries while developing countries have struggled. For instance, in 2010, SDI state of play assessment results of nine African countries averaged 30.70 over 56 or 0.55 while the SDI readiness index of the same countries averaged 0.50 on an index scale of 0 to 1 in 2016. The 2010 and 2016 assessments concluded that in African countries, SDI development was slow. To address the problem of slow SDI development in Africa, this paper proposes an on-going improvement theoretical approach anchored on the theory of constraints.

Keywords: geoinformation; theory of constraints; SDI assessment; SDI readiness index; state of play

1. Introduction

In the field of geo-information, data acquisition and management have manifested into technologies such as global positioning systems, remote sensing, geographical information systems, unmanned aerial vehicles and improved photogrammetric processes. With all these improved technological capabilities, geospatial data collection, processing and dissemination have become possible in greater proportions. To reap from this technological boom, the geospatial information community came up with a pervasive network enabling concept known as spatial data infrastructure (SDI), which was politically embraced and promoted by the president of the United States of America in 1994 through an executive order [1]. SDI development and assessment has since been carried out in a number of jurisdictions across the world and in recognition of this, positive advancement [2] and slow progression [3,4] in SDI development are recorded in the literature. The assessments associated with SDI have, overall, been presumptuous that improvement was going to come along in response to low scores. The presumption of success, for instance [2], has been modelled in reference to developed countries as opposed to those that are developing and struggling with the concept. The interest of this paper is to come up with a purposive proposition that is geared towards ordering the problems faced by SDI development within the context of developing countries, in particular focusing on the African experience.

This paper articulates a novel proposition named SDI on-going improvement (SDIOGI), which is anchored on a scientific management approach known as the theory of constraints (TOC) [5]. The SDIOGI is suggested as an approach that allows for audits and focusing

of various SDI constructs in its implementation and assessment. To advance the SDIOGI approach, a critical review of two past continental Africa SDI assessments is undertaken and their results treated as constraint agents within the framework of the TOC. From the components assessed, temporality of the two assessments and the TOC is used to advance a compelling case for the SDIOGI approach. The SDIOGI approach is advanced as a contribution to on-going SDI discourses and an attempt to call SDI implementers to undertake its systematic implementation and review with the objective of scaling up its advancement at all levels. In a theoretical proposition it will be shown that: SDI assessments reveal the level of its constraint to performance, but its progression is as good as the main constraint. This approach is expected to add to the current literature on SDI, and if utilized, it can facilitate SDI development pace and create opportunities for focused SDI design and implementation.

SDI developments in various jurisdictions have been taking place since the early 1990s. In line and in response to their development, assessments have been carried out for instance state of play [3,6]; SDI readiness index [4,7,8]; performance management [9–11]; organizational perspective [12] and multiview assessment [13,14]. What has emerged from some of these assessments is that Africa has been experiencing slow progression of SDI advancement despite the corresponding explosion in technology supporting SDI [3,4,15]. In addition to technology, the assessments mentioned above possess various constructs such as data, human capacities, legal framework, and overall organizational dynamics, which have to be well construed to facilitate a smoother SDI progression. Hence, a question is raised: what could be the cause of slow SDI development and how can it be tackled for improved implementation? This question is hypothetically answered by assuming that the slow progression of SDI could be attributed to a lack of an improvement approach that addresses the constraints of the infrastructure on its development path. In this hypothetical assumption, SDI constructs are regarded as constraints that need to be studied, understood, ordered, and contextualized to facilitate an improved systematic SDI implementation and advancement.

The main purposes of SDI are to enable seamless sharing, exchange of geographic information and allow for the discovery and creation of new products in a digitally interconnected and interoperable world. The impact of SDI on societies has to be felt at local, national, regional, continental and global levels [16–18]. In recognition of the various levels of SDI, its components have been deduced largely to be the following: organization, people, access networks, policy, standards and data [16,17]. In their paper, Ref. [16] insist on a comprehensive understanding of these components in the context of a social system with the import that "*the characteristics of the social system strongly influence the approach taken to the development of an SDI initiative*". The influences of the social system as opined in [16] can largely be identified within the context of political support, organizational interests, data representation approaches, technology advancement, historical spatial data handling and various levels of collaboration.

Going by the above paragraph, we need to understand and appreciate the several influences that aid development chains and successes of SDI. One way to improve understanding could be the performance of a robust SDI Assessment. SDI assessments, as mentioned earlier, have been carried out by several scholars and they include state of play, readiness index, and multiview just to name a few [19]. The information that is portrayed by these assessments has attracted and helped facilitate the authoring of this paper. The fundamental outputs in these assessments are the results of the assessed components. The components include constructs such as organization, fundamental data, people, standards, policy and legal, which are found to be comparable among some assessments such as state of play and readiness index. The results in this case need to show SDI success and growth patterns, which can be directly affected by the various influences of the system in a complex environment. This paper consequently views constraints in the major components of SDI as responsible for the slow growth patterns of SDI and hence a method of how to handle them is proposed. This method is envisaged to prop-up SDI development and improve

its assessment as a temporal phenomenon [20]. The next section crystalizes the envisaged methodology adopted for this paper. Emanating from the methodology, some results based on the time of SDI assessment are extracted and they are considered within the TOC to propose SDIOGI. A discussion is undertaken, and a conclusion is drawn.

