

## HOW RELEVANT IS THE IRON TRIANGLE AS A MEASURE OF CONSTRUCTION PROJECT PERFORMANCE

Ike Egboga<sup>1</sup> Cross Ogohi Daniel<sup>2</sup>

<sup>1</sup>Nile University of Nigeria, Abuja  
Department of Business Administration  
Email; [ikegboga@gmail.com](mailto:ikegboga@gmail.com)

<sup>2</sup>Nile University of Nigeria, Abuja  
Department of Business Administration  
Email: [danielcross@nileuniversity.edu.ng](mailto:danielcross@nileuniversity.edu.ng)

### Abstract

*The aim of this study was to carry out a systematic review of the iron triangle theory to determine, based on existing literature between the years 2000 – 2021 whether it is still relevant as a measure of construction projects performance. The study used SQAT (Systematic Quantitative Assessment Technique) to identify and review some peer reviewed journals, book chapters and conference materials published within the review period which examined the measures of measures of construction performance. The findings of the study were presented in date order in order to easily discern the trend of relevance of the performance measures over time. Based on the evidence obtained from the examined literature and the corresponding review as conducted thereon, this study concluded that the iron triangle components of time, cost and scope are still relevant measures of construction projects performance.*

**Keywords:** Iron triangle, Construction, Projects, Performance, Measures, Success

### INTRODUCTION

One of the principal activities that make a significant contribution to the Gross Domestic Product of various countries is infrastructural development (Amadi & Amadi, 2020; Babatunde, 2018). Infrastructural development involves construction projects which in turn plays a key role in boosting the economic growth of nations, revenue generation and employment creation for both developed and developing nations (Amadi & Amadi, 2020; Akinbile, Olutayo, Oni & Agboola,

2018). Construction demands the commitment of substantial sums of money. Consequently, reasonable efforts must be made to align the construction project team around common shared goals to ensure a successful performance of such projects in line with specified prior objectives relating to the needs and desire of the owner by (Yan, Elzarka, Gao, Zhang & Tang, 2019; Oke & Aigbovboa, 2017). Since a failed project would entail huge financial losses, it is imperative that every project should have effective performance indicators or measures that should be used to assess compliance with established project objectives set prior to commencement (Amos, Au-Yong & Musa, 2021; He, Wang, Chan & Xu, 2020; Leon, Osman, Georgy & Elsaid, 2018;). Such indicators will be useful in getting early warnings against potential project failure (Moradi, Ansari & Taherkhani, 2021; Leon et al, 2018).

## LITERATURE REVIEW

The performance of construction projects has been a subject of research by many scholars. Due to the increasing complexity and dynamic nature of projects, it is still difficult to determine the critical performance criteria that should be used to measure performance as there are divergent opinions (Moradi et al, 2021; Mellado, Lou & Becerra, 2020). One of the earliest conventional and dominating measure is the completion of the agreed work scope and specifications within the constraints of the contractually agreed cost and time (Mellado et al, 2020; Mohamud & Samson, 2020), famously referred to as “iron triangle”. The iron triangle also known as the triple constraint has been criticized by many researchers as basically quantitative and not non-exhaustive in its application (Moradi et al, 2021; HE et al, 2020 Chan & Adabre, 2019). They are of the opinion that projects performance could be better measured by other factors that are qualitative or soft in nature such as stakeholders satisfaction, safety and environment, sustainability, profitability etc (Moradi et al, 2021; Amos et al, 2021; Castro et al, 2020).

The iron triangle is a hard and quantifiable project performance measure as its technical criteria of scope; cost and time are all tangible, objective and easily measurable (Hughes et al, 2016). The success or failure of a construction project would depend to a large extent on how the project team could work effectively to reliably predict these criteria. An accurate and reliable prediction of the project status of the iron triangle components of work scope, cost and time as measures of project performance is critical for construction projects success as any variations in

one or more of the components is an effective early warning of potential problems (Moradi et al, 2021). Based on the forgoing, many scholars like Amos et al (2021), Mellado et al (2020), Zid et al (2020) and many others agree that the iron triangle is a clear and effective measure of project performance.

