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Perceptibility of barriers and threats to successful and sustainable restoration of Heritage Buildings. *A perspective of UK's heritage practitioners.*

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ABSTRACT AND KEYWORDS

Purpose of this paper
The research set out to examine whether, among heritage practitioners, there is unanimity as well as notable discrepancies in what they perceive as the barriers and threats to the successful and sustainable restoration of heritage buildings.

Design/methodology/approach
The study collected data from 87 practitioners. These included professional building surveyors, conservation officers, designers, main heritage as well as specialist heritage subcontractors. This heterogeneous sample was subject to the same research instrument. The data generated was chiefly non-parametric.

Findings
Principally, the notable barriers explored are 'Prognosis–intervention barriers'. These are represented by a lack of knowledge about the principles of conservation and repair; followed by inconsistent repair standards. Even among the most dexterous heritage practitioners, the study noted a marked variation in the prognosis of structural failure as well as routine inconsistencies in the defects diagnosis methods. These challenges are contemporaneous within the sector as the likes of Historical England, (as custodians of Ancient Monuments) are continually seeking long term, and in some cases imminent interventional solutions. It is worrisome, however, to note that the custodians themselves are trapped in paralysis as the cycle between episodes of intervention become longer. The corollary is that, throughout the UK, most grade 1, grade II* and Ancient Monument structures are making the 'risk register': too many buildings, face the threat of being lost foreever.

Research limitations
The study concludes that a wider UK sample will be needed. This is because some of the applied technologies, preferred by practitioners, are not widely practised, especially in a sector where planning consent and wholesome depature from established principles, the local siginifcance attached to buildings are not only inimitable but demand solutions which are intagible and incomparable.

Practical implications

Within the heritage sector, the ongoing concerns about the slow rate of sustainable restoration merits considerable attention. Likewise, the challenges intrisic in the technical heritage doctrines such as 'reversibility' should in turn, be embraced as offering sustainable low carbon retrofit solutions. Indeed, by putting emphasis on the 'reversibility' ethos, a multi-perspective analysis unveils the fact that among practitioners, a sense of optimism is generally lacking. The study concludes that the sector lacks 'can-do' attitudes. As a result, it is diffuclt to innovate and to find solutions to the inexorable cycle of disrepair and the enormous restoration bill, currently estimated to run into several billions of Pound sterling. Sadly, locked-in with this, is the enormous high carbon foot print due to the ensuing restoration and repair activity.

Keywords: *Low carbon restoration, reversibility, inexorable disrepair, risk register.*

1. INTRODUCTION

A heritage asset is defined as a 'shorthand' for any component of the historic environment. In the UK, the National Planning Policy Framework – NPPF defines a heritage as a 'building, monument, site, place, area of landscape identified as having a degree of significance meriting consideration in planning decisions, because of its heritage interests'. Given this wide ranging definition, this study only focuses on heirtage buildings. The siginficance of this is obvious in that in 2016, Oxford Economics (2016), on behalf of the Lottery Heritage Fund, presented its findings and articulated the role, relevance and part played by the heritage sector. It stated that:

> 'The role and impact of the heritage sector is considerable. Including direct, supply chain, and wage-expenditure effects, in 2015 the heritage tourism sector alone supported a £20.2 billion gross value added contribution to UK GDP and 386,000 jobs. That is £1 for every £93 of UK GDP in 2015, and one job for every 81 in the broader economy is a derivative of the heritage sector activity (Oxford Econimcs, p.35).

It is also noted from Historical England (2019) that the 'heritage at risk register' is increasing year in and year out. The corollay to this is the actual backglog of restoration action and the increase in the consequential cost of refurbishment and low-carbon retrofit activity. As the UK is already committed to the Tyoko agreement, and its own 2050 zero carbon emission target, the continued accumulation of the very desolute stock of heritage buildings in need of restoration activity, remain a long term challenge. In concert, these issues are prominently threats and salient barriers to the UK's comittment to the Climate Change Act (enacted in 2008).

Similar concerns have been raised by the official advisor to the UK's government on climate change - the Committee on Climate Change or CCC. As part of its advisory mandate, a report to the UK Paliament, by the Committee (CCC, 2019) is rather emphatic and remains concerned that even a zero-net effort to decarbonise the UK's built environment sector up to 60% by 2050 remains a very ambitious target. In reference to the heritage sector, the CCC report is concerned that activities on the ground confound the very thought that government is on target.

As a key driver of the UK's remit on climate change, current estimates are well too ambitious. Indeed, in its concluding statement, the May 2019 CCC report, ascertains that the heritage sector is one of its target zone with the potential for deep emission reduction. This description postcribes the sector, in ways unexpected by the UK's government. It is partly explained by the fact that the heritage sector is habitually ignored owing to the stringent nature of heritage legislation.

There is an inherent but adhoc concentration of the 'harder-to-reach' as well as 'harder-to treat' heritage stock. The CCC (2019) is uneasy about the increasing rate at which heritage buildings are now being designated as on the blink of disappearance, thus making the risk register. It is this same stock that is difficult to turn around without prohibitive intervention costs. In the main, this stock, tends to be beyond the reach of many people who owns these buildings. These issues are inherent of the heritage sector and will never go away.

Furthermore, across the UK, the current approaches and attitudes to decarbonising heritage stock conjures up the same image: of all the sectors within the built environment, it is the heritage sector that is the hardest hit. Worse still, this is also the sector with the most reduced capital spending

receipts from government. The corollary to this, and given the aforesaid, is that the heritage sector is also the slowest to respond to any external demands to decarbonise its building stock. With these constraints in mind, the study sought the insights of heritage practitioners with a view to exploring variations in the perceptibility of barriers and threats to the successful and sustainable restoration of heritage buildings.

2. RESEARCH DESIGN, STRATEGY AND PROCEDURES

The heritage sector contributes in excess of £20.2 billion gross value added contribution to the UK's GDP. It is therefore an important sector vital to the treasury UK and society at large. Given this upshort, researchers felt it necessary to identfy both the apparent and the indescenible barriers with a view to understanding better, the threats to the successful and sustainable restoration of heritage buildings. However for this to happen, the views and opinions expressed by heritage practitioners were needed. For this reason, access to heritage practitioners formed a key episteological component of the study.

Practitioners are defined as professionals with a vested interests in the heritage sector and that their daily and unique experiences would enable the study to reveal some of the challenges which are intrisic yet remain deep-rooted to the heritage sector. It is from this upshort that the study collected data from 87 professional practitioners. These included building surveyors, conservation officers, designers, main heritage as well as specialist heritage subcontractors. This heterogeneous sample was subject to the same research instrument and the data generated was chiefly non-parametric.

3. FINDINGS

The study set out to explore practitioners' perception of the barriers and threats to the successful restoration of heritage buildings. A list of twenty five factors were generated from literature and as part of the exploratory work looking into the adaptation of new technology in the heritage sector. Researchers attended several workshops and these platforms, as pilot stages, assisted the researchers to reduce the twenty five factors to only eight. The eight were found to be the most recurring factors and thus worthy of subjecting to the main sample.