2. Methodology

The purpose of this section is to elaborate on the approach that was undertaken in the completion of this paper. The overarching methodology used in this study has followed what is known as a systematic literature review [21]. Fundamental points considered in this approach included methods of SDI assessment, data, and time. For SDI assessment, a systematic scrutiny of existing literature and critically analysing their related results in the context of this paper were undertaken. In terms of time, the period between assessments is paramount in the evaluation of how constructs measured in the previous assessments in a given jurisdiction have evolved. The forgoing put emphasis on the temporal characteristics of an SDI assessment as an important research data component. An assumption is made that temporal proceedings of organizational pursuits vary from time to time such that if constructs are assessed in a given year, they are expected to improve in order to reflect a better output in a future time. The interest here is to look at constructs and variables that have been studied in SDI with the objective of comparing them to appreciate the result they are showing and come up with new theoretical propositions and knowledge. This thinking is summed up in [20] through a question which reads: "*In sum, is there some way to integrate the findings of the existing studies to enable us to create a more common understanding of what has been done to date and where we should go from here to further build on existing knowledge?*". What must be noted is that SDI assessments have been conglomerated into what has been called the Multiview assessment framework, which allows for the flexibility of assessment in a complex and dynamic environment associated with SDI implementation. SDI state of play and the readiness index are part of the Multiview assessment framework [13,14] and hence their results in 2010 [3] and 2016 [4] are used as existing knowledge to ground a theoretical improvement proposition based on the TOC.

2.1. Systematic Literature Review Method

The methodology followed in this paper is known as a systematic literature review (SLR). This methodology entails critically reviewing literature of past similar studies as data for the current research. The origins of the systematic literature review methodology can be traced to health sciences research and has been embraced in areas such as information systems, software engineering, social sciences, management, and organization science [21]. SLR serves a completely new purpose as a methodology in research as opposed to the conventional literature review, which is often associated with setting the context for the research. Furthermore, Ref. [21] alludes that "*there exists another type of literature review that constitutes an original and valuable work of research in and of itself*", where structure, procedure, explicitness, comprehensiveness, and reproducibility qualify it as a methodology. SLR, therefore, makes reviews of existing literature and use results from the reviewed articles as data without collection of any new primary data. In so doing, Ref. [21] set out eight (8) principles as fundamental to the rigor of the SLR approach and they are given as: (a) purpose of the literature review (b) a detailed protocol of the review (c) explicitness in literature search (d) practical screening of the reviewed articles (e) quality appraisal or screening for inclusion or exclusion (f) data extraction (g) synthesis or analysis of the reviews and (h) writing of the study, which essentially shows reproducibility of the methodology.

This method was rigorously utilized by [22] in their study focusing on the effectiveness and improvement of enterprise architecture implementation methodology (EAIM) based on 46 existing studies. The study by [22] is best placed in the realm of computing and/or information technology, which can be said to be directly related to the area of SDI in terms of the access network construct. Another relevant use of this method was by [23], in which

they focused on studying "*user involvement*" with a system of computing nature and their effectiveness on its success. Following the SLR method, past SDI assessments in Africa were searched at continental level with the purpose of reconsidering SDI progression in the context of their assessment results. Some of the SDI assessments studied include [3,4,15,24–26].

2.2. SDI as a Temporal Phenomenon

Mapping of activity to time is articulated by [20], citing a number of transformational stages such as single activity mapping, repeated activity mapping, single activity transformation mapping and multiple activity mapping. These mapping categories are self-explanatory with time as an important factor for activities to occur over a period. In view of SDI, all these mappings are possible in assessment processes as means of gauging SDI advancement at corporate, local, national, regional, and global levels. Following this logic and the SLR approach, SDI assessment articles in Africa discovered are put under the microscope on the basis of the time that they were completed and constructs were measured. The objective associated with this is to evaluate how far the SDI assessable constructs have improved over the given time frame in continental Africa. Further to that, a constraint-oriented approach in improving SDI development in view of the results is advanced. To aid this, the next section addresses itself to how the SDI constructs are conceptualized into constraints.

2.3. Consideration of the SDI Constructs as Constraints

In order to propose the SDI on-going improvement (SDIOGI) approach, the constructs of SDI assessments were regarded as key indicators to what could be called constraints. Constraints are considered and explained within several study domains, for example in mathematics, information technology and management. In mathematics, constraints are agents that are studied with the primary aim of optimizing the underlying system and are usually expressed as equations in the form of equality, inequality, and integers. In management, a complex set of constructs are feasible as constraints and they include organizational setups, legal framework, funding models, capacity, technical production, and all other arrangements that ensure the effectiveness of the production of goods and services. These constraints can act as insurmountable obstacles to nonparticipation in a new intervention needing multi-organizational efforts [27]. SDI is a multi-organizational activity that is aimed at geospatial information sharing by various stakeholders across an economy, and hence constraints affecting it need to be studied and understood for the benefit of participants and optimization of its implementation processes.

In the context of temporal SDI assessment, data that reveal the extent of the progress are obtained or yielded from the instruments of measurement, as shown in Table 1. The obtained data are usually explained in a generic form, in the sense that they do not disaggregate the measured constructs into their level of strength and weakness regarding SDI advancement. The SDI assessment usually concludes in general superlatives, such as slow, low readiness, weak, needs to be improved, without pointing to specific approaches that have to be followed for improvement. This paper aims to fill this gap and advance a specific approach that can be followed to improve SDI implementation following the results of the assessed stakeholder perceptions from one time-period to the next and into the future. The TOC is used to critically express associated SDI constructs as visible constraints to SDI development in Africa.

