

RESEARCH IMPLICATIONS OF DATA AND THEORY TRIANGULATION IN OPERATIONS RESEARCH INVESTIGATIONS

NDU, EUGENE CHIGOZIE

DEPARTMENT OF HOSPITALITY MANAGEMENT AND TOURISM,
FACULTY OF MANAGEMENT SCIENCES, UNIVERSITY OF PORT HARCOURT

E-MAIL: reformation2021@gmail.com; eugene.ndu@uniport.edu.ng

AND

EKETU, CONTINUE ANDDISON (PhD)

DEPARTMENT OF HOSPITALITY MANAGEMENT AND TOURISM,
FACULTY OF MANAGEMENT SCIENCES, UNIVERSITY OF PORT HARCOURT

E-MAIL: eketuresearch@gmail.com

Abstract

This paper sought to establish and validate the research implications of data and theory triangulation in operations research (OR) investigations. Two research questions and hypotheses guided the study. Using the descriptive survey design, with triangulated methodologies (Data and Theory) and a sample of 32 OR lecturers, the study found that: both data and theory triangulations have significant and far-reaching research implications in OR investigations. Based on these, it was concluded that data and theory triangulations are effective tools for OR investigations; and that no research effort in OR is complete without a measure of data and theory triangulation. Although the study may have been limited by the relative small sample size used, it highlighted some implications. These include among other things that, there is need for a 'paradigm shift' from the 'hard core' quantitative lining of most OR investigators to a triangulated paradigm. Hence the study recommended that OR investigators should endeavour to apply data and theory triangulation in their research efforts; they should view and practice triangulation (Data and Theory) as a modern global approach to research; data and theory triangulation techniques should first be studied and understood before applying them so as to avoid the possible drawbacks of their wrong application.

Keywords: Cognitive Process, Fallibilism, Paradigm Shift, Research Methodology, Triangulation of Methodologies.

Introduction

Right from the cradle of civilization when man existed in pristine simplicity, the need to understand social phenomena and consequently explain them has been a daunting challenge. At first, man found solace in theological justifications; then metaphysical and currently scientific approach to social reality. Science, according to Sullivan (1992) cited in Asawo (2015), is a method of obtaining knowledge about the world through systematic observations. Scientific research according to him involves a rigorous process of data collection, systematic observation, analysis, and reporting. This gives rise to a systematic methodology in the conduct of scientific inquiry. Usually, one's philosophical suppositions about ontology and epistemology determine his

methodology in scientific research. Two basic philosophical assumptions exist. They are positivism which tilts towards the nomothetic methodology and largely relies on quantitative data; while the other is subjectivism which tilts towards ideographic methodology and largely depends on qualitative data (Flor, Gill & Johnson, 1991 cited in Asawo, 2015). Each of these approaches has its own merits and demerits; hence the need for **methodological triangulation** which entails combination of quantitative and qualitative methods in a single research. However, triangulation goes beyond its application to methodologies; and in a broad sense, refers to integrating numerous perspectives and approaches in one activity. Specifically, social scientists refer to it from the perspective of

combining two or more approaches (which may include methodology, theories, data sources, investigators etc.) in a particular study so as to converge on a single construct. It can be employed in both qualitative and quantitative studies.

In recent years, the combination of perspectives in a single study has received substantial support among researchers and scholars (Beitmayer, Ayres & Knafl, 1998; De Vos, 1998; Duffy, 1993; Jakob, 2001; Ndu, 2009 & 2012). Consequently, it has become not only fashionable, but a standard exercise to combine perspectives in administrative and behavioural studies. The origin of this act in the social sciences can be traced to the works of Campbell and Fiskel (1959), Web (1966) and later, Denzin (1970), whom it is believed extended its use beyond the conventional application to research methods and designs. Hence, different forms of triangulation exist – Theoretical triangulation, investigator triangulation, data triangulation, time triangulation, methodological triangulation, analysis triangulation, space triangulation, study setting triangulation etc. Each of these has its own advantages and disadvantages. However, it is believed that triangulation can help researchers overcome, or at least compensate for the inherent biases and challenges of the single approach method.

The operations research (OR) as a field or branch of the management practice “attempts to quantify some areas of management such as planning, decision making and control in the form of mathematical symbols and models” (Nwachukwu, 2009. p. 33). They rely heavily on the use of quantitative data and mathematical models for analysis and decision making. Hence, OR investigations are largely dependent on the use of quantitative techniques and analysis. They rely heavily on the use of quantitative data and mathematical models for analysis and decision making. Too much reliance on quantitative data and analysis in research processes often downplay the use of qualitative data or even ignore it totally. When this happens, research tends to be used as a mere validating activity

rather than a cognitive process. The resultant effect is that OR investigations become a mere academic exercise of playing the numbers rather than using it to solve societal problems. When numbers are played, there is a tendency to be “boxed-in” in old ideas rather than think outside the box and possibly develop new theories. This portends limitations and sundry biases on the efficacy of OR researches such as lack of originality, lack of credibility and reliable result / interpretation, lack of bonding with the research, dryness and absence of the touch of finesse etc. These notwithstanding, OR practitioners sometimes use theories and qualitative data to explain concepts before resolving them into quantitative analysis. Thus, the use of both quantitative and qualitative approaches (triangulation) in OR investigations is not exactly new; even though some researchers may be opposed to the idea.

