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Proceedings
Of
The

8th International Conference on Appropriate Technology
Songhaï Center,
Porto-Novo, Benin

Université d'Abomey Calavi

November 22-25, 2018

Endogenous Knowledge, Appropriate Technology and Innovation: Linking the Past and the Future

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Benzophenone photochemistry and Repercussions on ketoprofen's pharmacovigilance

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Abstract
Ketoprofen (KTP), a prominent member of the AINS arylpropionic acids is known for inducing photosensitized skin reactions, especially after topical administration. In this connection, the dispensation of Ketum gel in France was suspended for a time in 2009. Within this context, MOCL (Medicinal Organic Chemistry Laboratory) realm of activities has been dedicated over the last decade or so, to fostering drug science through the discovery of new chemical entities of therapeutic relevance with a special accent on sustainable development and green chemistry, basing its main approach on biodiversity, green chemistry and development of hemisynthetic processes, using biometric catalysis. Photochemistry is especially suited for this purpose and easily amenable to green chemistry. Along this line, the photochemical behavior of benzophenone and some structurally related analogs was studied to discover which photochemical events are responsible of the photosensibilization side-effects noted for KTP after solar skin exposure. Two sets of experiments were carried out, the first one on benzophenone (BZP) itself and the second one on BZP derivatives. Our results clearly indicate the strong involvement of BZP triplet, a biradical species stabilized by the so-called « capto-dative effect ». A detailed mechanistic approach along with experimental data provide compelling evidence for the above statement. For the perspectives, we therefore provide drug design suggestions for the synthesis of future AINS drug candidates which are not photosensitizing.
Keywords: ketoprofen, green chemistry, benzophenone, triplet state, capto-dative effect.
Paper category: Health

Introduction

Green chemistry over the last ten years has attracted the attention of scientists through its desire to promote sustainable development with a concern to preserve biodiversity [1, 2]. Recall that its purpose is the use of principles and methods to reduce or even eliminate the use or production of substances harmful to the environment and therefore health, all accompanied by higher yields and a decrease in the number of synthesis steps. Green chemistry frequently uses novel protocols and novel synthetic pathways emphasizing soft catalysis. This philosophy has been extended to pharmacochemistry by giving rise to green medicinal chemistry and its corollary, eco-pharmacovigilance [3-5].
In the context of pharmaceutical sciences, pharmacovigilance refers to the activity of recording and evaluating the side effects that accompany drug intake [6]. The number of patients included in clinical trials prior to the issue of marketing authorization (MA) for a new active ingredient does not always reveal low-occurrence side effects. This is why it is necessary to set up a pharmacovigilance system that monitors patients under this new drug and this on a larger number of patients after AMM. Pharmacovigilance data of a drug are collected and analyzed by the laboratory in a regular periodic safety update report, which is provided regularly to government health authorities [7].
In the same way as "cosmetovigilance", the activity identified by the follow-up of patients under medication has been extended to other sectors. Eco-pharmacovigilance (EPV) is an example of discipline that takes into consideration the environmental impacts caused by the drugs from the moment of their conception to their synthesis, their development, their marketing and therapeutic use, their in vivo biotransformation as well as their fate (degradation) in the long term in the biosphere [8-9]. It is in this favorable context that

MOCL, UAC's center for inter-faculty research in organic medicinal chemistry, has included in its activities research focused on the DDD (drug design & discovery) sector within the general framework of sustainable development, preservation of biodiversity and green chemistry.
In this article, we report our recent efforts on the photochemistry in the UV-VIS of benzophenone, a chromophore present in ketoprofen (a first-class NSAID that has hit the headlines with severe erythematous reactions that led in France to temporary removal of Ketum Gel (Menarini)).

2- Experimental part

2-1-Materials

2-1-1-Solvents and reagents

The chemicals used are all commercial: (Aldrich Chemicals, Milwaukee, Wisconsin, USA) benzophenone, 4-hydroxybenzophenone (4-OH-BZP), benzyl (BZ), fluorenone, 4,4 ' dichlorobenzophenone (4,4'-dichloro-BZP), 2-chloroacetophenyl, 4'-bromoacetophenone, ketoprofen (KTP), and solvents (ethanol, 2-propanol, glacial acetic acid, formic acid, etc.)

2-1-2-Light sources

Two light sources were used: UV rays from the sun and a laboratory photolyser. This device shown below (image) is a Nail Star brand 36W UV Nail lamp Model: NS-01 used to vitrify nail polish (polymerize) after the application of a lacquer generally colored in female cosmetics. It uses four ultraviolet discharge bulbs (l= 365nm) with a power of 9W each.