Table 1. Extracts from continental Africa spatial data infrastructure (SDI) assessments.

Time	Types of SDI Assessment Done	SDI Constructs Assessed					
		Organizational Points = 12	Funding Points = 8	Legal Points = 12	Technical Data Point = 12	Metadata Points = 12	Total Points = 56
Year 2010 and 2016 SDI Assessments	State of Play (SoP) Average Values (Extract, [3])	9.11	4.67	4.37	6.45	6.11	30.70
	SoP Simple Index (2010)	0.76	0.55	0.36	0.54	0.51	0.55
	Readiness Index (RI) (Extract, [4])	Organization	Financial	Human	Technology	Informational	
	Overall (2016)	0.58	0.47	0.47	0.53	0.54	0.50

2.4. The Theory of Constraints (TOC)

Based on the reviews of continental SDIs in Africa, SDI on-going improvement (SDIOGI) is proposed. In the proposition of SDIOGI, several methods of on-going improvement such as Deming management method [28]; diffusion of innovations model [29]; McKinsey model [30]; Lewin's three step change theory [31]; Kotter's change model [32]; Bridge's transition model [33]; Harris five step model [31]; technology acceptance model [34]; Prosci ADKAR Model [35], this is an acronym for; awareness, desire, knowledge, ability and reinforcement, which is a change model; Greiner's change process model [31]; Fullan's change theme set [31]; and theory of constraints (TOC) [36] were systematically reviewed for fitness as theoretical approaches. Out of all these, the TOC was selected to facilitate the SDI on-going improvement approach alongside SDI assessments. The TOC was selected as a theoretical proposition because of the following reasons:

(a) Among the reviewed methods, the TOC was perceived to be more scientific in approach.

(b) The TOC has been found to perform better than other improvement methods by [37]. They reported its prowess on things such as lead times, performance, inventory levels improvement, increase in throughput and better prospects in aspects of financials as compared to other improvement approaches.

(c) The TOC was viewed to be much simpler and capable of easily handling complex constructs that are associated with SDI: organization, standards, access networks, legal framework, and financial framework.

(d) The fundamental objective of TOC is "focusing", and it is viewed to augur well for SDI as an intervention and it can be easily utilized across recognized levels of corporate, national, regional, and global.

(e) The TOC is also found to relate to the aspects of challenges with much ease. Most technical organizations dealing with interventions such as SDI prefer to identify challenges associated with the development of systems or infrastructures. Hence, SDI will help them to systematically proffer solutions for the challenges. This will be demonstrated through the SDIOGI proposition later in this paper.

The theory of constraints (TOC) came through the work of Goldratt with constraints as the central theme of proceedings in organizational operations, tactics, and strategy. In his work, Goldratt opined and concluded that in every system implementation, there is a constraint that inhibits or limits optimum performance and if not solved then improved production becomes a fallacy [37]. In their paper, Ref. [37] reviewed the work of several scholars and concluded that in most of its applications, the TOC has worked well even under situations where it was partially used. Their report also indicates that TOC utilization was largely in manufacturing, probably due to its origins (Goldratt), and this is confirmed by other scholars, for example [27,38]. In theory and practice, there are three recognizable domains to TOC: the five focusing steps, thinking process tools and

performance management system [27,36,39,40]. The TOC is systematically reviewed in this work to facilitate an approach in focusing SDI development and assessment. In this paper, the five focusing steps are followed because they are the bedrock of the TOC. The focusing steps by nature provide a time dependent iterative intervention that dictates that a main constraint be determined. A solution is then sought for the main constraint until it no longer inhibits the development or progress in a product or service. Once this is achieved, new major constraints are determined and solved in a similar manner over time. The scenario obtained in this method speaks volumes, and in relation to SDI development and assessment, it is viewed as useful to facilitating focus.

3. SDI Results, Analysis and SDI On-Going Improvement Proposition

Based on the reviews of continental SDIs in Africa, results from various articles are referred. For the purpose of temporality, two main assessments by [3,4] are reported in depth with constructs of comparative data extracted in Table 2 of Section 3.1. Section 3.2 reports on the steps of the TOC. Based on the findings of Sections 3.1 and 3.2, Section 3.3 formulates a proposition for SDI on-going improvement (SDIOGI).