It was observed earlier that there are different types of triangulation; but for the purpose of this study, triangulation in OR investigations were limited to data and theory triangulation. Consequently, the purpose of this study was to ascertain, validate and highlight the research implications of data and theory triangulation; as it applies to operations research investigations. Specifically, the study sought to ascertain if data triangulation has research implications in OR investigations; and if theory triangulation has research implications in OR investigations. The study asked and answered two research questions; as well as stated and tested two hypotheses. These are:

Research question 1: Does data triangulation impact on the efficacy of research in OR investigations?

Research question 2: Does theory triangulation impact on the efficacy of research in OR investigations?

Hypothesis 1: Data triangulation has no significant impact on the efficacy of research in OR investigations.

Hypothesis 2: Theory triangulation has no significant impact on the efficacy of research in OR investigations.

It is expected that by pointing out the lopsided nature of single-source and single-theory researches; this study will demonstrate the need for data and theory triangulation in OR investigations. It will encourage OR practitioners to balance and validate their findings by triangulating data and theory. This will help to increase the credibility, acceptability, reliability and applicability of their research findings. However, this study may have been limited by the relatively small sample size used. The study proceeded by reviewing the theories of 'data' and 'theory' triangulation as it applies to OR investigations. The construct of triangulation was x-rayed; pointing out the different approaches to triangulation, their usefulness and inherent challenges in applying them. In terms of methodology, the study combined both 'within-method' and 'between-method' paradigms to generate data for the analysis. This formed the bases for the analysis and findings of the study. Furthermore, the findings were subjected to detailed discussions; with the implications highlighted. Consequently, conclusions were drawn with far-reaching recommendations made.

Literature Review

Theoretical Framework

Theories that debate on the combination of methods of research can be traced to arguments about the application of 'survey' and 'fieldwork' or 'interviews' and 'participant' observation. Thus, two distinct and apparently opposing schools of thought exist (Kohlbacher, 2005); with a third one having emerged as a middle ground between the two. The first is the **quantitative school** which Kohlbacher calls the 'QUANs', emanating from a nomothetic paradigm; with belief in empirical methodology (empiricism) to research process. They rely heavily on the use of quantitative tools and techniques as a proof of their scientific method of inquiry. They seem not to pay serious attention to qualitative data as it appears not to validate their findings. To them,

research is about validation and not essentially a cognitive process. The second is the **qualitative school** which she calls the 'QUALs', lining on the ideographic paradigm; they rely heavily on the use of theories, observation and case studies to arrive at logical conclusions. To them, research is a cognitive process deepened in social phenomena that are largely unpredictable. Debate for and against the appropriateness of each of these methods in social research is still on-going; and there seem not to be an end in view. In fact, scholars admit that heated discussions, and what is often referred to as 'paradigm war' (Kohlbacher) exist between the adherents of the two schools – the 'QUANs' and the 'QUALs' (Brannen, 1992, pp.3-5; Bryman, 2004, pp. 452-454; Hammersley, 1992, pp. 39-41; Kohlbacher, 2005; Tashakkori & Teddlie, 1998, pp.3-13). A major feature of this argument appears to be in the divided way in which the quantitative and qualitative paradigms of research were showcased; as well as the resultant stern divergent logics of the two. Consequently, controversy has trailed the application of one type of method or the other; while personal philosophies have largely been responsible for the choice of method. The resultant effect is the favouring of a particular type of method by certain schools of thought in each discipline and disparaging the other as well as their proponents.