There are other schools of thought who are in disagreement with the iron triangle as an effective measure of project performance. The 1<sup>st</sup> group regards the iron triangle as merely a project management approach that will at best lead to project management success and not project success (Orihuela et al, 2017; Leon et al, 2017). In their opinion, meeting the constraints of scope, cost and time is a tactical but not strategic success as the later must be in alignment with the strategic objectives of the organization. The 2<sup>nd</sup> group regards the iron triangle as simply a measure of project management efficiency and an efficiently delivered project may not necessarily lead to the realization of benefits by the owners (Turner & Xue, 2018; Harrin, 2018; Oke & Aigbavboa, 2017). A 3<sup>rd</sup> group is partly in agreement with the iron triangle but includes stakeholder satisfaction, profitability, safety, environment, sustainability etc (Moradi et al, 2021; He et al, 2020; Castro et al, 2020; Yan et al, 2019).

We have seen from the different schools above that the iron triangle is a measure of project performance. However, there are divergent views regarding its appropriateness as a veritable measure of project performance. The divergent views are contemporary and still evolving. How relevant the iron triangle is as a measure of project performance is the central research question that this study seeks to answer. Accordingly, the objectives of this study are to review the evidences from existing literature linking the various critical success criteria to projects performance and to determine how relevant the completion of work scope to specifications within the cost and time estimates (the iron triangle) remains as a measure of construction projects performance. To arrive at the desired conclusion, 45 articles from journal publications, conference materials and book chapters relating to the triple constraints or iron triangle and projects performance or success were downloaded, reviewed and discussed. Based on the results of these reviews, the relevance of the iron triangle to construction projects performance was determined and used as a basis to conclude on the critical research question.

## **METHODOLOGY**

To be able to conduct an effective critical review, the “Systematic Quantitative Assessment Technique” (SQAT) which was developed by Pickering & Byrne (2013) was adopted. The SQAT uses a systematic approach in assessing papers that will be included in the critical review procedure. The objective, according to Pickering & Byrne (2013) is to maintain a very high quality of papers by concentrating only on peer reviewed journal publications. SQAT has generally been acknowledged to be logical, reliable, simple and an easy to replicate means of evaluating the prevailing status of a field of study (Pickering & Byrne, 2013).

Five important steps have been recommended by SQAT for conducting an effective critical review. Table 1 below gives a summary of the five steps and how they have been used in this study. It defines the topic of study, formulation of the central research question, identification of key words and the method for obtaining and assessing the relevant research materials to ensure that all potential biases are minimized by the application of these clearly defined steps.

Due to limitation on peer reviewed articles within the review period as regards the central research question, conference materials and book chapters from same data bases were included.

**Table 1: Application of SQAT**

S/N	Step	Application in this study
1	Define topic	The “iron triangle” and construction project performance
2	Formulate research question	One central research question: <i>How relevant is the “iron triangle” as a measure of construction project performance?</i>
3	Identify key words	Iron triangle, construction projects, performance, success
4	Identify and search data bases	<ol style="list-style-type: none"> <li>1. 12 data bases were used as follows: Emerald; Elsevier; Sage; Springer; Taylor &amp; Francis; Wiley, Cambridge; Jstor; Oxford; Inderscience; Ingenta and Heinonline journals</li> <li>2. “All in the title” search using “iron triangle” + “performance measurement”; “triple constraint” + “performance measurement”; “iron triangle” + “project execution” and “iron triangle” + “project success” from 2000 - 2021</li> </ol>
5	Read and assess article	Read the abstract of articles found from above search to ensure they are dealing with the iron triangle or triple constraint and construction projects performance or execution or success and then full text of article when necessary.