Table 2. The SDI on-going improvement (SDIOGI) proposal (Maphale, 2019)**.**

Time	Steps	Theoretical Aspect: Theory of Constraints Process of On-Going Improvement [40]	Conceptual Aspect: Spatial Data Infrastructure (SDI) Progression	Spatial Data Infrastructure (SDI) Process Description
Implementation and Assessment Over Time	1	Define the system's GOAL.	Define SDI (Corporate, Local, State, National, Regional, Global)	SDI Development set up with vision and mission statements and well-articulated objectives and goals
	2	Determine System performance measurements	State SDI Operations Resources and Performance	This step sets the development agenda for an SDI and pronounce input and output needs over a particular time of implementation
	3	Identifying the System's constraints	Identify SDI Constraints	All development constraints are identified and the primary constraint that is considered highly inhibitive to SDI development to progress is identified. e.g., Legal Framework
	4	Exploiting the System's constraints	Prioritizing SDI Constraints	SDI Development processes, being undertaken by ensuring that the SDI constraint(s) identified in step 3 is solved and removed from inhibiting SDI progression. e.g., Ensuring that Legal Framework is in place as a pre-requisite to commencing SDI
	5	Subordinating of System's Constraints	SDI Constraint Subordination	SDI Development processes are subordinated to the identified main constraint to ensure that the identified major constraint is solved first.
	6	Elevation of System's Constraint	SDI Assessment Mechanism	Undertaking SDI Assessment at some point in time to objectively absolve the constraint identified in step 3 and remove it from the weak link bracket
	7	Go Back to Step 1 or 3 but Avoid Inertia	New Constraints Frontiers back to Step 3	Further Constraint exploitation or Identifying new main constraint (go back to step 3) following SDI Assessment performed in Step 6.

3.1. Past Continental Africa SDI Assessments

Online literature research was undertaken for continental Africa SDI assessments or reviews or evaluations. A number of continental SDI assessments in Africa were discovered, notably: state of play [3,4], a gap analysis focused evaluation [15] and an evaluation of spatial data clearinghouses' implementation [24–26]. According to [26], implementations of spatial data clearinghouses were found to consist of 5% in continental Africa. From these SLR results, SDI assessments in Africa where specific construct perceptions were measured are those of [3,4]. In these two studies, specific SDI construct perceptions were measured to gauge the state or readiness of a country in implementation. These two SDI assessments were reviewed extensively, and the associated overall results of constructs were extracted based on the same countries reviewed in 2010 and 2016. In this case, the results of Botswana, Ethiopia, Kenya, Malawi, Nigeria, Rwanda, South Africa, Tanzania, and Zimbabwe were extracted and summed into Table 1. SDI state of play and readiness index can at best be described as contemporary approaches in view of their proposal in 2004 [24–26] and 2005 [7]. The methods of assessment tend to measure similar constructs: organization, finance, legal, people and information. In this regard, the method employed here is to critically review the construct perceptions measured, to specifically report on their improvement or lack thereof between 2010 and 2016. The extracted results are reported in this paper as Table 1. These results are essentially major perceptions of those involved with SDI, but for the purpose of gauging they are treated in ratio scale format to enable analysis, ordering and comparison.

A continental review of SDI in 29 countries was achieved by [3], but as explained earlier, only nine (9) countries are sampled and the result summaries extracted for the purpose are in Table 1. The nine countries were purposefully sampled since they had SDI assessment results in a later review by [4]. The extracted results from [3] are normalized to give indices by simply dividing the scores of each measured construct by the total score of each construct. For example, taking the average value of organizational total score for the nine countries, which is calculated as 9.11, as reported and dividing by 12 gives a value of 0.76. This is a simple extended calculation of the reported results in [3] so that they appear as indices in a similar fashion as those in [4] to aid easier comparison. The continental Africa SDI review of 2016 took the form of an assessment called the readiness index, which was conceptualized by [7]. In their definition, Ref. [7] defined SDI readiness "*as the degree to which a country is prepared to deliver its geographical information in a community (local, national, regional or global). It demands a variety of geospatial services offered in the widest connectivity to satisfy government, business and citizen geoinformation needs*". In their work, Ref. [4] followed this method in reviewing SDI readiness of African countries and the overall results of similar countries to those sampled in [4] are also summarized in Table 1.

When discussing the results, Ref. [4] made a number of observations that particularly focused on the spread in the numbers. In their discussions, Ref. [4] noted great disparities that existed within the constructs across the countries. From the results: Rwanda obtained the highest SDI readiness index with a value of 0.65 while Botswana got the lowest with 0.35. In recognition of a number of low indices in their results, Ref. [4] opined that "*lower indices imply that a lot more effort is required by the respective countries*". They went on to strongly recommend for human and financial constructs to be prioritized across African states in SDI development based on their overall indices, which were less than an index of 0.5 out of 1. This recommendation resonates with that of [3], their state of play continental Africa SDI review states that "*there is a clear need to speed up implementation of NSDIs in Africa*". The recommendations advanced by these scholars are quite related since when we look at some examples of individual countries, some countries have very low values on the legal construct, e.g., Botswana and Malawi in 2010. By inference, that should have been their immediate concern for SDI implementation for those two countries in 2010.

From the above systematic review of the previous SDI assessments, constructs associated with 2010 and 2016 SDI assessments are further analysed in Table 1 to aid the SDI on-going improvement proposition. What is emerging is that the constructs used in the two

assessments bear a lot in common if not out-rightly so. For ease of discussion the involved constructs along their method of assessment are extracted and reproduced as Table 1 with the objective of revealing similarities in the measured constructs and the temporal nature of the two SDI assessments. Table 1 essentially has the first column emphasizing the year that an SDI assessment was undertaken. Column two (2) shows the type of SDI assessment undertaken, in this case state of play (SoP) in 2010 and readiness index (RI) in 2016. Columns three (3) to eight (7) show results of the constructs that were assessed. An attempt is made to align the constructs on the basis of similarity or closeness in description, e.g., aligning organization in SoP to organization in RI. Column eight (8) is the cumulative results of the constructs for the assessment methods.