Threats to restoration are defined as a series of factors likely to hinder the successful restoration of a heritage asset. Kangwa and Olubodun (2010) outlined the logistical constraints likely to negate the succesful refurbishment of heritage buildings and found them to be wide ranging yet unique to a geographical location, legislative by laws. The hollistic understanding of these variables all contribute to the successful restoration of a heritage asset. Gorse and Highfield (2009) admit that unlike ordinary buildings, listed buildings are more challenging because of the unpredictability of the regulations. Taylor (2011) observed that even the sentimental decisions of project conservatioal officers tend to vary from one building to the next even when managed by the same officers. The sector has gone extensive reviews a lot of changes post the Pinfold review. Given the aforesaid a question emerges: what do practitioners perceive as the ongoing threats to sustainable restoration of heritage buildings?

3.1   Perceptibility of barriers and threats to restoration of heritage buildings (BaTRes).

The pilot stages helped the study to reduce twenty five threats to successful management of heritage assets down to eight. Respondents were then probed to provide a rating relative to the degree of threat each factor presented. A rank order rating of 1 denoted a factor perceived to offer the greatest

Table 1:   Perceptibility of barriers and threats to restoration of heritage buildings (ranking at aggregate level)

Abbreviation	Perceptibility of threats to successful restoration of heritage assets	Aggregate	Rank	Implied meaning
	Sample n = 87			
BaTRest4	Adapting to modern technologies when establishing extent of decay/damage	2.038	1	Reversibility : Avoidance of
BaTRest3	Avoidance of unintended damage to other parts of a building	3.019	2	unintended structural damage
BaTRest1	Retaining the Historic value of a building	3.377	3	
BaTRest7	Finding a network of well reputed restoration contractors	4.113	4	Micro-knowledge of a building's
BaTRest6	Local significance/relevance behind listing status of a historic building	4.396	5	local heritage definition
BaTRest8	Finding buildings materials tracked by Historical England	4.500	6	
BaTRest2	Keeping an accurate inventory of extent of ensuing work	5.283	7	Blurred technological
BaTRest5	Establishing extent of archaeological interest	6.189	8	interface

threat, and so forth up to 8. Factors at the bottom of the Table 1 portray areas with the least impact on restoration activities.

Since the respondents for the study were captured from various heritage backgrounds, with various years of working in the heritage sector a fair representation of the extent and order of perceptibility of threat was possible. Starting with the *implied meaning* (refer to Table 1) the results are now discussed in turn.

Reversibility: under listed building or scheduled monument consent heritage planning policy requires that the historial value receives the utmost consideration, whatever the proposed restoration or repair solution. All the main custodians of heritage buildings (Historical England, the Association for the Protection of Ancient Buildings, and Natural England to mention a few) are renown for insisting that restoration is not driven by 'replace' rather than *repair to retain* (RtR) value whether it is individual or a sum of building elements. This criteria drives a deeper sense of valuing a building to be a sum of individual components which in temselves define the both historical and present value of a building. In some cases, simply being able to understand the vulnerability of the original materials available at the time and effort to seek *like to like* (LtL) *materials or assembly techniques* all go some way in retaining the orignal fabric and thus the heritage value of a building. Any prognosis of repair should prioritise these issues: they echo the need for a sympathetic approach to restoration. Among conservational officers and planning officers they belive that these doctrines have been proved to be correct time after time (Gorse and Highfiled, 2011). They result in challengingly complex technical solutions but whose resulting effects allow the building to remain true to its original heritage value. In order to acquire these attributes, no amount of training is ever enough for a heritage practitioner.

Following on from here it is notable from Table 1 that indecisioness of the heritage sector is also a threat to the conservation process. In particular, obtaining listed building and ancient monument consents during planning process can take months if not years respectively. Buildings are therefore left overexposed between longer cycles of non intervention. The resulting effect is that structural damage occurs but despite this, every effort to rebuild the former structural integrity adopting the *RtR* and *LtL* are unique restoration attributes and rooted in the *'reversibility'* (Rv) doctrine.

A further inspection of Table 1 shows unanimity among practitioners that managing heritage assets hinges on getting an accurate diagnosis of structural defects but that the prognosis of the extent of decay and resulting structural damage are not cursory factors to the chosen restoration techniques. It is clear from the ranking that these are the hardest and most in dispute topics held between restoration contractors and the conservation officers. The common goal is to ensure any design efforts to restore a building's historical value.

Micro-knolwedge of local heritage definition. BaTRest 7,6
The second most severe threat relates to the almost inevitable issue associated with finding specialist heritage practitioners when you need them most. Any remedial work involves soft stripping and gradual exposure of sections or parts of a building that are beyond repair or reinstitution. Exposing the elements that are beyond repair requires an understanding of the intricate and elaborate ways in which old buildings were assembled. Inevitably, even with the greatest care of the most dextrous craftspersons, other parts of a building are bound to be damaged. This problem can also be explained by the fact that challenges that besiege the heritage sector also include the difficulties in finding specialist heritage contractors. These tend to be expensive and work can only take place when they are available and not when necessarily when the building owner needs them.

Striking a balance between immediate intervention to minise structural damage and the associated costs and restoration of the heritage value implies that one cannot succeed without the other. The custodians of heritage buildings are not necessarily the owners of the buildings protected by statute. However as heritage custodians, Historical England, The Society for the Protection of Ancient Buildings and Natural England should all focus on bolstering the skills and training critical to dealing with some of the inimitable restoration techniques which most colleges and institutions of higher

learning hardly seek to provide. There is no replacement or substitutes for such skills and thus when it comes to restoration, there is no place to hide but to see their effect even among practitioners. Any lessons by the heritage contractor or the building owner can be expesive and must be avoided at all costs.

Consequently, finding bridinging initiatiives that allow tradespersonnel to develop their dexterities and encompassing the very understanding of the doctrines enshrined in reversibility: *hence Rv = RtR + LtL*. Ancient techniqure skills allow practitioners to Repair to Retain value (***BaTRest 6)*** and to adopt the use of Like to Like material and assembly techniques. These are the attributes that give credence to the doctrine of Revesibility (Rv). The knowledge and experience needed to understand the varied and conflicting needs of old buildings lies in understanding traditional methods of construction. This draws attention to the need to focus on trades training and specialist heritage skills which are all pivotal to the successful restoration of heritage buildings.

The least perceived threats shown in Table 1 are three equally very important areas of heritage management, namely:

Retrofitting Technology- BaTRest 8*; record keeping of heritage work - BaTRest2 and* ***archaeological record-keeping - BaTRest5.*** all three sources are threats to the restoration process and perhaps an indication that heritage practitioners are getting used to the various technologies which target the new build sector and not necessarily the refurbishment or maintenance sector.

The call for the use of drones in the heritage sector is an interesting one; it reflects a repsonse to the challenges contractors have in providing specimen details of structural damage or most recent status of structural damage to ascertain extent of remedial work necessary. Where these may needed to confirm the cost of the work drones can reduce the drastic waiting time to confirm the status of a fledling structure in danger of collapse. Drones are a perfect match for a non destructive methodology often insisted upon by custodians. Yet as this study shows, the heritage sector has not woken up or fully embraced the drones-technology. In a sector where the time between expression of interest and the award of contract can be several years apart, the presence of drones would allow a quick update of the structural status of a building. They can inform the heritage contractor to revise their quotations and therefore their loss, a win win situation for the client as well. Even if the building were to be perlilous and about to collapse, drones would act as a non destructive method.