Picture 1: Laboratory photolyser

2-2-Methodology

Two series of manipulations were performed. The first series concerns the pilot reagent which is benzophenone and its purpose is to assess the reaction behavior of this reagent after irradiation under UV / VIS in ethanol and 2-propanol. The second series of manipulations was designed, programmed and carried out on ketone substrates judiciously selected on the basis of their proximity to the structural plane keeping constant the "benzophenone" operational motif or at least the following benzoyl sequence: [C6H5-CO-].

2-2-1-Irradiation of benzophenone

In a 100mL Erlenmeyer flask, precisely introduce about 2.0 g of benzophenone. Using a graduated pipette, add 10 mL of 2-propanol or ethanol as appropriate. Mix well, then add with a Pasteur pipette 60 µL of glacial acetic acid. Transfer the mixture into a glass test tube that is sealed with aluminum foil. Insert the test tube into a metal support which allows free access to solar radiation, then irradiation in the sun for 1 Day or, if necessary, 3 Days. It is important to underline that all this operation must be carried out away from the ambient air because oxygen is known to drastically reduce the quantum yield of the reaction by direct interaction between the triplet states induced by benzophenone and dioxygen. This case is identical to that of the photo-halogenation of alkanes. This is the reason why this type of

photochemical reaction can be conducted only in the condensed phase and not in the gaseous state.
At the end of the reaction, the solution is placed in the refrigerator overnight. The next day, the crystals possibly formed are wrung out using a Buchner funnel. Then, the crystals formed (white color) are dried at room temperature and ambient air before being weighed. The operation is repeated until a constant mass is obtained.
The filtrate obtained is preserved in case it gives rise to subsequent precipitates. In this case, these products will be treated in the same way as above and after verification of their conformity, and if they are compliant they will be added to the first crystallization jet.

Table 1: Summary of the 1st series of irradiations

REAGENTS	CONDITIONS AND REACTION ENVIRONMENTS		
	SOLVENT	LIGHT SOURCE	DURATION
BZP (11mmol)	C_2H_5OH	D. l	1 Day
BZP (11mmol)	C_3H_7OH	D. l	1 Day
BZP (11mmol)	C_2H_5OH	D. l	3 Days
BZP (11mmol)	C_3H_7OH	D. l	3 Days

D. l: day light

2-2-2- 2nd series of irradiations

The protocol used here is similar to that of the first series of irradiations with a few nuances. We replaced benzophenone with a series of ketones composed of 4-hydroxybenzophenone (4-OH-BZP), Benzil, fluorenone, 4,4'-dichlorobenzophenone, 2-chloroacetone, 4'-bromoacetophenone and ketoprofen. Ethanol and 2-propanol have also been used as reaction solvents. About 1.5 g of ketone was weighed precisely each time to obtain after dissolution a volume of 10 ml. Finally, 60 µL of glacial acetic acid is added to the reaction mixture, which is then irradiated for a period of 24 h when the light source is the sun and 48 h for the photolyser of the laboratory. .
The crystals formed are then filtered with Buchner, dried and finally weighed at constant weight as described previously for the first series of manipulations.

3-RESULTS AND DISCUSSIONS

1st series

Figure 1: Histogram

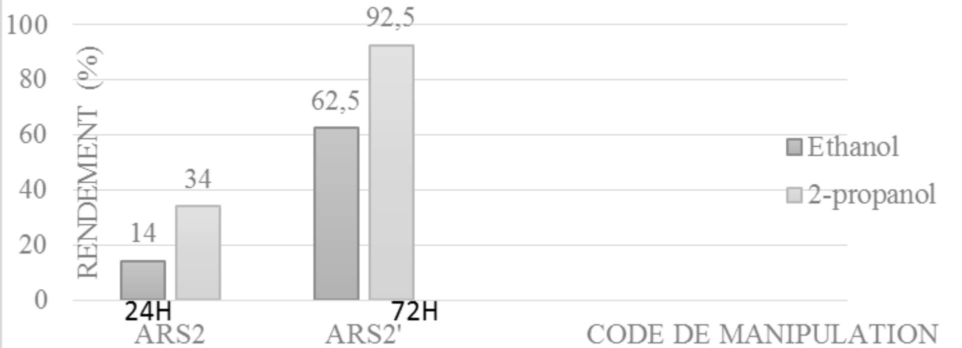


Table 2: Yields of the second series of irradiations

REAGENTS	YIELDS (%)
Benzile	29
Ketoprofen	96
9-fluorenone	98
4,4'-dichloro-BZP	65