Also, a few peer reviewed articles from recognised construction and engineering journals outside the databases were included. The two journals used (Journal of Construction Engineering and Management and Journal of Management in Engineering) are all in top 5 ranking of construction management journals based on quality rating, research origins and circulation (Wang et al, 2020 & Chau, K.W., 1997). The outcome of the search is given in table 2 below. It shows for each data base, the number of publications accessed and the number of publications selected for review. The publications selected for review were further broken down into peer reviewed journals, conference materials and book chapters. A total of 1,314 publications were accessed and assessed. Based on content, 45 were selected for further detailed review.

**Table 2: Outcome of the search for articles**

Database	Materials accessed	Materials reviewed	Peer reviewed journals	Conference materials	Book chapters
Emerald	242	11	11	0	0
Elsevier	324	10	8	2	0
Sage	142	5	5	0	0
Springer	202	5	1	1	3
Taylor & Francis	52	1	1	0	0
Wiley	107	2	2	0	0
Cambridge	54	0	0	0	0
JSTOR	40	0	0	0	0
Oxford	42	1	1	0	0
Inderscience	57	4	4	0	0
Ingenta	0	0	0	0	0
Heinonline	52	0	0	0	0
Others		6	6	0	0
Total	1,314	45	39	3	3

*Others: Journal of Construction Engineering Management and Journal of Management in Engineering*

## DATA ANALYSIS

The first part of this section discusses the link between the iron triangle and construction projects performance based on the studies already conducted by scholars and their various opinions thereon. The second part is a presentation of the results of the current study identifying different measures from literature and the discussions thereon by this study. The output of these two parts

in combination provided the answer for this study on the central research question on how relevant the iron triangle is as a measure of construction project performance.

### **Linking the iron triangle to construction performance**

The iron triangle also known as the triple constraints as was developed by Barnes in 1967 for use in the measure of project performance. The three constraints each representing the vertex of a triangle are time, cost and scope / specifications of a project (Amos et al, 2021; Turner & Xue, 2018; Osei-Kyei & Chan, 2017; Albert et al, 2017 & Koops et al, 2016). Some authors prefer quality rather than scope / specifications as the third vertex of the triangle (Moradi et al, 2021; Mellado et al, 2020; Yan et al, 2019; Oyebisi et al, 201 & Chan & Adabre, 2018). However, this research has adopted the former as the third vertex given that quality is build into specifications. Some authors recognize the iron triangle as a clear and effective measure of performance (Amos et al, 2021; Mellado et al, 2020 & Zid et al, 2020).

However, many other authors have disagreed with the concept of the iron triangle as envisaged by Barnes. According to the 1<sup>st</sup> opposition group, the iron triangle measure is not enough and to its components of time, cost and scope should be added; client satisfaction (Mellado et al, 2020; Oyebisi et al, 2019; Adinyira et al, 2013 & Muller & Jugdev, 2012), Stakeholders satisfaction (Amos et al, 2021; Zid et al, 2020; Adabre & Chan, 2018; Orihuela et al, 2017 & Oke & Aigbavboa, 2017), profit (Mohamud & Samson, 2020; Castro et al, 2020; Yan et al, 2019; Harrin, 2018 & Wai et al, 2012). A 2<sup>nd</sup> opposition group believes that it is merely a measure of efficiency or project management success (Turner & Xue, 2018; Harrin, 2018; Oke & Aigbavboa, 2017). To this group, project success goes beyond meeting project scope within the agreed time and cost but must deliver satisfactory benefits or value that meets business or public needs.

### **Presentation of the results**

A lot of studies have been done regarding the iron triangle and project performance but there is no agreement on the extent of relevance of the iron triangle to construction projects performance. This study reviewed 45 (39 from specified databases and 6 from other popular construction management sources) on trending performance measures. The results of this study have been presented in table 3 below. The results have been arranged by authors in date order in order to properly shown the trend. The data base for each is shown in column 4 where others mean either

Journal of Construction engineering and Management or Journal of Management in Engineering). Nine (9) significant measures as identified by the various authors have been used and identified as A –I in columns 5 – 13 where: A = time; B = cost; C = scope / specifications; D = Quality; E = client satisfaction; F = stakeholders satisfaction; G = health, safety and environment (HSE); H = profitability, value / benefits and business success; I = sustainability. Finally, the location of study is indicated in column 14 and where no location is indicated means either a book chapter or results of literature review encompassing many locations. A tick of ‘x’ indicates author’s agreement with the particular measure as an indicator of performance.