The reluctance in adopting these modern technologies compared the new built sector again confirms that restoration and refurbishment activitities are cinderrela activities to those of the new built sector. Given the heritage sector is characterised by very strigent archaic rules it leaves the sector disjointed and perhaps ad-hoc and with such attributes the heritage sector must be quick and ready to embrace new technologies.

3.2 Bivariate analysis: ranking of barriers and threats relative to heritage experience

The last fifteen years have seen drastic changes in the UK's regulations and planning procedures relating to refurbishment and restoration of listed buildings. The next stage therefore, was to establish extent of unanymity or concensus in the ranking of barriers and threats relative to heritage experience.

Thus as Table 2 shows, a cross tabulation between heritage experience and working purely in the

Table 2 Cross tabulation between construction and heritage experience

	Years in historical sector				
Construction experience	*0 to 9yrs*	*10 to 14yrs*	*15 to 19yrs*	*20+*	***Total***
0 to 4yrs	1	0	0	0	1
5 to 9yrs	7	10	12	7	36
10 to 14yrs	6	8	1	1	16
15 to 19yrs	4	1	0	1	6
20+	5	19	1	3	28
Total	**23**	**38**	**14**	**12**	87
	Percentage				
YEICO	*0 to 4yrs*	*10 to 14yrs*	*15 to 19yrs*	*20+*	***Total***
0 to 4yrs	1.1	0.0	0.0	0.0	1.15
5 to 9yrs	8.0	11.5	13.8	8.0	41.38
10 to 14yrs	6.9	9.2	1.1	1.1	18.39
15 to 19yrs	4.6	1.1	0.0	1.1	6.90
20+	5.7	21.8	1.1	3.4	32.18
Total	26.4	43.7	16.1	13.8	100.0

construction sector was made. The table shows that up to 70% of practitioners for this study indicated to have only up to 14 years of heritage experience. Only 30% of the sample had more than 15 years and of heritage experience. Given this imbalance, it was important to use this as a criterion for determining extent of variance in the ranking attitiudes of the repsondents. The concern was that the 70% sample may have different views to the most experienced (heritage veterans) and therefore skewing or spoofing the outcomes of the study.

As a follow up Table 3, shows a bivariate analysis with practitioners split on this same basis: years spent working in the heritage sector. Therefore Respondents with between 0 to 14 years were identified as the *X* group, whereas respondents with 15 years and above were labeled as the *Y group*. As stated above, the purpose of undertaking this bivariate study was to ascertain the degree of association in the perceived barriers and threats and whether the very experienced practitioners ranked some threats greater than those with the less heritage experience.

Table 3: Relative ranking of BaTRest by designated heritage experience

Sample(R)	IV1 n = 61 up to 14yrs	Rank (X)	IV2 n = 26 15yrs +	Rank (Y)	Difference of ranks (d)	d^2
BaTRest4	1.79	1	2.25	1	0	0
BaTRest3	2.64	2	3.36	2	0	0
BaTRest1	3.12	3	3.61	3	0	0
BaTRest7	4.40	5	3.86	4	1	1
BaTRest6	4.00	4	4.75	6	-2	4
BaTRest8	4.92	6	4.25	5	1	1
BaTRest2	5.44	7	5.14	7	0	0
BaTRest5	5.68	8	6.64	8	0	0

$$\sum d^2 = 6$$

Spearman rank correlation was deemed the more appropriate bivariate method to help decipher the extent of the agreement or disagreement among the practitioners. It helped the study to address the following question:

> *Does heritage experience dictate practitioners' views of the prevailing barriers and threats to successful restoration of historical buildings in the UK's heritage sector?*

Kvnali et al (1999; 2016); and Kangwa (2004) Bryman and Cramer (2016) have all suggested the need to establish whether the relative mean rank for each of the eight perceived threats (BaTRest) is either high and traceable to practitioners with less experience or whether the opposite, is in effect,

In their work, using a similar approach, Yockey (2011), Yung, and Chung (2012) observed that as soon as the sample mean rank for each item was identified, the rest of the bivariate analysis was easy to conduct despite not having a central distribution,the fact that the data is generally non parametric makes the central distribution less relevant.

As shown in Figure 1, the Spearman's (r_s) rank correlation test was deduced as the most suitable bivariate analysis as it measures degree of agreement between two groups of practitioners: heritage practitioners *X*:(experience n= 61) and heritage practitioners *Y:* (experience n = 28) in e positioning of the each eight rated item as a perceived threat succesful and sustsinable restoration of heritage buildings.

3.2.1 Test of hypothesis

> H_0: No association in ranking of BaTRest factors exists between X and Y practitioners relative to heritage experience.

The Spearman rank correlation coefficient, given by the formula below was utilized to determine the degree of agreement.

$$r_s = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$

$$r_s = 1 - \frac{6\,(6)}{8(8^2 - 1)}$$

$$r_s = 1 - \frac{36}{504}$$

$$r_s = 0.929$$

Based on this value, it is noted a significant positive relationship exists between heritage experience and perceptibility of threats to the successful restoration of heritage buildings. The value of r_s is neary 1, an indication of a higher level of unanimity in the rater-attitudes towards what are perceived barriers and threats to the restoration processs.

In order to determine whether a derived value of r_s = 0.925 was large enough to support the aforementioned conclusion, a test of the hypothesis that uses rank correlation r_s as a test statistic was set out as below.

According to Howitt and Cramer (2011) and Laer Statistics (2013), the applicable test of hypothesis is a rank correlation value r_s which the study set at a significance level of α = 0.05, with n = 8.

Table 4 summarises the test procedure, which is to reject H_0 if $r_s > 0.643$ taken from the critical value of Spearman's Rank correlation represented at 95% confidence level where n = 8.
As noted in Table 4, the computed value of the Spearman's rank correlation coefficient is 0.929 and

Table 4: Spearman's rank correlation test of hypothesis

	n = 8	
Confidence leve	95%	99%
Significant level	0.05	0.01
ChiSquare Table	0.643	0.833
Computed rs val	0.929	*Significant Reject H0*

far exceeds the Table value **0.643. T**he study can proceed to reject the H_0 in favour of the alternative H_1 which shows that association exists between two sets of practitioners pitted against heritage experience. The ranking is undistorted, thus justifiable and credible that experience does not play a siginificant part. It also endorses the study's methodology in trying to extrapolate the extent to which the eight factors reflect the daily concerns of heritage practitioners.

Moreover, the outcome points to a higher degree of agreement between the two sets that that even when checked against the *p*-value α = 0.01 (99%); the noted chisquare value (as shown in Table 4) is siginificantly higher (0.833) than the derived calculated value.