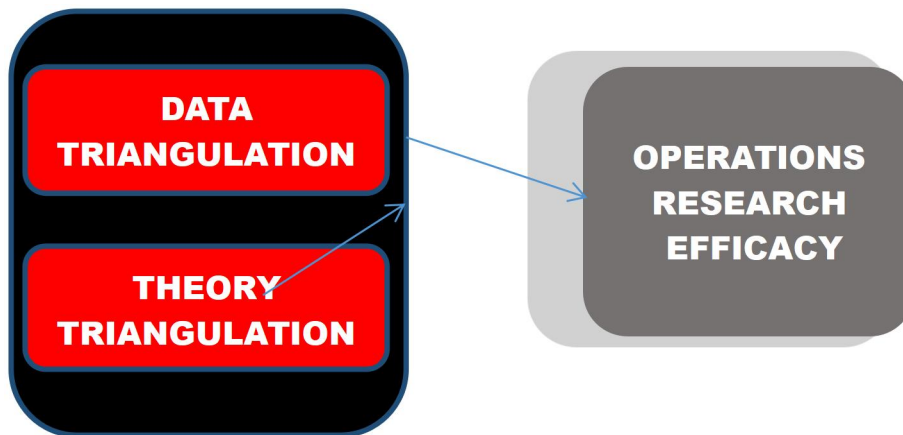
Obviously, there are inherent challenges with each of these approaches; hence the need for a new school of thought – the '**mixed-method**' (triangulation) **school**; which I have called the 'QUANTIQUALs'. Some mixed views have trailed the practice of combining methods in studies. For instance, Olsen (2004) opined that the argument put forward for triangulation by some authors merely serves the purpose of growing and deepening the knowledge of the phenomenology. Others like Webb et al (1966), Campbell (1966), Smith & Kleine (1986) and Denzin (1978) are of the view that triangulation can be used to improve on the accurateness of a research; hence it can be used as a measure of validity. Another criticism of the combination of both methods in a single

research is based on the argument that the two methods differ from each other both ontologically and epistemologically (Hunt cited in Yeasmin & Rahman, 2012). These arguments do not hold sway as they are based on a lopsided understanding of the theory. Moreso later propositions by Denzin (1978) and Campbell (1956 & 1966) defeat the essence of their arguments. These arguments notwithstanding, the

triangulation paradigm has received wide acceptance and support from several scholars (Blaikie, 1991; Diesing, 1971; Hales, 2010; King & Ehiers, 2004; Kohbacher, 2005; Jick, 1979; Sieber, 1973; Smith, 1975; Webb et al., 1966; Ziyen, King & Ehiers, 2004). It is based on the theoretical ideology of this triangulation school that this study was attempted.

Conceptual Framework

Fig.1: Conceptual Framework of Data and Theory Triangulation and the Efficacy of Operations Research Investigations.



Source: Adapted from Ziyen, King and Ehiers (2004); Denzin (1970); Downward and Mearman (2008).

From figure 1 above, it could be seen that data and theory triangulation is capable of having a direct impact on the efficacy of operations research investigations. This is evidenced in the direct arrow lines. Some of the authors who share the same views and form the contributing source to the model are Ziyen, King and Ehiers (2004); Denzin (1970); Downward and Mearman (2008). From this model, hypothesized relationship was subjected to statistical testing.

The Concept of Triangulation

Researchers do not know the exact origins of triangulation. However, speculations are that antediluvian Egypt and Greece practiced it widely in early civilizations. As an applied concept, it has come to be associated with maritime navigations, surveying and civil engineering. The

basic principle being that when measurements are taken from two different positions, they can be used to predict or derive a third position or measurement (Downward & Mearman, 2008). This same triangulation principle is what is being replicated in the Global Positioning System (GPS) technology. According to Hales (2010), a GPS receiver is able to process and determine longitude, latitude and altitude by processing radio signals sent from four distinct satellites. Hales maintained that this same result can be obtained from the signals of three satellites; however, for the purpose of improving the precision of the result, four are usually used. Given these basic principles of geometry which Smith (1975) refers to as 'the triangulation metaphor', several perspectives make for greater accuracy. In the

same vein, social and behavioural scientists can improve the quality of their results by gathering different types of data that relate to their subject of interest.

On a general note, triangulation involves the combination of several insights or viewpoints in a single research or investigation. Different authors have defined it from different perspectives. For instance, Denzin, (1978, p. 291) sees it as "the combination of methodologies in the study of the same phenomenon". To Cohen and Manion (2000), it is an attempt to vividly explain the richness and complex nature of the behavior of humans by studying it from different viewpoints. It can also be seen as a way of verifying data from different sources in order to find out the uniformities in such data (O'Donoghue & Punch, 2003). To Audrey (2013) cited in Wikipedia (2015), triangulation equally validates or substantiates information so as to produce precise and reliable results based on the certainty and accurateness of data collection. Whereas Altrichter, Feldman, Posch. & Somekh (2008) argue that with triangulation, a more comprehensive and balanced view of the situation is seen. The efforts of these scholars at defining triangulation are quite commendable. However, these simple definitions mask a range of its meanings and uses; hence the need for a broader definition such as captured by Yeasmin and Rahman (2012, p.156). According to them, triangulation entails the incorporation of several viewpoints and methods in a verification process so as to increase validity. It involves the combination of two or more methods, theories, data sources or even investigators in the study of a single phenomenon so as to agree on a single construct; and can be used in both quantitative (validation) and qualitative (inquiry) researches.