**Table 3: Presentation of results**

S/ N	Author	Date	Data base	A	B	C	D	E	F	G	H	I	Location of study
	<b>Period 2000 - 2010</b>												
1	Shenhar et al	2001	Elsevier	x	x	x		x			x		Israel
2	Chan et al	2002	Others	x	x	x			x				-
3	Chan & Chan	2004	Emerald	x	x	x	x	x		x			HongKong
4	Norrie & Walker	2004	Sage	x	x		x				x		N/America
5	Bryde	2005	Wiley	x	x	x		x					UK
6	Bryde & Robinson	2005	Elsevier	x	x	x		x	x				UK
7	Kupakuwana & Berg	2005	Inderscience	x	x	x		x		x			-
8	Bryde & Wright	2007	Sage	x	x		x	x	x				UK
9	Lam et al	2007	Emerald	x	x	x	x						HongKong
10	Ahadzie et al	2008	Elsevier	x	x		x	x		x			Ghana
11	Bryde et al	2008	Springer	x	x		x	x					-
12	Lam et al	2008	Others	x	x	x	x						HongKong
13	Radujkovic et al	2010	Taylor & Francis	x	x		x	x					SE/Europe
14	Toor & Ogunlana	2010	Elsevier					x	x	x		x	Thailand
	<b>Period 2011 - 2021</b>												
15	Samiaah et al	2011	Elsevier	x	x		x	x	x		x		Malaysia
16	Muller & Jugdev	2012	Emerald	x	x	x		x			x		-
17	Wai et al	2012	Sage	x	x	x					x		Malaysia
18	Adinyira et al	2013	Springer	x	x		x	x		x			Ghana
19	Yeung et al	2013	Others	x	x	x	x	x	x	x			HongKong
20	Cullen & Parker	2015	Emerald	x	x	x	x						-
21	Ngacho & Das	2015	Inderscience	x	x		x			x			-
22	Williams et al	2015	Elsevier	x	x		x	x	x				N/America

23	Davis	2016	Elsevier	x	x		x	x	x				UK
24	Koops et al	2016	Elsevier	x	x	x			x	x	x		NW/Europe
25	Albert et al	2017	Emerald	x	x	x		x	x		x		-
26	Koops et al	2017	Emerald	x	x			x	x	x	x		Netherlands
27	Leon et al	2017	Others	x	x		x	x	x	x	x		-
28	Oke & Aigbavboa	2017	Springer	x	x	x	x		x	x	x	x	-
29	Orihuela et al	2017	Elsevier	x	x		x		x	x			-
30	Osei-Kyei & Chan	2017	Sage	x	x	x					x		Ghana / HK
31	Adabre & Chan	2018	Wiley	x	x	x	x		x	x		x	-
32	Harrin	2018	Oxford	x	x	x	x				x		-
33	Turner & Xue	2018	Emerald	x	x	x					x		Europe
34	Chan & Adabre	2019	Elsevier	x	x		x	x	x				-
35	Kissi et al	2019	Emerald			x					x		Ghana
36	Oyebisi et al	2019	Inderscience	x	x		x	x			x		Nigeria
37	Yan et al	2019	Others	x	x		x	x	x	x	x		China
38	Castro et al	2020	Emerald	x	x	x	x	x	x	x	x	x	Brazil
39	He et al	2020	Others	x	x	x	x	x	x	x	x	x	China
40	Khalife et al	2020	Emerald	x	x							x	-
41	Mellado et al	2020	Emerald	x	x		x	x			x	x	-
42	Mohamud & Samson	2020	Sage	x	x	x	x						Kenya
43	Zid et al	2020	Inderscience	x	x	x	x		x				-
44	Amos et al	2021	Springer	x	x	x			x	x			-
45	Moradi et al	2021	Springer	x	x		x	x	x	x	x	x	-
													-

Based on the above different schools of thought, we are discussing our findings in table 3 in chronological orders given that the opinions have tended to change with time and new measures are continually emerging with time also. We have, therefore grouped our findings into two distinct periods (2000 – 2010 and 2011 – 2021) to enable us determine the current trend and make possible projections.