Table 3: In ethanol

REAGENTS	YIELDS (%)
4-OH-BZP	-
2-Cl-acetophenone	-
4'-Br-acetophenone	-

Table 4: In 2-propanol

REAGENTS	YIELDS (%)
4-OH-BZP	-
2-Cl-acetophenone	-
4'-Br-acetophenone	-

Nuclear magnetic resonance spectra were recorded for the purpose of determining whether the irradiated materials were chemically modified after light treatment. To do this, initially from the Chem Draw (2D structure) file of the expected benzopinacol we generated the NMR spectrum of both protium and carbon-13.

If the experimental spectrum corresponds to that simulated (calculated) using an incremental method, it can safely be affirmed that the reaction has gone to completion in the direction of reductive photo-dimerization. If one does not obtain a complete correspondence (matching signal experimental versus calculated signal) one can deduce two things: or the reaction did not go to total completion or it was carried out following another reaction way. In addition, we also simulated the spectra of the reactants, and we proceeded in the same way as described above. This allowed us to observe that in some cases the reactant was inert to light in our experimental conditions. In the case of completion in the direction of formation of the benzopinacol derivative, this result was corroborated by dual tandem mass spectrometry.

3-1- Factors influencing reaction performance

- The solvent: In the presence of a hydrogen donor (C-H bond in the capto-dative position) and in the UV, the benzophenone absorbs a photon and is promoted from the singlet ground state to the triplet excited state. This reaction, as is clear from the results of the first series of manipulations, is all the more important in a protic polar solvent where the departure of a hydrogen in the alpha position of the functional group is compensated by various electronic phenomena. This explains the achievement of a higher qualitative and quantitative yield in 2-propanol (Yield = 34%) compared to that found in ethanol where the yield found is much lower (Yield = 14%).

- Irradiation time: A second factor closely related to the reaction efficiency is in the irradiation time. Indeed, the longer the exposure time to UV radiation, the greater the amount on a molar basis of benzophenone that populates the triplet state.

3-2- The triplet state of benzophenone

The triplet state of benzophenone can be represented by a biradical species formed through the homolytic breakdown of the pi bond at the carbonyl level. This break is to be considered as the decisive step of this reaction. The results we obtained during the second series of manipulations support this assertion. It should be noted that the second series of manipulations clearly demonstrates the important implication of electronic effects (substituents present in the vicinity of the C = O bond) in this key step of the reaction. This reaction, which proceeds with both BZP and 4,4'-dichloro-BZP, does not occur in the case of 4-OH-BZP. This could be explained by the fact that the phenolic group -OH is known as an electron-rich group producing a strong mesomeric donor effect enhances the electron density at the -C = O bond, which greatly disrupts the stereo-electronic characteristics of this carbonyl. However, in the case of 4,4'-dichloro-BZP, the two substituents -Cl in the para position act synergistically on the electron density of the carbonyl group and confer on it the stereo-electronic characteristics favorable to the generation of a triplet state. A second element that always comes from this second series of manipulations is that other arylketones such as 4'-bromoacetophenone and 2-chloroacetophenone should a priori behave globally as 4,4'-dichloro-BZP. These molecules, however, under irradiation with solar white light were found to be inert in our experimental conditions as evidenced by carbon-13 nuclear magnetic resonance spectra. Again, the two halogens which in some way adjoin the carbonyl act globally by their sensor effect, thus reduce the electron density at the carbonyl level and consequently negatively disturb the stereo-electronic characteristics. It is likely that photolysis at lower wavelengths (we are going towards more energetic wavelengths) these molecules leads to a photochemical fate that does not necessarily go in the direction of dimerizing photo-reduction: we think among others photo-dehalogenation or photo-substitution reactions.

The diphenyl ketyl radical is very stable because the single electron resides on a benzylic carbon and thus stabilized by mesomerism; moreover this radical is stabilized by the capto-dative effect as schematized in the following figure.

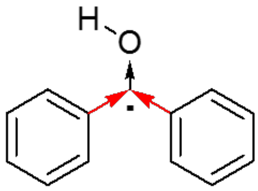


Figure 4: Radical diphenyl ketyl stabilized by capto-dative effect.