This definition did not only capture the main essence of triangulation, but also identified the different types of triangulation. For this reason and for the purpose of our study, this definition by Yeasmin and Rahman will be used as the working definition of triangulation throughout this study.

Types of Triangulation

There are different categorizations of triangulation approaches. Ziyen, King and Ehlers (2004) identified seven categorizations to include data, investigator, space, time, methodological, theory and analysis triangulations. Other categorizations may include study-setting triangulation, observer / respondent triangulation etc. However, Denzin (1970) presented four different types of triangulation which has been widely accepted. They include **data triangulation** (combining different sets and types of data from several sources so as to form a single body of data), **investigator triangulation** (combining multiple insights from different observers on a subject matter in generating and interpreting data instead of that of a single observer), **theoretical triangulation** (interpreting data from more than one theoretical position) and **methodological triangulation** (the use of more than one research methods or data collection technique in a single research). According to Yeasmin & Rahman, methodological 'triangulation' denotes the most commonly understood meaning of the term among the four approaches. None of these methods is superior to each other, it is the purpose of a study that determines the type of triangulation to be chosen; and two or more triangulation types can be used in one study. The main idea is to compensate for the inherent shortcomings of chosen methods as each of them obviously has its own strengths and weaknesses. The rest of the discourse is centred on data and theory triangulation because they form the main thrust of this research. Hence, a closer look at them is pertinent.

Data Triangulation (DT)

DT according to Cohen & Manion (1997) and De Vos (1998) entails the collection of data from several sources so as to get the different views of the phenomenon being studied in order to enhance the validity. Banister, Burman, Parker, Taylor and Tindall (1994: 146), opined that DT entails collecting accounts from diverse participants in a given setting, as well as from different phases in the activities of the setting; and if suitable, the sites of the setting should equally

be different. To Guba and Lincoln (1989) and Patton (1990), it also involves double-checking the constancy or reliability of specific and factual items of data from several sources through the use of multiple methods at different times. Usually, when different sets / types of data are combined in a particular study, we say DT has occurred. A typical example is the use of survey data alongside time series data. Downward and Mearman upheld that data could be spatially or temporally differentiated. In other words, a person's insights at different times could be triangulated so as to infer on the entire time period. On the hand, different persons could be questioned once, but at differing times. For instance, survey and interview data could be combined. However, certain rules guide the combination and integration of data from different sources. For instance, Moran-Ellis et al (2006) cautioned that it is only at the analysis stage that data from different sources can be integrated. While Denzin (1978) observed that data triangulation can be within-method or between-methods.

Strengths and Weaknesses of Data Triangulation

A major benefit of data triangulation lies in its use to generate much data for a study; which Wray, Markovic and Manderson (2007) refer to as 'data saturation'. Other benefits of data triangulation according to Hales (2010) include the fact that findings from other sources methods, theories and investigators can be used to confirm findings in a particular study. According to him, comparing and contrasting different views / findings on a particular situation / phenomenon can be quite effective in finding the inconsistencies in data as well as provide opportunities for further research. He further posits that DT can be used to reinforce the validity and reliability of a research finding; thereby making it very easy to explain and justify such findings. It can also be used to generate new insights into a given situation by providing a more complete and comprehensive perspective on that situation.

The possible weaknesses of data triangulation seem to be associated with the quality and quantity of the data. For instance, when the data used is too few, the triangulation process will most likely produce meaningless results. Moreover, poor quality data in triangulation can totally undermine the usefulness of the process (Hales). Data triangulation may also pose serious problems if qualitative data are analysed quantitatively. A better way of handling such situation is to give qualitative data codes that will help in making them compatible with quantitative results. However, this too can produce false results; giving rise to misleading analysis capable of jeopardizing the conclusions.

Theory Triangulation

This entails using more than one theory or hypothesis in the course of examining and analysing a phenomenon (Denzin). The underlying idea is to look at the situation from several and differing viewpoints so as to obtain satisfactory answers to enquiries in the mind. According to Hales, the more divergent the theories are, the more likely they are to identify different issues and / or concerns. Hence, they do not have to be similar or compatible.

Strengths and Weaknesses of Theory Triangulation

One major advantage of theory triangulation is its ability to further probe research findings. It increases the explanations for observed phenomenon. In the words of Wray, Markovic and Manderson, it helps to achieve the development of grounded theory. According to Hales, the use of only one theory is capable of reducing the number of alternative explanations that can be given for a particular situation or phenomenon. In fact, he espoused that using several or even differing theories / hypotheses is capable of challenging analysts to go beyond obvious explanations to find better and sharper ways of probing and elucidating findings.