A close look at figure 1 below shows how close the threats are ranked between X and Y respodents. It can be seen that BaTRest 7, BaTRest 6, and BaTRest 8 are the only threats where the two professionals could not possibly tie completely. The Scaterplot of Figure 1 endorses this position.

As per Figure 1, the closeness in the ranking between practitioners with up to 14 years and over 15

Figure: 1 Comparative ranking of BarTRest by heritage experience
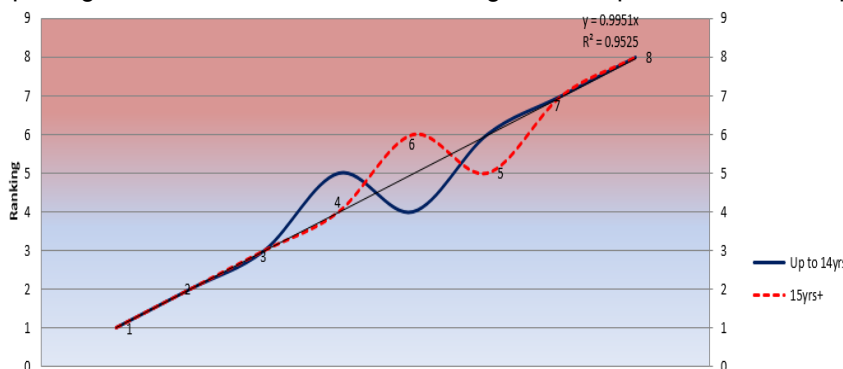
years pitted against each other reveals a higher level of unanimity. Certainly, the two sets of ranking can hardly be seperated, an indication of the nearness in the perception of the barriers and threats. Considering there are 61 (70%) of the sample with between 0 to 14 years work experience, the imbalance is hardly a compounding factor to distort the perceiptibility of the most severe threats and thus barriers that militate the successful restoration of heritage buildings. Indeed, Figure 2 endorses that when a greater level of unanimity is registered - both in the magnitude of threat and extent of perceptibility of the rank order of the barriers – then their effect could not be a mere chance occurence. While the 70% respondents (0 to 14yrs) has a notable impact on the mean scores the results opposes the view that two camps are anything but closer. The veteran heritage practitioners (with 15 years +) have as much coners as the less experienced practitioners. The threats and barriers are sufficiently visible.

Figure 2. Scatterplot of practitioners relative to mean pitted against 15yrs+ heritage experience
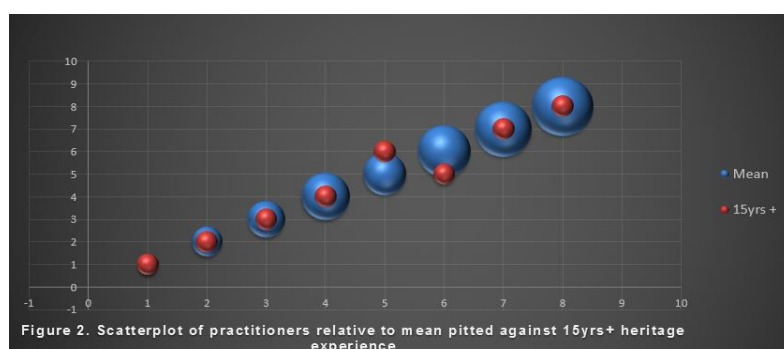
4. DISCUSSION OF FINDINGS AND CONCLUSION

This study reveals the threats likely to impede the successful restoration management of heritage buildings. Further to this, the research defined threats as areas that can inform the measures necessary for ensuring the success of most restoration projects. Overall, eight threats appear to point to those areas where the practitioners are likely to find challenges and which impede their ability to operate well in the sector.

The next threat is associated with the difficulties in understanding mediaval building assemebly methods. This outcome is important in that it reflects the general constraint of skill shortage in the built environment. With heritage sector being so unique, it comes as no surprise that the shortage of well-trained professionals has emerged as one of the biggest threat.

The study concludes that the sector lacks 'can-do' attitudes. As a result, it is diffuclt to innovate and to find solutions to the inexorable cycle of disrepair and the enormous restoration bill, currently estimated to run into several billions of Pound sterling. Sadly, locked-in with this, is the enormous high carbon foot print resulting from the backlog of restoration and repair activity.

5. LIMITATIONS

The prevailing absence of information, on all manner of heritage activities, leads to increasing uncertainty in the diagnosis and prediction of restoration strategies. There is unanimity that these issues will, collectively, combine to allow the perceived threats and the consequences of unintended damage to heritage buildings to remain as major sources of concerns. Recently introduced legislation including governmentt reviews for the sector appear to have had little effect to ephase these concerns.

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Rainwater Harvesting: an important element of water sustainability in Bloemfontein

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ABSTRACT AND KEYWORDS

Purpose: Some major cities in South Africa have been experiencing water shortages over the years. Bloemfontein has experienced its share of water shortages over the years and looking at the rate of population growth, depending on municipal water supply alone may lead to situation where water demand will exceed supply. This study thus sought to explore the possibility of using rain water harvesting as s solution to the frequently occurring water problems in Bloemfontein.

Research methodology: Qualitative research approach was used for this study. Structured interview questionnaire made up of closed and open ended was used to collect data from purposefully selected construction professionals made up of quantity surveyors, project managers and estate developers. Excel statistical tools was used to analyse the data collected.

Limitation: The study concentrated on Bloemfontein city and data was collected from only construction professionals operating from Bloemfontein

Findings: The findings indicate that harvested rainwater can be used as an alternative water supply in conjunction with municipal water supply to ensure water sustainability for Bloemfontein in the near future and to decrease the pressure on municipal water supply. It was also revealed that estate developers do not make provision for water harvesting storage facilitate after the development because clients do not request for it; client see it as an obstruction to the aesthesis of the buildings and they not see water shortage as a serious problem in Bloemfontein.

Practical implication: the implication is that, letting go rainwater without storing them for future use will come to bite the municipal authority in the near future as the population increases causing water demand to exceed supply. It is therefore recommended that the municipal authorities should take action now and sensitize the populace and estate developers to install water storage facilities to supplement the municipal water supply.

Keywords: Bloemfontein, harvesting, rainwater, water sustainability

1. INTRODUCTION

Water using fixtures vary from plumbing (both in bathrooms and kitchens), external water installations for irrigation of the garden or landscaping. South Africa is becoming a water scarce country due to a couple of factors such as drought and the natural increase in population, engineers and architects are forced to keep water usage and energy savings in mind during the designing phase (Von Bormann and Gulati, 2014). They are forced to design in such ways because of the desire to design green systems and the increase in urbanization in larger cities such as Bloemfontein. This leads to various alternatives in the installation of water consuming fixtures such as toilets, taps and showers. These alternatives have some disadvantages such as the high capital and installation cost, maintenance and

regular inspections by technicians, which ultimately have a negative influence on the operational cost of buildings (Spigarelli, 2012).