3-3- The capto-dative effect

Radical reactions play a crucial role in many chemical reactions. The capto-dative effect is the stabilization of the radicals by a synergistic effect of an electron-withdrawing substitute and an electro-donor substituent. This term comes from the fact that the Electro-Withdrawing Group (EWG) is sometimes called the "captor" group, while the Electron-Donating Group (EDG) is the "dative" substituent. . When the EDGs and the EWGs are close to the radical center, the stability of this one is increased. The substituents in question can kinetically stabilize radical species by preventing said molecules or other radical centers from reacting with the site stabilized by the capto-dative effect. This particular electronic arrangement of substituents also thermodynamically stabilizes the center by relocating the radical by delocalization of the electron deficiency formally represented in the radical center (single electron) [11].

3-4- Mechanism of photo-toxicity of benzophenone and its derivatives (ketoprofen)

Benzophenone, triplet photoexcited, can therefore attack the carbon-hydrogen bonds, forming a biradical which then leads to the establishment of a new carbon-carbon bond or a double bond. Transposed in media other than in concentrated solution, benzophenone can experience a different photochemical spell and abstract a hydrogen from a C-H bond located in its near environment. This situation is illustrated in the following figure (see figure).

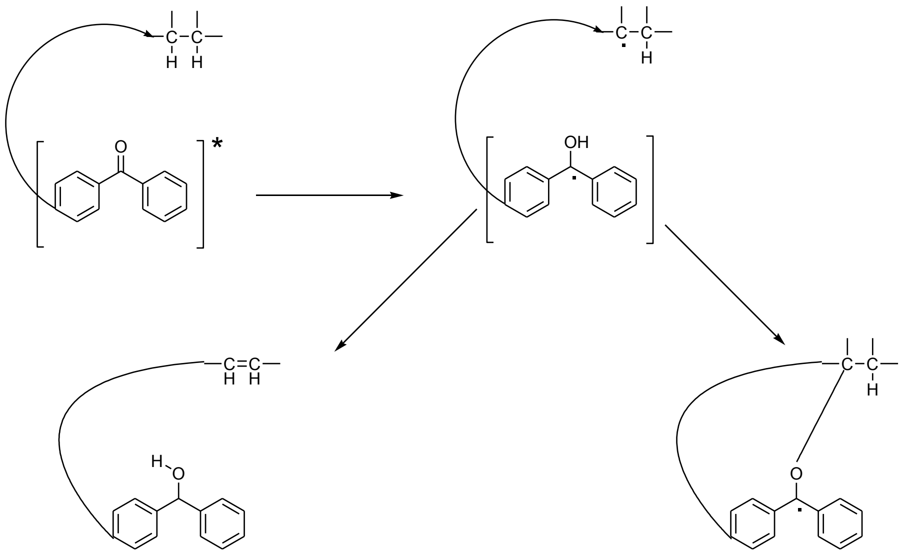


Figure 5: Mechanism of the remote functionalization by benzophenone [13].

Furthermore, in environment where oxygen is present, the diphenyl ketyl radical is likely to react with molecular oxygen [14]. The activation of this molecular entity, which-let's call it-is present in the triplet state in its ground state (and therefore in the biosphere) can be mediated by the direct interaction of two triplet states, namely that of the benzophenone triplet and triplet dioxygen or relay via the diphenylketyl radical (which abandons a hydrogen radical that can combine with the oxygen to form a radical hydro-peroxide). This state of affairs is shown schematically in the figure below [15].