In critically analysing these constructs, a question focused on their level of improvement between 2010 and 2016 is posed. A glance at the results in Table 1 reveals that the indices are on average hovering generally around 0.5 in both years of measurement. In some cases, constructs that were seemingly doing well in 2010 have declined down to some degree, for instance, organization in 2010 versus organization in 2016. SDI legal construct, which was independently measured in 2010, returned the lowest score of 0.36 [3], but in 2016, readiness index [4] assessment is subsumed under the organization construct. The value of organization is quite low for the 2016 assessment, by inference this could be attributed to the legal construct. Therefore, a conclusion is reached that there has been no notable improvement between 2010 and 2016. In view of these temporal SDI assessments and results revealing a lack of any significant improvement, a proposal geared towards on-going improvement is advanced. The proposition advanced is referred to as the SDI on-going improvement (SDIOGI) approach and it is anchored within the context of the TOC [5].

3.2. The Theory of Constraints Focusing Steps

In this paper, the TOC five focusing steps were discovered, but the emphasis made by [39] regarding two other earlier steps by Goldratt is also adopted to transform the five focusing steps to seven. Therefore, in this proposition, the seven-step approach is followed to advance the SDIOGI approach. For ease of reference, the seven focusing steps are: (a) define the system's goal (b) determine the system's performance measurements (c) identifying the system's constraints (d) exploiting the system's constraints (e) subordinating the system's constraints (f) elevation of system's constraints (g) avoid inertia—go back to step one or three [39,40]. These steps, within a system approach, can be regarded as a waterfall cyclic approach; hence, we can refer them to time. Hence, in respect to time, the TOC can be utilized to study the behaviour of SDI constructs in respect to the results reported in [3,4]. Regarding application, the TOC has never been implemented in SDI conceptions and its implementation processes, and hence it is viewed here as a knowledge gap that is going to be filled by this work. Through this paper, an attempt is made to fulfil a bridge in that knowledge gap by grounding the SDIOGI on available SDI assessments completed for Continental Africa. This approach has already been proposed and the comprehensive write-up can be read in the PhD thesis of [5]. The approach is summarized through Tables 2 and 3 and in the next section.

Table 3. Propagating SDI constraints (source: [5]).

Time	Steps	SDI On-Going Improvement	Composite Constraints	Underlying Constraints
Year 2010-Implementation and Assessment Over Time—Year 2016	1	Define SDI.	National	State, Local, Corporate, Objectives, Goals
	2	State SDI Operations Resources and Performance	Country Stated Inputs/Outputs	SDI inputs/outputs for State, Local and Corporate
	3	Identify SDI Constraints. ([3], 2010)	Organizational, Funding, Legal, Technical Data and Metadata with lowest index scale	Coordinator, Stakeholder-Participation, Political-Influence, Budget, Self-Sustenance, Data-Pricing Law, Data Use Law, Data Creation Law, Interagency Data-Coordination, Data Standards, Electronic Data Access, Metadata Captured, Metadata Standard, Clearinghouse data Communications
	4	Prioritising SDI Constraints	Select and exploit Composite Constraint with lowest index scale	Select and exploit all the related Underlying Constraints with lowest index scales
	5	SDI Constraint Subordination	State Composite Constraints Subject to Subordination	State underlying constraints that will be subject to subordination
	6	SDI Assessment Mechanism. ([4], 2016)	SDI Assessment based on the Multiview SDI Assessment framework	Institute SDI Assessment based on the Multiview SDI Assessment framework (select suitable method, in this case SDI Readiness Index).
	7	New Constraints Frontiers back to 1 or 3	Determine new constraint as per the SDI assessment	Determine related primary constraint SDI components.

3.3. SDI On-Going Improvement (SDIOGI) Approach

SDI assessment has been discussed comprehensively in [19], where there are a number of methods, but generally, the measured constructs are mostly consistent with those in Table 1. To proceed, the Table 2 is coined so that the TOC is intertwined with SDI assessment to crystalize into what is referred to as the SDIOGI approach. SDI assessment results considered in the case of [3,4] have laid a foundation for the proposition of this SDIOGI approach. In coming up with the SDIOGI approach, a tabular format (Table 2) is used in order to make a much clearer visual alignment of SDI implementation processes with TOC. The table is handy in that it facilitates visible intersections of the various steps of TOC and SDI. An explicit intersection of SDI goals with constraints and expectation of stakeholders is promulgated from early-on. In this table, each step is numbered and there are four columns: the step number, the TOC focusing steps, the conceptual aspects of SDI and descriptions of its implementation processes. After numbering the steps, the TOC focusing points as per [40] are tabulated in a single column. In the second column, all the conceptual aspects of SDI are tabulated to relate with the TOC points on the second column. In the third column, the implementation processes are tabulated with descriptions of the processes as they refer to SDI. The import in this proposition is that the time of SDI development is an important parameter at all stages as shown by the overarching column talking to implementation and assessment over time. This table is configured to be coherent and to easily guide stakeholder organizations on the fundamentals of the temporal undertakings of the SDI.

According to Table 2, the conceptual aspects of SDI are premised on threshold of defining the SDI in terms of its hierarchy and goals. The second point is premised on the existence of the organizational structure, resource availability and envisaged outputs. With the first and second focus areas in place, a comprehensive review has to be undertaken

and SDI constraints determined and agreed on. What has been established as the main constraint has to be solved as a primary concern to SDI implementation. A time-period for the next evaluation has to be set and should be carried out at step number 7 on the elapse of time.