In spite of these benefits of theory triangulation, certain drawbacks have come to be associated with it. First, the use of theories / hypotheses that are not well defined in theoretical

triangulation can be confusing and may lead to unproductive results (Hales). More so, using opposing theories / hypotheses in triangulation could as well be confusing and unproductive. These weaknesses are rather cautionary to analysts and more specifically to OR investigators who do not rely much on theorizations. It should be noted that the credibility of findings do not lie automatically on the fact that they are supported by theories.

Methodology

The descriptive survey design was adopted for this study. The study utilised both the quantitative and qualitative approaches to research methods; thereby guaranteeing methodological triangulation. The qualitative approach was used to gain useful insights into the data and theory triangulation practices of OR investigators. It involved formal and informal interviews of these investigators with a view to understanding their perception and application of triangulation techniques. These insights were used to formulate an instrument for the quantitative analysis. This integration of research methods was utilised in order to expand the understanding of the scope of data and theory triangulation in OR investigations and increase confidence when results are generalised (Mitchel 1986).

The study population comprised 32 OR lecturers in higher institutions in Rivers State (this was based on personal findings of the researcher and are distributed as follows: University of Port Harcourt – 12; Rivers State University of Science and Technology – 8; Rivers State Polytechnic – 6; Ignatius Ajuru University of Education – 4). Since this is a relatively small sample size, all the sample units were considered in the sampling. Data was collected from the primary source using a questionnaire designed by the researchers; and from the secondary source using available published articles on the subject matter, thus guaranteeing between-method data triangulation. The instrument was validated both at the face and content levels through constructive inputs of

triangulation and OR experts. While its reliability was ascertained through the test-retest method at a stability level of 0.78; using the Pearson's Product Moment Correlation technique. The instrument was structured to generate both quantitative and qualitative data thus guaranteeing within- method triangulation. Questions for eliciting quantitative data were structured with responses in a 5 point Likert-like scale measured as follows: Great extent (G) - 5, Considerable extent (C) - 4, Moderate extent (M) - 3, Low extent (L) – 2, and Not at all (N) – 1. While that for qualitative data was structured as open ended questions to enable the respondents comment freely on the questions.

Operational Measures of the Variables

Data triangulation was operationalized using a four item scale; by asking such questions as “I usually combine data from both the primary and secondary sources in my investigations” “When I questionnaires in my investigations, they are usually designed to generate use both qualitative and quantitative data”. Theory triangulation was operationalized using a four item scale that asked such questions as “I usually combine different theories in a single research so as to give a clearer picture of the phenomenon being discussed” “I use theories to buttress my quantitative results”. Operations research efficacy was equally operationalized by a four item scale which asked such questions as “My OR investigations are usually depict a convergence of data and theory triangulation that validate my results and make my findings reliable”, “My OR investigations show different viewpoints which help to bring out the beauty of my research findings”. These scales where validated using factor analysis which showed a score of 0.78 and above for all the items (Nunnally, 1978; Muldoon, Barger, Flory & Maruck., 1998; Rossi, 2009).

Data Analysis Technique

The percentage analysis technique was used to analyze the data that was generated and answer the research questions. While the Spearman's rank order correlation (Rho), which is a non-parametric test, was used in testing the hypotheses at a significant level of 0.05. The

quantitative aspect of the observed variables which were measured in ordinal scales made the data suitable for the requisite correlation; as well as the confirmatory tests for normality, linearity and homoscedasticity (Pallant, 2013; Tabachnick & Fidell, 1996). The Statistical Package for Social Scientists (21.0) aided the analysis.

Analysis and Results

A total of thirty two questionnaires were administered out of which twenty-eight were responded and returned; giving rise to a response rate of 80.50%. Out of this number, only twenty-

five were found to be valid for the analyses. This resulted to 78.125% valid response rate. Consequently, the number of responded questionnaires used for analysis was twenty-five. The results have been set out below.

Research Question 1: Does data triangulation impact on the efficacy of research in OR investigations?

The answer to this research question has been shown in table 1 below. For the purpose of the analysis, only 'Great' and 'Considerable' extents were accepted as applicable.

Table 1: Percentage Responses on Data Triangulation

| Decision | Frequency | Percent | Valid Percent | Cumulative Percent |
|---------------------|-----------|---------|---------------|--------------------|
| Great Extent | 18 | 72.0 | 72.0 | 72.0 |
| Considerable Extent | 5 | 20.0 | 20.0 | 92.0 |
| Moderate Extent | 2 | 8.0 | 8.0 | 100.0 |
| Low Extent | 0 | 0 | 0 | 100.0 |
| Not at all | 0 | 0 | 0 | 100.0 |
| Total | 25 | 100.0 | 100.0 | |

Source: Survey Data, 2015

Table 1 showed that out of the 25 respondents, 18 representing 72.0% answered to a great extent; 5 representing 20% answered to a considerable extent; 2 representing 8% answered to a moderate extent; while no respondent answered to a 'Low extent' or 'Not at all'. This means that 92% (23 respondents) agree that data triangulation has research implications in OR investigations. Further analysis showed the following as applicable implications of data triangulation in OR investigations: Improves the quality of research findings; gives a balanced view

of respondents' responses; validates respondents' responses; compensates for the inherent challenges in generating data only quantitatively or qualitatively; increases the researcher's confidence in the result of data analysis; increases the credibility of research efforts and findings.