### Period 2000 – 2010

During this 11 year period, only 14 publications were available from the chosen database. Out of the 14, 13 authors mentioned time and cost as measures of performance. Next to time and cost is client satisfaction (10) and closely followed by scope and quality (8 each). Stakeholders' satisfaction and health, safety / environment had 4 each while profitability / value / business



success had 2 and sustainability only 1. Worth mentioning is that only Toor & Ogunlana (2010) did not mention any component of the iron triangle as a measure but rather focused on satisfaction of clients and stakeholders as well as HSE. They made the only mention of sustainability as a measure in this period. It is clear from table 3 that in this review period; time, cost, scope, quality and client satisfaction were the predominant determinants or measures of construction projects performance. This finding is substantially in agreement with the position of the 1<sup>st</sup> school of thought that the iron triangle is not enough measure but must be complemented with both client satisfaction and the satisfaction of other stakeholders.

### **Period 2011 - 2021**

During this 2<sup>nd</sup> 11 year period, there were 31 publications from the chosen data base. This is significantly higher than the 14 in the prior 11 year period. This is because more interest has been kindled in the subject matter especially the emerging performance measures of health / safety / environment, profitability / value / business success and sustainability. Out of the 31 publications, 30 authors mentioned time and cost as performance measures. Next to time and cost is quality (21) followed by stakeholders' satisfaction (18). This is followed closely by scope and health / safety / environment (16 each). Client' satisfaction and profitability / value / business success comes next at 16 each while sustainability is 7. Unlike in the 1<sup>st</sup> period where time, cost, scope, quality and client's satisfaction were predominant measures; in this 2<sup>nd</sup> period stakeholder's satisfaction, health / safety / environment, profitability / value / business success have gained substantial prominence and ranks equally or slightly higher than client satisfaction as performance measures. Also sustainability is gradually gaining traction. Although mentioned only 7 during the period, this is substantially higher than the single mention in the prior period. Also all the 7 were recorded during the 2<sup>nd</sup> half of this review period (2017 – 2021) suggesting that the trend is northwards.

In terms of the relationship of the location of study to the above findings, there seems to be no such relationship as shown in table 3.

Based on the evidence provided by the results of this study in table 3 linking the iron triangle to construction project performance and the analyses for periods 1 and 2 above, it is evident that the iron triangle is still relevant in the determination of construction projects performance.

## CONCLUSION AND RECOMMENDATION

The relevance of the iron triangle of time, cost and scope as a relevant measure of construction projects performance has been adequately analysed in this study through the evidence from 45 published articles, conference materials and book chapters during the period 2000 to 2021. The evidences were grouped into nine (9) performance measures including the iron triangle of time, cost and scope in date order. The study was further divided into two groups from 2000 – 2010 and from 2011 – 2021.

The available evidence from this study demonstrates that there is no congruence yet on construction performance measures. However, the traditional iron triangle is still dominant and acceptable but not exhaustive as the performance measures have expanded beyond that to include other emerging indicators. Client satisfaction was a significant measure during the two periods of study in addition to the iron triangle. During the 2<sup>nd</sup> period of study, stakeholder satisfaction, health / safety / environment and profitability / value / business success also became significant measures. Also, in the 2<sup>nd</sup> half of the 2<sup>ne</sup> period of study, sustainability joined as a significant measure and trend seems northwards. Based on the foregoing, this study concluded that although there are other measures of construction performance, they are only complementary to the iron triangle and consequently, the iron triangle is still relevant as a measure of construction projects performance.

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