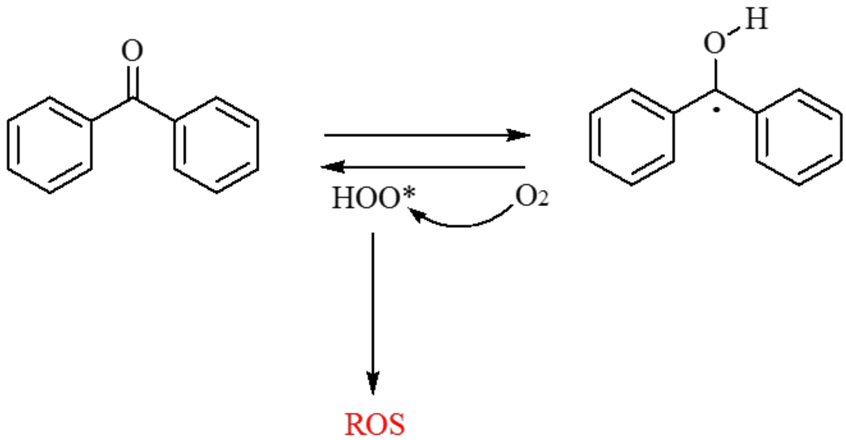
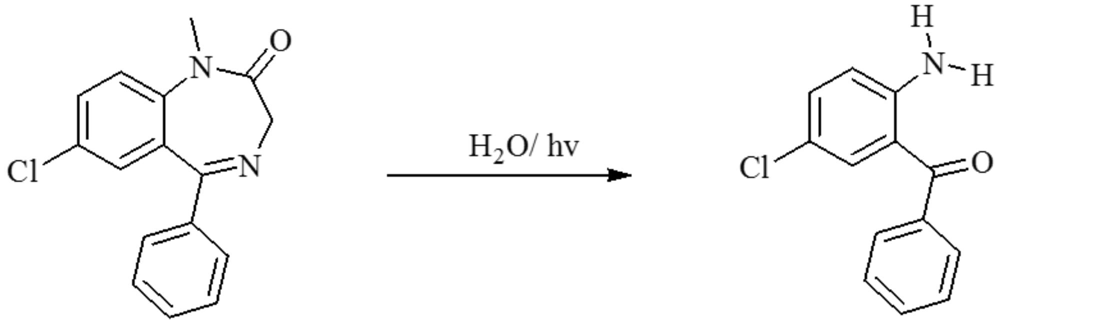


Figure 6: Production of free radicals of oxygen (ROS) by triplet oxygen and diphenylketyl radical.

The fundamental process of photo-activation of oxygen as described above (see figure above) is a special case of molecular relay by propagation of radical species as presented in FIG. 6 and is not without recall the work of Ayadin *et al* [16]. The hydrogen abstraction induced by the diphenyl ketyl radical allows the molecular grafting by a covalent bond of a sterically highly congested residue on endogenous targets that may be physiologically crucial and thus render some biological entities totally inoperative (induction of toxicity, mutagenic effects, and apoptosis). Concomitantly the photoactivation of oxygen is likely to induce the production of reactive oxygen species (hydro-peroxides and hydroxyl radicals, and superoxide anions) [17]. This event as evoked here can promote the lipid peroxidation and finally participate in the thinning of the plasma membrane which will also induce (but by another mechanism) the programmed death of the cell [18].

Our work as well as the argumentation that we have just presented make it possible to put under the same banner the well-documented photo-toxicity of benzodiazepines. In fact, the aqueous photolysis of diazepam, chosen here as a representative pilot molecule, leads to a derivative of benzophenone which will have the same photochemical fate and therefore potentially side effects similar to benzophenone and its derivatives. Recall here that the parent molecule diazepam and 2-amino-5-chlorobenzophenone both have a residual absorbance at 360 nm. In the benzodiazepine structure, the imino bond may be considered a ketone bioisosterone. Intuitively speaking, it is conceivable that this molecule can be photochemically active and bio-activated under the influence of light. In other words, it is not excluded that this double hydrolysis affecting both the amide and imine bonds is photochemically assisted. Indeed, under standard conditions of hydrolysis (thermal process) such reactions can be performed only at extreme pH and high temperatures [19].



Diazépam 2-amino-5chlorobenzophénone

Figure 7: Photolysis in an aqueous environment in presence of dioxygen Diazepam [19].

CONCLUSION

In this experimental study, we have studied in a fundamental way the behavior of benzophenone (BZP) and of a series of analogous or homologous ketones selected on the basis of their close structural proximity to BZP, under UV / VIS irradiation in the ethanol and 2-propanol. This study was conducted to provide a rational explanation for photosensitization reactions observed with ketoprofen (KTP). This approach has highlighted the involvement of a triplet state of stabilized benzophenone by the "capto-dative" stabilization effect of radical species. This photochemically activated state is capable of producing abstraction reactions of a hydrogen atom of a CH bond located in its near environment or of interactions with molecular oxygen (in environment where oxygen is present) and thus to induce the deleterious production of reactive oxygen species such as hydro-peroxides and hydroxyl radicals, as well as superoxide anions.

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Design of Efficient Welding Process for Rail Car Bracket Assembly using Taguchi and Response Surface Methodology

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Abstract

An efficient welding process is one which is fast, safe, cost-effective and produces welded structure that combines high strength with integrity. In this study, the Taguchi and Response Surface Methodology (RSM) was used for the design of the welding process for the assembly of the lower bracket of the rail car. Using the Taguchi method, the designed experiment consists of an orthogonal array of L8, eight degree of freedom (DoF) with the welding parameters in the following ranges: voltage (22-25 V), current (200-250 A), speed (0.003-0.007 m/s) and arc length (0.03-0.07 m) as input variables. The matrix generated nine experimental runs over four levels and five factors. Taking the response of the designed experiment as distortion, physical experiments were carried out according to Taguchi process parameters combinations. Also, the response surface methodology was used to study the cross effect of the input welding parameters. The statistical analysis of the results obtained brought about the development of a predictive model for the determination of weld distortion as function of the independent welding input parameters. In addition, the results indicate that the input welding parameters are critical factors that affects welding processes significantly, hence the need for effective control.