Research Question 2: Does theory triangulation impact on the efficacy of research in OR investigations?

The response to this research question has been shown on table 2 below.

Table 2: Percentage Responses on Theory Triangulation

| Decision | Frequency | Percent | Valid Percent | Cumulative Percent |
|---------------------|-----------|---------|---------------|--------------------|
| Great Extent | 14 | 56.0 | 56.0 | 56.0 |
| Considerable Extent | 6 | 24.0 | 24.0 | 80.0 |
| Moderate Extent | 5 | 20.0 | 20.0 | 100.0 |
| Low Extent | 0 | 0 | 0 | 100.0 |
| Not at all | 0 | 0 | 0 | 100.0 |
| Total | 25 | 100.0 | 100.0 | |

Source: Survey Data, 2015

It could be seen from table 2 above that out of the 25 respondents, 14 representing 56% answered to a great extent; 6 representing 24% answered to a considerable extent; 5 representing 20% answered to a moderate extent; while no respondent answered to a 'Low extent' or 'Not at all'. This result showed that 80% (20 respondents) agree that data triangulation has research implications in OR investigations. Further analysis showed the following as applicable implications of theory triangulation in OR investigations: It gives a balanced view of the construct under investigation; brings out the different sides to an argument or discourse; helps the researcher in forming his

opinion on the matter or construct being investigated; helps in conviction of theoretical position; aids in discussing research findings; provides theoretical support for or against research findings; helps in identifying gaps in literature and areas for further studies.

Testing of Research Hypotheses

H₀₁: Data triangulation has no significant impact on the efficacy of research in OR investigations.

This hypothesis was tested using the aggregated scores for data triangulation and OR investigations. The result has been shown in table 3 below.

Table 3: Correlation of Data Triangulation (D.T) and OR Investigations

| Correlations | | | Data Triangulation | OR Investigations |
|----------------|--------------------|-------------------------|--------------------|-------------------|
| Spearman's rho | Data Triangulation | Correlation Coefficient | 1.000 | .882** |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 25 | 25 |
| | OR Investigations | Correlation Coefficient | .882** | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 25 | 25 |

** . Correlation is significant at the 0.01 level (2-tailed).

Source: Survey Report, 2015.

It could be seen from table 3 above that rho = 0.882 and P = 0.000. Since P < 0.05, the correlation is significant at the 0.05 level. Consequently, the null hypothesis of no relationship was rejected. The researchers therefore state that data triangulation has

significant impact on the efficacy of research in operations research investigations.

H₀₂: Theory triangulation has no significant impact on the efficacy of research in operations research investigations.

The result for this analysis has been shown in table 4 below.

Table 4: Correlation of Theory Triangulation (T.T) and OR Investigations

| Correlations | | | Theory Triangulation | OR Investigations |
|----------------|----------------------|-------------------------|----------------------|-------------------|
| Spearman's rho | Theory Triangulation | Correlation Coefficient | 1.000 | .811** |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 25 | 25 |
| | OR Investigations | Correlation Coefficient | .811** | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 25 | 25 |

** . Correlation is significant at the 0.01 level (2-tailed).

Source: Survey Report, 2015.

As can be seen from table 4 the result showed a high direct and significant relationship ($r = 0.811$ and $P = 0.000$). Since P is < 0.05 , the correlation is significant at the 0.05 level of significance. Consequently, the null hypothesis of no relationship was rejected. We therefore state that theory triangulation has a significant impact on the efficacy of research in operations research investigations.

Discussions

The result of the analysis of hypothesis one which showed that there is a high significant impact of data triangulation on the efficacy of research in OR investigations, is not surprising at all. Support for it was found in the works of Cohen and Manion (1997), De Vos, (1998), Ziyen, King and Ehlers (2004). Some of the reasons for and implications of this finding as advocated by the respondents include the point that by triangulating data, it helps to validate respondents' responses. It stems from the fact that since it presents similar or same questions from different perspectives, it ostensibly increases the validity and reliability of the data (Hales, 2010; Holtzhausen, 2001; Kohlacher, 2005; Yeasmin & Rahman, 2012). Respondents equally stated that data triangulation helps them compensate for the inherent weaknesses in using data only from the quantitative or qualitative perspective (Holtzhausen, 2001; Jakob, 2001; Kohlacher, 2005). The researcher was particularly enthused to find that OR investigators agree that they rely heavily on the use of quantitative tools, techniques and data in their researches; but that these could be misleading in the sense that it does not bring out the clearer picture of the social phenomena being investigated. So to them, qualitative data captures that essence and compliments their quantitative techniques. This was particularly corroborated by Downward and Mearman, (2008), who in their study 'Decision-Making at the Bank of England: A critical Appraisal' found that the bank triangulated among other reasons, for data inadequacy. Reiss cited in Jick, (1979), also supported this, when he admonished that