Bloemfontein is frequently dealing with water problems for a couple of years. Existing challenges that are related to this problem are ageing infrastructure, water quality, and supply constraints. There are currently two sources, supplying water to Bloemfontein, namely; Bloem Water, which supplies 70%, and The Maselspoort Water Treatment Works which supplies 30% (Macnamara, 2017). Statistics done by the Municipality indicates that if the population grows by 1.2% per year, the water demand will increase with approximately 30% over the next 20 years (Macnamara, 2017). Realising the urgency, the municipality has been seeking solutions to relieve water pressure in a bid to address the arising problem which will lead to demand exceeding supply.

Examples of successful rain water harvesting relieving the pressure on water supplied by local authorities, can be seen in many countries all over the world (Cunninghame, 2017). In South Africa, the City of Cape Town and the surrounding communities can be witness where the government took action to reduce the water consumption (Cunninghame, 2017). The advantages of rainwater are that, it can be harvested and stored for future uses when municipal supplies are limited and can also be installed to supply water to toilets, baths and gardens throughout the year (Earth Eclipse, 2018). A possible alternative relevant for Bloemfontein to relieve the water demand from consumers is by harvesting rainwater in the raining season for use during periods of water scarcity, hence the need for this research.

2. LITERATURE REVIEW

2.1 Water Harvesting

Water is the most general or main substance on the earth, covering more than 70% of its surface. Out of this 70% total volume of water on the surface of the earth, only 2% is fresh water (Dwivedi & Bhadauria, 2009). This fresh water is used by humans, for purposes such as domestic use, industrial use and agricultural use. According to Dwivedi & Bhadauria (2009), in many parts of South Africa, the quality of ground water is believed to be undrinkable and therefore rainwater harvesting may provide an alternative source of water for human survival.

Human civilization in South Africa entirely depends upon rivers, dams, and ground water to fulfil their fast growing demands for water. However, rain is the ultimate source that feeds all these supplying sources. The implication of rainwater harvesting is to make optimum use of rainwater at the place where it falls; that is to use it and benefit from it before allowing it to drain away (Dwivedi, & Bhadauria, 2009). Rainwater harvesting and storage systems are a very simple method to harvest or collect rainwater, traditionally from roofs of buildings, for an alternative water supply source and to reduce the increasing consumption of water supplied by the local authority. This can provide a very high quality of water if it is maintained and operated in accordance with the recommended guidelines (Australia Department of Water, 2011).

The harvesting of rainwater for later use is a very prehistoric technique and is becoming even more popular due to its inherent quality in terms of its smoothness, cleanliness and natural taste (African Development Bank, 2006). Rainwater nearly has a neutral Potassium Hydroxide (pH), and is free from impurities such as salts, minerals, and other natural and artificial contaminants (Dwivedi, & Bhadauria, 2009).The quality of stored rainwater may be reduced by contaminants like faecal coli, forms turbidity and insect larvae, these contaminants can be properly controlled by understanding the system operation and simple disinfection techniques if required (African Development Bank, 2006; United States of America, 2007).

2.2 Surface Run-Off Harvesting

The primary use for this type of harvesting system is for external uses such as gardening. It can be cleaned and purified if it is polluted by the catchment area and use for domestic purposes (Practical Action, 2016). The catchments' surfaces can be from various materials such as; rock surfaces, concrete channels, plastic sheets, treated soil, and paved areas. It is a very simple system for the catchment of rainwater from impervious areas.
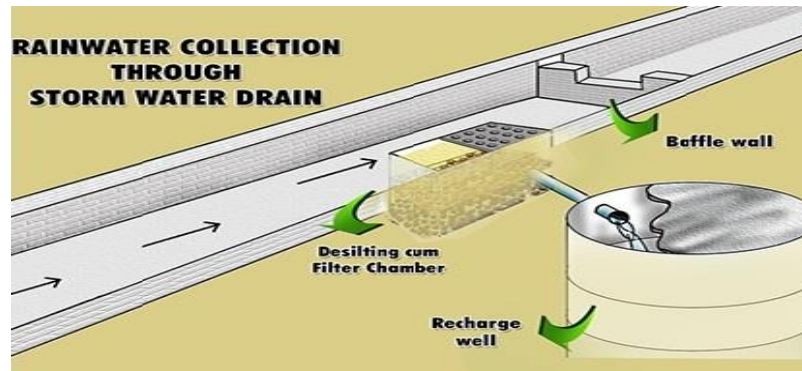
Figure 1: Surface Run-Off Harvesting (Cleanenvironment, 2018)

According Eldho (2013) the geological structure and contours must be taken into account with the ease of access when these collecting structures are installed. For example, as Cleanenvironment (2018) suggests, if the paved area is on a slope, a concrete channel can be installed at the bottom of the slope collecting rainwater and distributing it into a tank below the channels as shown in Figure 1. The tank can then be above ground level with a tap at the bottom of the tank for the use of stored rainwater. According to the African Development Bank (2006) with this type of water harvesting, the tank can be buried under the natural ground level, and pump is installed to pump out the stored water for later use. A mesh layer is also installed in the concrete channels to remove leaves and any unwanted materials before the water enters the tank. Maintenance and operation is the utmost importance for optimum harvesting and the essential quality of water (O'Brien, 2014: 37).

2.3 Roof Top Harvesting

Rooftop harvesting is a delicate process of collecting rainwater that is falling on the roofs of buildings and runs into the rainwater drainage pipes (Studer & Liniger, 2013). This water is then stored in a tank that is connected to the rainwater drainage pipes and situated next to the building as illustrated in Figure 2. Studer & Liniger (2013) suggest that the water harvested from the roof can be used by the residents of many households and the quality of the rainwater is influenced by the type and condition of the roof covering. Galvanised iron metal roof sheets provides the best quality of rainwater due to it smoothness surface and the heat of the sun on the steel helps to sterilize bacteria, provides the greatest yield of all roof covering types (Oas, 2018). Roof tile coverings that are glazed can be of good quality but contamination may exist in tile joints. On the other hand, thatch roof coverings provide poor quality water and are not preferable due to the little first flush effect that is gained from the roof (African Development Bank, 2006).

According to Dwivedi, & Bhadauria (2009), the use of the stored rainwater can be temporary (within a few days after a rainstorm), seasonal (throughout the areas rain season) or permanent (through the rain season and the dry season) except in years when the current area is experiencing adverse drought and it can be harvested and stored by the individual members of the household as it is not open to be used or wasted by members of the community. The harvesting of rainwater on roofs can be at various levels, individual, community or it can be on an institutional level, it is mainly used for domestic purposes. The quantity of rainwater that can be stored depends on that specific area's rain pattern, catchment or roof area, and then obviously the volume of the installed storage tank (United States of America, 2007).
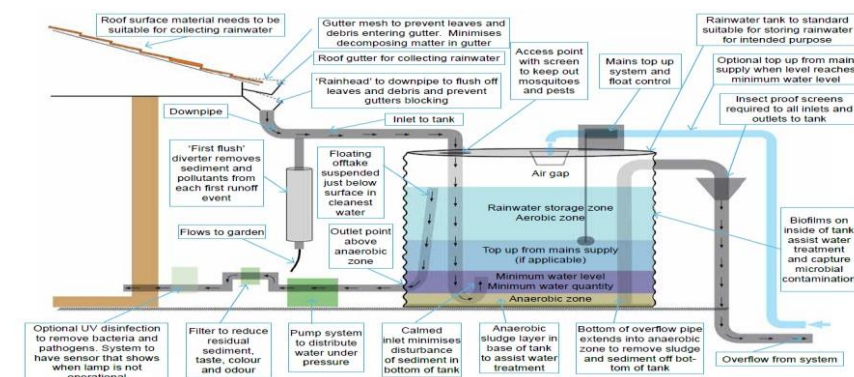
Figure 2: Roof Top Harvesting (Australia, Department of Water, 2011)

This method of rainwater harvesting can be very useful in areas with an annual rainfall of between 200 and 1000mm. If the specific areas' rainfall does not meet the favourable amount required per annum, it can still be efficient to lighten the burden of authorities supplying water (African Development Bank, 2006: 2). If one does not have the required equipment to store the harvested water, it may also be used to recharge the groundwater and water table by connecting a pipe from the rainwater downpipes to a nearby borehole (Dwivedi, & Bhadauria, 2009).