Once SDI has been implemented, regular assessments need to be completed to keep improving its planning and implementation. This scenario is well indicated by step number 7. Following this reasoning, Table 2 is further refined and crystalized into Table 3 grounded on the temporal assessments of SDI by [3,4]. The purpose of Table 3 is to show how SDI constructs can be ordered into main constraints and underlying constraints to advance the constraint-based SDI implementation approach. In Table 3, the SDI column in Table 2 is extracted and aligned to new columns, which specifically relate to the constructs of SDI assessment in [3]. Recognition is made here that the work of [3] concentrated largely on carrying out SDI assessment at the national level for about 29 countries. In keeping with the section dealing with SDI constructs as constraints, the main constructs are referred to as the composite constraints. The elements of the main constraints are referred to as the underlying constraints, and all these are tabulated accordingly. These constraints are measured yielded values and if their ordering is considered, the constraint with the lowest value for a country is taken as the most constrained.

If this approach was followed, then each African country would have solved its major constraints in the future, so that by 2016 they would have been exhibiting high SDI readiness indices. Going by this reasoning, legal would have been the most constrained in [3] assessment. If [4] is considered, the organization value has gone down compared to what it was in 2010 and it is interesting that legal is now one of the observational elements (underlying constraints). One may hasten to know if it could be possible that legal dragged this construct down in 2016. More strictly in terms of the TOC, legal as a constraint in SDI development was only transferred around without much solution or improvement. Hence, it could be proposed at this stage that SDI performance is only as good as its main constraint. The foregoing is put into a theory proposition as: SDI assessments reveal the level of its constraint to performance, but its progression is as good as the main constraint. Indeed, if SDI is developed and assessed with this proposition in mind, then the implementing organizations will tend to focus and plan their efforts in a much better way with a view to achieving desired outcomes.

4. Discussion

The SDIOGI approach is to facilitate the improved conception and implementation of an SDI. SDI, in reality, occurs at various levels and needs to be visualized in a stacked form as represented in Figure 1. Figure 1 reveals a complex environment that SDI assessments need to interrogate, for instance, in the two continental Africa assessments used to inform the SDIOGI approach, constraints associated with corporate and local SDIs of countries that participated in the studies have not been revealed and their impacts determined. Therefore, SDIOGI can be used to study SDI implementation processes through its various hierarchies. As such, issues affecting the SDI state of play and readiness index are not adequately determined. While all the measured constructs are determined at continental level, as specific scores of nations, a direct bottom-up modelling is still lacking. Referring to SDI constructs within the realm of constraints, Figure 1 is designed to show the cumulative nature that researchers and SDI implementers must be conscious about.
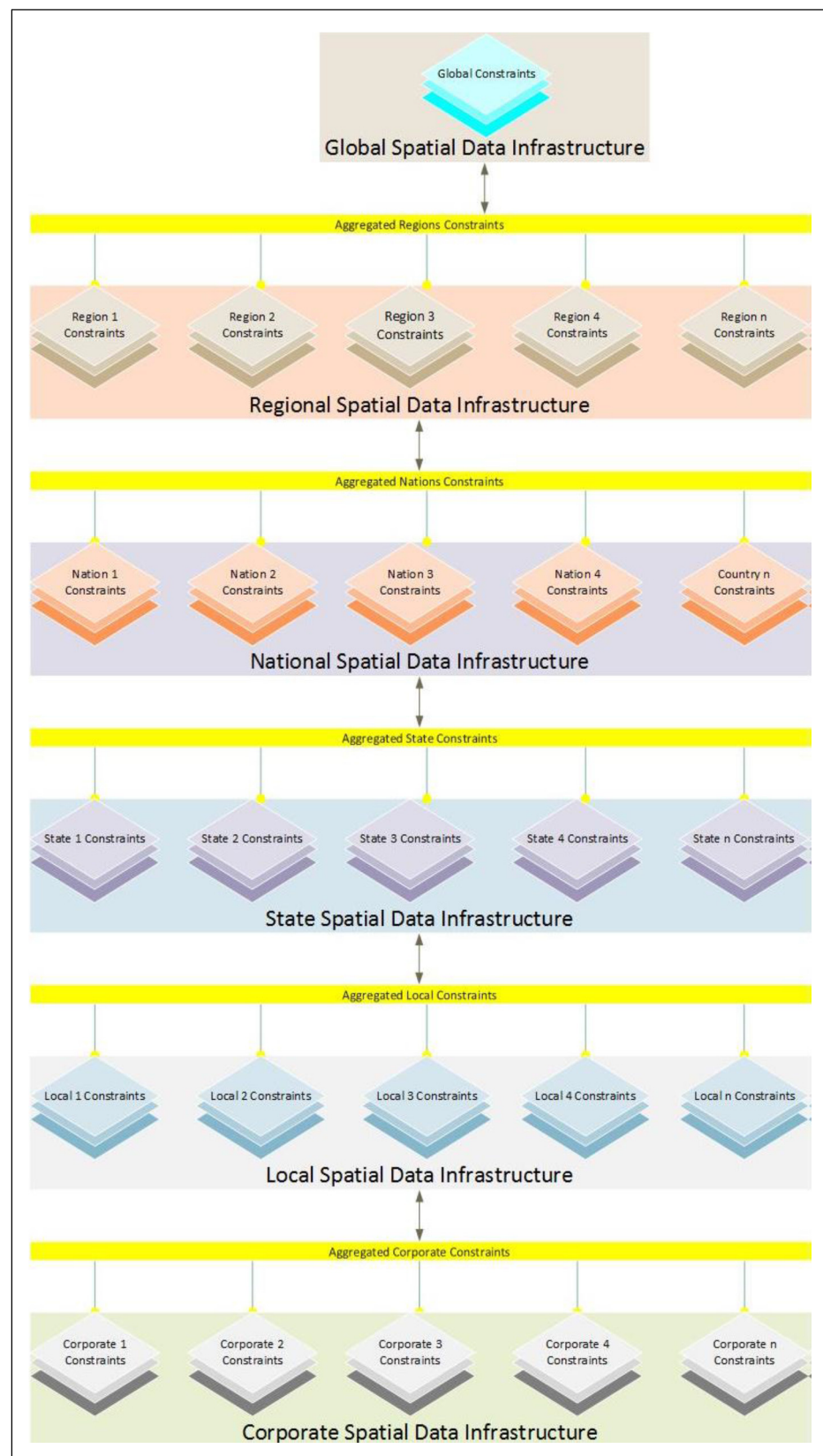
Figure 1. SDI hierarchy constraint modelling (source: [5]).