quantitative-oriented researchers are encouraged to exploit "the potentialities of social observation". Other reasons and implications for this finding are that data triangulation increases the confidence of OR investigators in their results, (Blaikie, 1979; Hammersly, 1992); and the acceptability of their findings (Holtzhausen, 2001; Kohlacher, 2005). It equally increases the credibility of their research efforts (Jakob, 2001; Hales, 2010; Kohlacher, 2005; Olsen, 2004) and improves the quality of their research (Bryman, 2004; De Vos, 1998; Smith, 1975).

The result of the analysis of the second hypothesis which showed that there is a high significant research impact of theory triangulation in the efficacy of research in OR investigations is equally not surprising. It stems from the fact that there are ample evidence and support for it in the literature. Firstly, respondents revealed that by bringing out the different viewpoints of a theory it gives them a balanced view of the construct / phenomenon under investigation. This was corroborated by Altrichter, Feldman, Posch & Somekh (2008) who argued that "triangulation gives a more detailed and balanced picture of the situation." Equally supportive was Downward and Mearman when they argued that one of the reasons for theory triangulation is to obtain a balanced view of the matter being investigated. Apart from this, respondents equally pointed out that theory triangulation helps one to form his opinion in OR investigations (Bryman, 2004; Smith & Klein, 1980); aids and provides basis for discussing OR research findings (Hammersly, 1992; Altrichter et al, 2008); and provides theoretical support for or against OR findings (Bryman, 2004; Olsen, 2004). Other implications of this finding as captured from interview sessions with some of the respondents which may explain this result is that it serves a confirmatory purpose (Hales, 2010; Shih, 1998); helps in identifying gaps in literature and hence, point out opportunities for further studies (Hales, 2010).

Research Implications of Data and Theory Triangulation in OR Investigations

The findings of this study may have been limited by the relative small sample size used and the study setting. Nevertheless, it is evident from the foregoing discourse on the findings of the study that it has far-reaching research implications in OR investigations. For the purposes of clarity, I have discussed them below under certain captions; which are by no means exhaustive. But before delving into that, a concise recapitulation of the intricacies of investigations in the operations research domain will help in appreciating these implications.

Operations Research (OR) is a discipline that deals with the application of advanced analytical methods to help make better decisions (British Operations Research Society). It is often considered to be a sub-field of mathematics (American Mathematics Society). As a field of management enquiry, OR draws techniques from other mathematical sciences, such as mathematical modelling, statistical analysis, and mathematical optimization, in order to arrive at optimum or near-optimum solutions to complex decision-making problems. OR often overlaps with other disciplines like industrial engineering and operations management, and equally draws on psychology and social sciences. A major thrust of this discipline is optimization; which is concerned with ascertaining maximum profit / performance / yield or minimum cost / loss / risk of some businesses and real-world objectives. These features of the OR discipline makes it rely more on quantitative data than qualitative data thereby making investigators in OR tilt towards the positivist philosophical underpinnings. And this might lead to a relative lack of triangulation (Frankfort-Nachmias & Nachmias, 1996). Again, sophisticated developments of regression analysis which is widely used by OR experts, tend to reinforce their claimed analogy to controlled experiments. This is capable of strengthening the widely held notion that some types of research methods essentially have greater statistical power, thus diminishing the need for triangulation. Consequently, most OR investigators rarely triangulate data and theory in their investigations. And even when they do so, they approach it from

the viewpoint of a necessary academic ritual rather than as a globally accepted research standard.

It was established earlier that data and theory triangulation provides researchers with several important opportunities. One of which is that it allows researchers to be more confident of their results stimulating the creation of inventive methods and new ways of capturing a problem (Jick, 1979). This portends certain research implications. First, is the need for a '**paradigm shift**' from the 'hard core' stance of quantitative or qualitative approach to a more flexible stance of triangulation. The resultant effect will be enhanced ability to 'think outside the box' and use research to proffer lasting solutions to societal challenges rather than the usual academic rigor of 'playing the numbers'. Consequently, OR experts who refuse to adopt this paradigm will be left to the old ways of doing research which does not leave much to be desired.