2.4 The Need for Rainwater Harvesting

Ninety-eight percent of available water in South Africa is already been allocated to the various consumption sectors, leaving South Africa with the status as a water scarce country (Von Bormann & Gulati, 2014). The need for harvesting and storing rainwater for later use has increased due to the increase in population and higher usage levels of water, thus water supply agencies are unable to cope with demand from available sources (Dwivedi, & Bhadauria, 2009; Adugna *et al.*, 2018).The trend to save water is not just a question for the local water suppliers, the responsibility also rests on water consumers. When residents of a specific house take a shower, wash their clothes, or make a cup of coffee, they ignore and underestimate both the environmental as well as a financial impact of their actions (Energy Saving Trust, 2013). This financial impact refers to the water account for residential home owners as every time one opens a tap or run a water using an appliance, he/she spends money, create carbon emissions and draw on our water minerals (Energy Saving Trust, 2013).

Based on the current usage trends in South Africa, it is estimated that population's demand for water will exceed the amount of water available by the year 2025 (Department of Water Affairs, 2016). To fan the flames of the matter even more, studies shows that the Mangaung Municipality system input volume will exceed the capacity of the bulk water systems within the next two years (ISS, 2018). It is therefore critical that water conservation and water demand management initiatives be accelerated as a matter of urgency and that additional long term sources and alternatives such as harvesting rainwater be identified and implemented (Mangaung Metro Municipality, 2016; ISS, 2018). The water use in different homes, with or without meters, varies to a great extent. This depends on the utilization of water and differences in daily water use practices. The findings of a study done by the Energy Saving Trust (2013) in the United Kingdom on the average water consumption per household indicates that, the average person uses about 142 litres of water each day for different activities, whilst the average household uses 349 litres of water each day. Bathroom water usage is the biggest with showers consuming 25% and toilets using 22%. People generally spend seven and a half minutes in the shower whilst 87% of people spend 10minutes under the shower daily. Only 41% of homes had a dual flush toilet allowing the usage of less water. Eighty-six percent (86%) of residents who used a bowl when washing dishes by hand, make use of the same water as grey water in their gardens (Energy Saving Trust, 2013).

It is therefore important for South Africans to recycle more water than we do presently as more and more water in households per person are consumed which may lead to water demand exceeding supply in the near future.

2.5 Water Sustainability in Bloemfontein

Factors such as rapid population growth, industrialization and climate change are having impact on the sustainability of water management are gaining increasing attention in both South Africa and the world at large. In South Africa, cities such as Bloemfontein are under severe pressure to respond not only to certain water challenges, but they are also facing challenges such as economic transformation, accelerating basic service delivery, and social tension divisions (Carden & Armitage, 2012).

According to Ukwanda (2009), a distinction must be made between water availability, water withdrawals and water consumption. Water availability is the amount or quantity of renewable water resources that are available for human use for either domestic, industrial or agricultural uses whilst water withdrawals are the amount of water that is diverted from available dams and rivers and pumped from aquifers for human use, but it is not necessarily consumed. Only a part of water that is withdrawn from resources is being returned to the environment after the use thereof. Consumed Water is the volume that is not returned to the environment after use, it is usually incorporated into products and organisms so that it becomes unavailable to other users (Ukwanda, 2009). For domestic use, 10% of water is withdrawn from resources and only 3% is consumed. The difference in percentages between water withdrawn and water consumed can be due to failing water meters and leakages in pipelines (Ukwandu, 2009).

The factors that cause population growth in a city such as Bloemfontein are the natural increase in population and the migration to cities (Bhatta, 2010). A study done by the United Nations shows that South African cities have experienced population growth from the fall of the apartheid era in 1995 up to 2015, as well as a population forecast from 2015 till 2030 (Writer, 2015). The results from these studies indicate that the growth in population for Bloemfontein moved from sixth place (1995-2015) to fifth place (2015-2030) in the overall rankings of population growth in South African cities. New solutions and alternatives to improve water sustainability of these cities is inevitable and the coordination of such implementations, the monitoring thereof, reporting and verification systems are proposed ways to bring long-term accountability to both the government as well as to the local community and population (Carden & Armitage, 2012).

3. RSEARCH METHODOLOGY

In this study, qualitative research methodology was used to gather data. The data collection instruments adopted for this study was the structured interview questions made up of tick box and open ended. The interview questions were personally distributed the correspondents in the construction industry (Mechanical Engineers, Civil Engineers, Quantity surveyors, Contractors, Project managers and estate developers) operating from Bloemfontein. The department of water in the Mangaung municipality was also interviewed. A purposive sampling was used as the topic under investigation is special and hence only people with in-depth knowledge can contribute. Purposive sampling is described by Welman *et al.* (2005) as a non-probability sampling used by researchers where they rely on their experience, ingenuity and/or previous research findings to obtain units of analysis in such a way that the sample they receive will be regarded as a representative of the relevant population. The researcher personally asked respondents' questions and filled in the questionnaire based on the responses given by the respondents. In order instances, where the respondents were not available to be interviewed, the researcher left the questionnaire with the respondents. The respondents then filled the questionnaire and then emailed it back to the researcher. Respondents were encouraged to seek any clarification they might need via email or telephone call.