Figure 1 shows that constraints aggregate and become much more cumbersome as they manifest in a complex environment of SDI processes [5]. In response, a theoretical

proposition of SDI on-going improvement (SDIOGI) based on the theories of constraints is put forward in this paper as a means of collating and solving SDI challenges. This framework is structured to trace the fundamental constraints of an SDI development and come up with ways of solving them to facilitate improved implementation. The effectiveness of this approach is entrenched within and in between SDI hierarchies as presented in Figure 1. Therefore, in the case of [3,4], it can be inferred that the system of constructs measured as constraints is actually subscribing to the fourth hierarchical level of SDI development. This is found to be consistent with [41], who said: *"we notice that the intermediate level (e.g., the regional level) is rarely taken into account and that the multiscale analysis of the SDI ecosystem is poorly studied"*. However, most likely, the respondents in the case of [3,4] would have been largely coming from the first hierarchy.

A number of scholars have sought to link SDI usefulness to governance, economic development, social stability and multi-sectoral sustainable management of the environment [9,41,42]. Figure 1 has been configured to take into consideration the community strata as foundations upon which SDIOGI should be embedded. Therefore, SDI assessments must be undertaken following the SDIOGI methodology as promulgated in Tables 2 and 3 by corporates that are involved with it, to primarily determine their constraints, which can then be aggregated at the next level in a bottom-up approach. A threshold date of the first SDIOGI focused assessment has to be well documented and the next period of evaluation has to be specified with the exploitation and solution of the identified main constraint as the objective to successful implementation.

The body of literature on SDI started in early 2000 and it has been growing over the years. Thus, the already existing SDI assessments have to be critically analysed to extract new knowledge and build theory aimed at best practice. Through this paper, an attempt is made to create a ground for research dimensions that are going to embrace the TOC within SDI discourses and literature. As it has been argued, the TOC promotes the focus of challenges experienced by a process such as SDI and seeks to maximize solutions for improved implementation. While Tables 2 and 3 and Figure 1 could be appealing as proposed models of visualizing constraints within the SDI development environment, Figure 2 is designed to further entrench them by invoking the concepts of its temporality and cyclic nature. With Tables 2 and 3 and Figures 1 and 2, the SDI on-going improvement (SDIOGI) approach is proposed as a theoretical means to addressing, understanding, and solving the challenges associated with SDI implementation. The foregoing enforces the theoretical proposition: SDI assessments reveal the level of its constraint to performance, but its progression is as good as the main constraint.