Second, is the need for OR investigators to use research as a **cognitive process** rather than a mere validating process (Kohlbacher, 2005). When OR experts play the numbers, they are simply trying to validate the process or best still, provide proof for the result rather than establishing why the result may not have been as expected. At the end, nothing new is learnt. This obviously is uninteresting and limits the purpose of research. When method / data is triangulated, Jick posits that it may help to reveal deviant dimensions of a phenomenon as well as act as the critical test (due to its comprehensiveness), for opposing theories. This eventually stimulates learning and most likely lead to new knowledge acquisition; or reinforces what is already known.

Third is the appeal to the theory of '**fallibilism**' which is a concept used to describe the belief that nothing is perfect (Downward & Mearman, 2008). Fallibilists believe that there is always a down side to everything; hence it is important to view things from multiple perspectives. Thus by minimizing the inadequacies of single-source research, triangulation spells out the need for OR investigators to triangulate their data and theory for a more credible and reliable

result/interpretation. It stems from the fact that two or more sources complement and validate one another; thereby reducing the impact of bias and provide a richer and more inclusive information.

Fourth is the **imperative for new theory development**. In the hard sciences where OR draws its strength from, there is a seeming belief that there are no more new theories to be developed. Consequently, most of their researches seek to justify existing theories or use them to validate their findings. Contrary to this, the use of multi-methods can also lead to a synthesis or integration of theories (which is the major thrust of theory triangulation); which is capable of producing new theories. Hence triangulation beckons on an OR investigator to be open to new theory development as it is possible with the triangulation paradigm.

Fifth is the **imperative for originality and bonding**. Since there are no spelt out combinations in triangulation, when a researcher triangulates (especially, data and/or theory), he is more likely to own the method and even the process; thus guaranteeing originality, which is a vital requirement in research. Sequel to this is the possibility of bonding (personal attachment) with the study elements. Jick (1979) confirmed this when he espoused that qualitative methods in triangulation play the likely role of helping the researcher sustain a gainful closeness to the study situation thereby allowing for greater sensitivity to the several data sources.

Sixth is a **touch of finesse**. Quantitative literature is often characterized by dryness (Mac'Odo, 2005) especially to the consumer of its information. The use of theory triangulation beautifies and brings out the beauty of findings making it easily readable and appreciated. In support for this, Jick advocated that qualitative data and the attendant analysis act as the gum that cements the interpretation of multi-method findings. According to him, in one respect, qualitative data can be used as the critical counterpoint to quantitative methods; and "in another respect, the analysis benefits from the perceptions drawn from personal experiences and first-hand observations. Thus enters the artful

researcher who uses the qualitative data to enrich and brighten the portrait".

Conclusions

This study which sought to establish and validate the research implications of data and theory triangulation in OR investigations drew from the origin and meaning of the word 'triangulation' (combination of two or more methods; usually quantitative and qualitative in a single research to describe an observed phenomenon), to establish that there are different types of triangulation; but that four are more generally recognized – methodological, investigator, data and theory (Denzine, 1978). Out of these four, the study x-rayed data and theory triangulations; bringing out their strengths and weaknesses. Using the descriptive survey design and a sample of 32 OR lecturers drawn from higher institutions in Rivers State for analysis, the study found that both data and theory triangulations have significant and far-reaching research implications in OR investigations. Based on these, it was concluded that data and theory triangulation are effective tools for OR investigations. It stems from the fact that it validates research findings; thus giving it credibility and reliability. It compensates for, and complements the inherent weaknesses in the utilization of single methods. By reinforcing the investigators confidence in the research process, it boosts his confidence in his research ability thereby encouraging more efforts. It positions research as cognitive process and not just a mere validating exercise. This breeds the discovery of new knowledge or at least reinforces what is known. It creates a richer picture of research findings in OR which according to Mac'Odo are often characterized by 'dryness'. In fact, as a result of these research findings and conclusions, it is safe to state that "no research effort in OR is complete without a measure of data and theory triangulation"

RECOMMENDATIONS

Considering what has been espoused so far, it is believed that implementation of the following recommendations will help drive home the message of this study.

1. OR investigators should endeavour to apply data and theory triangulation in their research efforts. This it is hoped will help them reap the benefits of triangulation marshalled out in this study.
2. They should view and practice triangulation (Data and Theory) as a modern global approach to research and not perhaps as a required ritual of academic investigations. This it is believed will help them appreciate, use and internalize the concept.
3. Drawing from the concept of 'fallibilism' discussed in this work, the triangulation paradigm can be extended to every facet of social observation and human endeavour. It brings out a better and balanced view of every phenomenon.
4. Proponents of the quantitative paradigm in OR are hereby encouraged to view, accept and utilize the qualitative paradigm as a complimentary methodology. Hence, let the 'war' stop! There is absolutely no need for it.
5. Data and theory triangulation techniques should be first studied and understood before applying them so as to avoid the possible drawbacks of their wrong application.

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