The research questions were made up of both closed and open-ended questions and were made easy to be answered by the respondents. As Reja *et al.*, (2003), put it, the close-ended questions limit the respondent to the set of alternatives being offered, while open-ended questions allow the respondent to express an opinion without being influenced by the researcher. In all 36 respondents were contacted for an interview of which 27 responded, given a response rate of 75%. The data collected were analysed through content analysis. Content analysis is the process of analysing verbal or written communications in a systematic way to measure variables quantitatively (Polit & Hungler 1995). Welman *et al.* (2005) on the other describes contents analysis, as quantitative analysis of s qualitative data, where the researcher counts the frequencies and sequencing of words, phrases and concepts in order to identify keywords or themes. The features of the respondents are shown in Table 1:

Table 1: Profile of the respondents

Respondents Profile	Frequency	Percentage	Code
Nature of the respondent's occupation			
Quantity surveyors	10	37%	
Project Managers	6	22%	
Contractors	5	19%	
Estate Developers	2	7%	
Civil Engineering	2	7%	
Mechanical Engineering	2	7%	
Total	**27**	**100%**	

Respondents employment industry			
Private Sector	**27**	**100%**	
The participants position in the organization			
Quantity surveyors	8	30%	QS1 to QS8
Project Managers	7	26%	PM1 to PM7
Facility Manager	2	7%	FM1 & FM2
Director	4	15%	D1 to D4
Contract Manager	4	15%	CM1 to CM4
Mechanical Engineers	2	7%	ME1 & ME2
Total	**27**	**100%**	
The participants level of education			
Bachelor degree	14	52%	
Honours Degree	8	30%	
Diploma	5	19%	
Total	**27**	**100%**	
Respondents work experience			
Below 5 years	9	33%	
5 to 10 years	2	7%	
10 to 15 years	2	7%	
Over 15 years	14	52%	
Total	**27**	**100%**	

4. RESULT AND DISCUSSION

4.1 The organization's experiences of water shortages in the past

This question was asked to identify how many of the participants' respective organizations have experienced water shortages in the past.
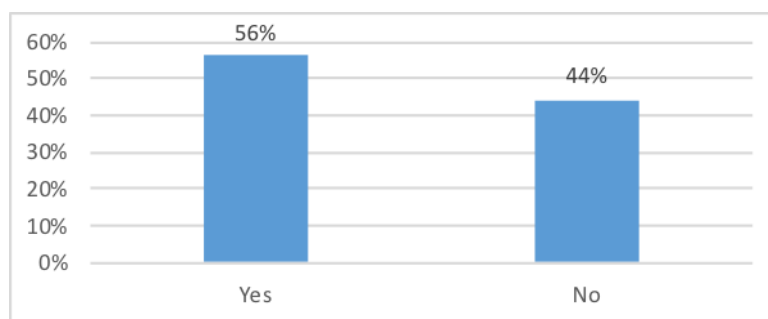
Figure 3: Experienced water shortages in the past

From Figure 3 it can be seen that 56% of the respondents have experienced water shortages in the past, while 44% of the respondents have not yet experienced water shortages.

4.2 Installation of rainwater storage facilities by the respondent's organizations.

This question was asked to determine whether the participants have installed rainwater storage facilities on their premises to date.
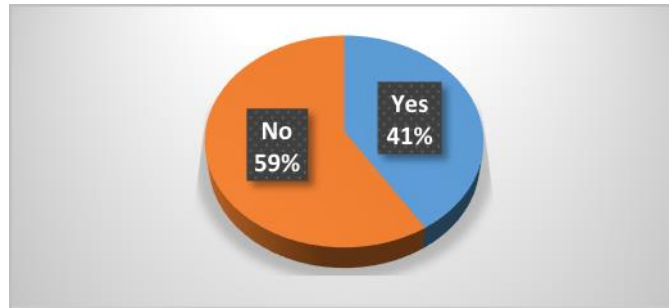
Figure 4: Installation of rainwater storage facilities by the respondent's Organizations

Figure 4 illustrates that 59% of the respondents have not installed any rainwater storage facility yet, while 41% of the respondents have installed a rainwater storage facility on their premises. The participants that answered no to this question stated the following as reasons; lack of space on their premises and infrastructure that cannot accommodate such an installation, they are currently looking into it as an alternative back up for municipal water in the near future; they are currently not consuming large volumes of water in their respective offices and the municipal water supply is enough; and the shortage is not severe yet, but they will do it in the near future as they know it is a good alternative water supply. These findings also indicate the respondents' belief in the necessity of rainwater harvesting as an alternative water supply to compliment the municipal water supply.

4.3 Involvement in property development by the respondent's organization.

This question was asked in order to determine whether the respondents are directly involved in property development.
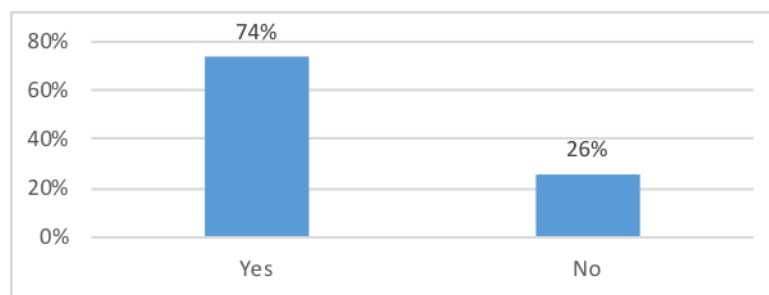

Figure 5: Respondents Involved in property development

From Figure 5, it can be seen that 74% of the respondents are directly involved in property development, while 26% of them are not directly involved in property development. Twenty-six percent (26%) of them, who are not directly involved, are consultants and are not physically involved in developments.

4.4. Making provision for rainwater storage facilities after development.

This question was asked to determine whether respondents make provision for a rainwater harvesting system after development. The result is indicated in Figure 6.
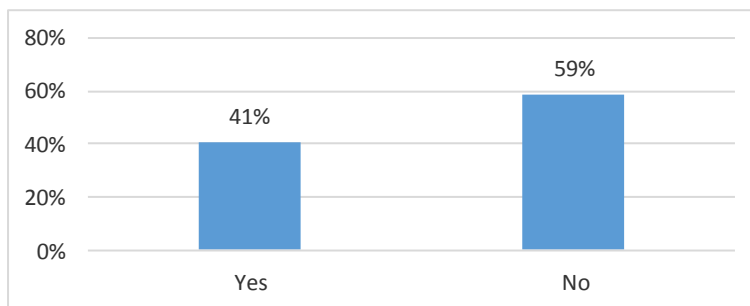
Figure 6. Rainwater storage after the development

The respondents who answered no to this question stated that, due to the bulky tanks and cost implications of a more complex type of rain water harvesting system they do even think of installing rainwater harvesting facilities after the development of the houses or offices. *FM2, CM, QS2 & QS6* stated that some clients do not want it because of the bad aesthetic appearance it has on a building and the extra costs it brings. *FM2* further stated that the installation of rainwater harvesting systems are not required by the market yet, but they are considering it in future projects. These findings clearly indicate that consumers think of the aesthetic nature of their houses more than cost saving for water by installing simple water harvesting systems such as plastic tanks. The developers also want the client to request for the installation of rainwater storage systems before they act.

4.5 Provision of rainwater storage facilities at the residential and office buildings

This question was asked to identify if the participants think that it is a good idea to make provision for such a system on their premises. All the respondents (100%) agree that it is a good idea to make provision for rainwater storage facilities at residential office buildings. Respondents are of the view that, a lot of rain water goes into drains during the raining seasons which can be better utilised in order to save water and decrease the load on the municipal water supply. Rain water will provide a cheap alternative water source in conjunction with the municipal water supply and decrease the amount money spend on water by home owners. Respondents also see the installation of rainwater storage facilities in residential and office buildings as water will become scarcer in the future due to an increase in the population as well as changes in the weather pattern with Municipal not being able to meet the demand.

4.6 Respondents opinion, on whether the Mangaung Municipality has made any provision to prevent water scarcity in Bloemfontein.