Taking Figure 1 into consideration, the SDIOGI with its temporal connotations is summarized in Figure 2. What has to be noticed from Figure 2 is that SDI has to be defined within the confines of its hierarchy and its associated constraints. Once this is completed, an SDI operational structure, resource and performance requirements have to be drawn. Then, all of its constraints or limiting elements have to be identified with the objective of selecting what is known as the main constraint in the theory of constraints (TOC). The main constraint is prioritized as a solution for the optimization process of the SDI implementation or advancement. The other constraints are subordinated to the main constraint. All these are completed with a cyclic implementation period in mind, whereby at the end of the term, the SDI assessment is performed, and new frontiers of constraints are obtained. These new constraints are then subjected to the selection of the new main constraint and subordination of the others. This process has now become a permanent feature in SDI implementation processes. For this reason, it is termed the SDI on-going improvement (SDIOGI) approach. This optimization process can be performed within and across hierarchies as a response to the requirements of SDI.
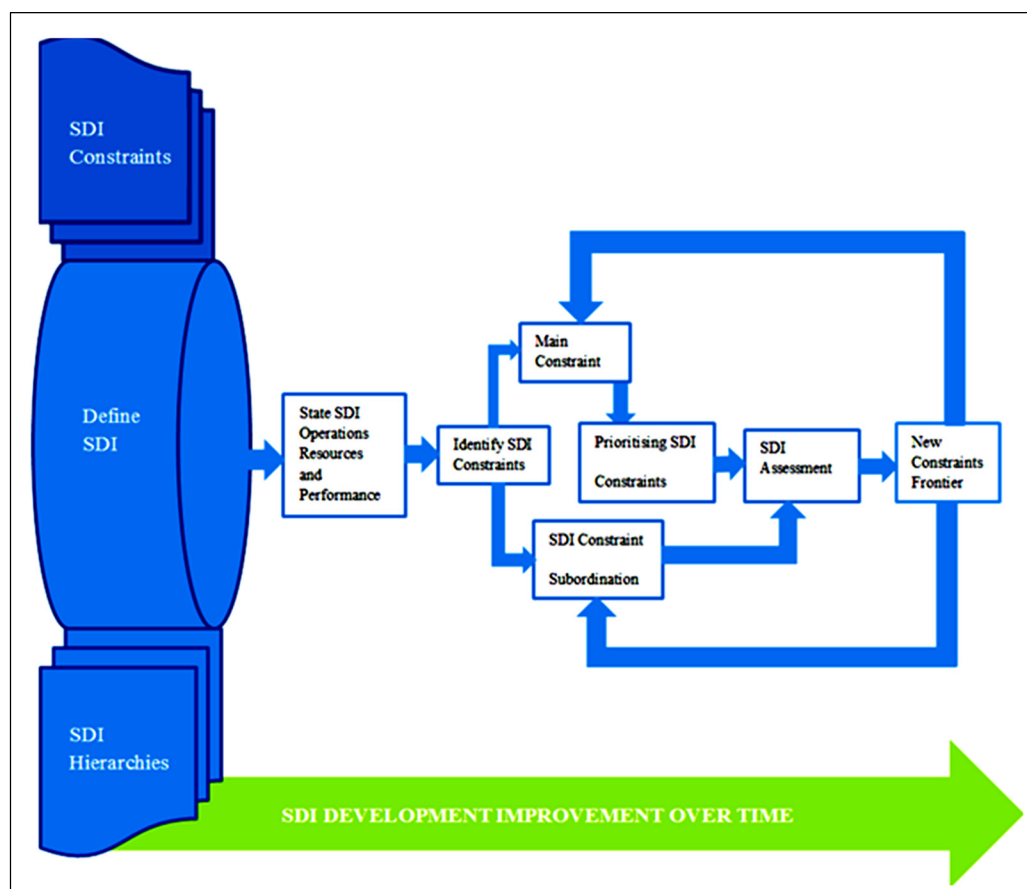
Figure 2. SDI temporal model.

Figure 2 has been designed to aid the graphic view of Tables 2 and 3 coupled with Figure 1. It has to be noted that in Figure 2, the definition of SDI is shown as a big drum that is home to ideas of developing or improving an SDI. On the one hand, this drum of ideas is surrounded by levels at which SDI events are occurring, and on the other hand by a bundle of constraints. This diagram then takes into consideration that organizations usually focus on resources and performance, and hence through this diagram, an emphasis is made that constraints must be identified and ordered into main and subordinate constraints irrespective of the SDI level. The main constraint is then prioritized for the solution. After some passage of time, SDI assessment is completed to evaluate and elevate the constraints. If the main constraint is indeed solved, new constraints are identified and the process of focusing is continued as a cyclic process. SDI implementers can set their implementation and assessment times as they see fit.

It has to be noted that this approach allows for different methods of SDI assessment in the whole cyclic phase of the SDI implementation process. Fundamentally, it is acknowledged that a thorough SDI assessment needs to be carried out within a jurisdiction to put all measurable constructs into proper country context. For example, if we consider a national SDI, it becomes apparent that constraints can directly emanate within participating institutions, and hence each participant has to look from within. However, that does not stop the national SDI from analysing their own constraints and aligning them with those of the corporates as depicted in Figure 1. The important part here is that constraints at the lower level will tend to affect the upper structure; hence, they must be identified, solved, and rationalized through the whole implementation process.

5. Conclusions

This paper took the route of grounding a constraint-based SDI development approach on existing assessments defined by their temporal executions and theoretically proposing that: SDI assessments reveal the level of its constraint to performance, but its progression is as good as the main constraint. A method to complete this was articulated in accordance with [21], called a systematic literature review, which led to a critical analysis of two SDI assessments by [3,4]. The constructs measured in these assessments were advanced within the context of the theory of constraints (TOC). Through this paper, it has been opined that the TOC can be applied to the implementation processes of SDI so as to map associated constraints and solve them in a prioritization sequence that solves main constraints. The approach suggested is largely a waterfall cyclic method, but it is considered to be robust enough to focus the SDI implementation process. This approach, if used, will tend to collate, and instigate a more purposive SDI implementation. With the ideas of [42] in mind, it is considered beneficial for this approach to be attempted within the context of countries such as Botswana, which have been struggling with the implementation of SDI. Though coined on the basis of results of the African experience, this approach can be adopted and adapted by any SDI nation anywhere across the world.

Abbreviations

The following abbreviations are used in this manuscript (in alphabetical order):

EAIM	enterprise architecture implementation methodology
SDI	spatial data infrastructure
SDIOGI	spatial data infrastructure on-going improvement
SLR	systematic literature review
TOC	theory of constraints

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