This question was asked to get the respective opinions of the respondents on whether the Metro has made any provision to prevent water scarcity in Bloemfontein in the near future. The result is shown in Figure 7.
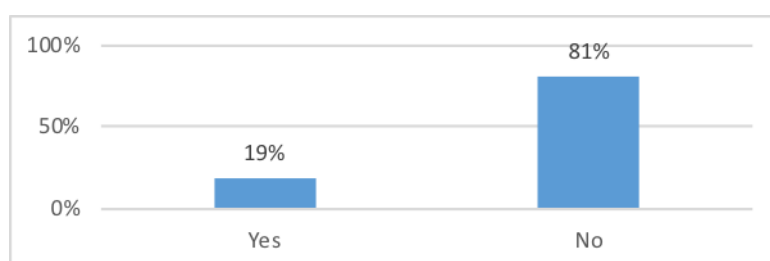

Figure 7: Whether provisions are made by the municipality regarding water shortages

Participant's, who answered yes, are of the view that there are water restrictions that the municipality have set in place and they believe that this restrictions are being followed by the consumers. The municipality has plans to build another pipeline from the Gariep dam in the next couple of years to increase the volume of water supplied to consumers, but lack of funding is delaying this project to take off. On the other hand, the respondents who answered in negative to this question

stated that, the municipality do not even attend water leaks in the systems currently hence water shortages are eminent. *QS3 & ME2* stated that there are not enough experience personnel in the municipality to manage water resources effectively and efficiently leading to water shortages. *FM2 & PM1* are of the view that the municipality has no adequate alternative water supply in place currently to overcome any water shortages that may confront them in the near future due to financial constraints. However, in interview with the municipality, they confirmed of the construction of another dam to boost the water supply but the funding for the project is not yet secured.

4.7 Rainwater harvesting as a solution to water scarcity in Bloemfontein in future.

Respondents were asked to share their opinions on whether rainwater harvesting can be a solution to water scarcity in Bloemfontein in the near future. The responses to this question is represented in Figure 8.
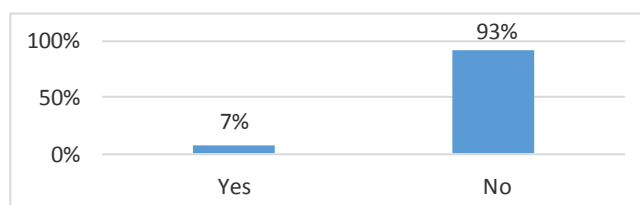

Figure 8: Whether rainwater harvesting is a solution for water scarcity in Bloemfontein

The respondents (93%) who answered in affirmative stated that if water is stored and reused, it would lessen the burden on municipal water supply. *QS1 & PM5* stated that, if rainwater is harvested and reused to their full potential, it can reduce the total water usage from the municipality and also help people to save on water bills. *FM1, CM1 & CM4* were also of opinion that, if each home or business has rainwater storage facilities, less water will be used from dams and this will reduce pressure on the municipality for increasing water supply to meet consumption levels by the households. *PM2, D1, D3 & QS3* also stated that the amount of water available is insufficient for human usage and consumption hence rain water that is collected on the correct methods can be utilized as drinking water in times of drought. On the other the 7% of the respondents who disagreed that rainwater storage cannot be a solution stated that the average rainfall of ±400mm per year in Bloemfontein is too low to make any impact and that large catch up areas is required to store enough water which is not feasible for a small residential building. Others stated that the high cost implications in terms of treating rainwater for safe use in households.

4.8 Techniques of reducing water consumption by Mangaung Municipality.

This question was asked to get opinion from respondents on how the Municipality can reduce water consumption. General answers provided by the participants are boarded on the general maintenance of the water infrastructure by the municipality. *QS2* stated that, the municipality should maintain the infrastructure and fix leaks in pipe lines immediately they occur and for this to happen, the Municipality must have more frequent inspections with qualified technicians and better staff. *ME2* also opined that, the municipality should advertise on social media platforms and channels to inform consumers on water scarcity and restrictions. They should implement penalties on late payments of water bills to encourage consumers to pay their water bills. *FM1 & FM3* also proposed the successful installation and implementation of rain water harvesting systems for storage and re-use and that the Municipality must educate consumers on the importance of water and how to use it sparingly in conjunction with

rainwater harvesting. *CM2* on the other hand suggested that, the municipality must also harvest rainwater that goes to lost in storm water channels and utilize it when the need arises.

4.9 Making it a requirement for all new buildings to install rain water harvesting facilities

This question was asked to get various opinions from the respondents on making it a requirement for all new buildings to install rain water harvesting systems and the utilization thereof during later stages. All the participants were in favour of making rainwater harvesting installations a requirement for all new buildings. Respondents were of the opinion that the rainwater harvesting system can be used in conjunction with municipal water hence if it made as a requirement in the by-laws, then it will force the developers to comply. Others are of opinion that rainwater is a good alternative and must be implemented in the South African National Building Standards (SANS).

4.10 Alternative solution for the households that cannot afford a rainwater harvesting system.

The purpose of this question was to get suggestions and alternatives from the respondents for households that cannot afford a rainwater harvesting. The participants suggested that the harvesting of rainwater can be done by using plastic container and then boil it to get rid of any germs that might be in the water and use it as drinking water. The installation of water fixtures such as hand wash basin taps with mist spraying taps and showerheads with "water saving showerheads" can also reduce the water consumption. Connecting rainwater gutters with a normal plastic pipe and use the water in their sink, wash hand basins and washing machines or gardens can also be cheaper option for households. As suggested by *FM1* stated that, "*rainwater harvesting system does not have to be expensive and complex, it merely involves installing a Jo-Jo tank that must be subsidised by the municipality that catches up rainwater and can even be used in the development of RDP-houses*". *QS2* also suggested that the Municipality should subsidise home owners with a smaller scale rainwater harvesting mechanism and then adds a percentage to the consumer's monthly water bills till the amount is fully paid back by the customer.

5. CONCLUSIONS AND RECOMMENDATIONS

The findings of the study indicate that the successful harvesting of rainwater and the re-using thereof in conjunction with municipal water definitely is a water alternative to assure water sustainability for Bloemfontein in the near future and to decrease the pressure on the municipal water supply. The utilization of harvested rainwater will reduce the load on the municipal water supply as it can be used in many areas in the house, thereby reducing the stress on the municipal water supply and savings on the bills paid by consumers. It is therefore an ideal to install rainwater harvesting system to supply water to areas such as toilets, wash hand basins, washing machines and the gardens. The findings also indicate that consumers perceive the installation of the rainwater storage system as too expensive and will also destroy the aesthetic features of their houses. It is therefore recommended that the municipality intensify education on the rainwater harvesting as an alternative water in conjunction with municipal water to ensure water sustainability for Bloemfontein in the near future. By-laws can also be put in place to make it compulsory for all new developments to have rainwater harvesting facilities installed to decrease the pressure on municipal water consumption in time of need. The municipality can also introduce a subsidy scheme to assist the households who cannot afford the installation of a rainwater harvesting system.

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