Keywords: assembly, control, distortion, model, welding
Paper category: Manufacturing

1. INTRODUCTION

The welding processes are fast, reliable and economical way of joining different materials together by fusion during manufacturing processes (Huang *et al.,* 2014; Wahid *et al.,* 2017; Sharma *et al.,* 2018). An efficient welding process is one which is fast, safe, cost-effective and produces welded structure that combines high strength with integrity. There is need to control welding process in order to prevent the introduction of distortion in final welded structure which can cause loss of loss of strength and change in geometry or orientation in welded structure, costly rework and production delays (Farkas and Jamai, 2007; Michaleris, 2011; Kozak and Kowalski, 2015; Smith *et al.,* 2017). According to Long *et al.* (2009), the arc welding process to obtain a butt surface is a combination of two mechanisms namely; frictional heating and plastic deformation. The temperature of the material is raised beyond the yield point of the material causing the material to deform plastically under the application of thermal stresses. The effects of welding residual stresses on the structural integrity, fatigue performance, service security, and service life of the welded structures are often significant (Zeinoddini *et al.,* 2013; Song and Dong, 2017), hence the need for control. There are several parameters that influences the process of welding as well as the integrity of weld such as; voltage, current, speed, arc length, degree of heat flow, welding temperature (Hu *et al.,* 2010; Nata and Babu, 2012; Hosseinzadeh and Bouchard, 2013; Sun *et al.,* 2017). Both the numerical method and experimental studies have been used to study design efficient welding processes in order to obtain feasible solutions to weld defects (Chougule *et al.,* 2104; Liu *et al.,* 2014; Xu *et al.,* 2015; Kartal *et al.,* 2016; Sun *et al.,* 2017; Smith *et al.,* 2017), however, the aim of this study is to design of an efficient welding process for rail car bracket assembly using Taguchi and response surface methodology. The combination of these methodologies for the simulation of welding processes has not been sufficiently highlighted by existing literature. Hence, this work provides design data for welding processes and optimizes welding processes via the reduction of the production cost, increases in welding efficiency and productivity thereby resulting in the production of quality and reliable welded structure.

2. METHODOLOGY

The mass of penetrated metal during the weld pass for a time t can be calculated as Equation 1.

$$m = \gamma . I . t \qquad (1)$$

where;

$t\ is\ the\ welding\ time$ (120 s);

$I\ is\ the\ current$ $(240\ A)$ $and\ \gamma\ is\ the\ coefficient\ of\ penetration$ $(31.788\ As/kg)$

$m = 31.788 \times 240 \times 120$

$m = 915.5\ kg$

The speed of welding S is expressed by Equation 2.

$$S = \frac{L}{t} \qquad (2)$$

The welding speed is given as 0.006 m/sec, therefore for 120 sec of welding, the weld length is calculated as 0.72 m from Equation 2.

The weld distortion is expressed by Equation 3

$$\delta = \frac{mL^2}{8EI} \qquad (3)$$

Where;

$EI\ is\ the\ flexural\ rigidity\ for\ the\ steel$ $(6.625904 \times 10^6 Nm^2)$.

The thermal impulse due to welding T is expressed as Equation 4.

$$T_i = \frac{\epsilon \rho A V}{\gamma} \qquad (4)$$

where;

$\epsilon\ is\ the\ thermal\ efficiency$ $(0.68\ for\ butt\ welds)$; $V\ is\ the\ arc\ voltage$ $(24\ volts)$;

$S\ is\ the\ welding\ speed$ $(0.006\ ms)$;

$A\ is\ the\ cross\ sectional\ area\ of\ the\ weld$ $(0.002\ m^2)$;

$\rho\ is\ the\ density\ of\ steel$ $(7.85 \times 10^3 g/m^3)$; and

$\gamma\ is\ the\ coefficient\ of\ penetration$ $(31.788\ As/kg)$

Hence, the thermal impulse from Equation 5 is calculated as

$$T_i = \frac{0.68\times 7.85\times10^3\times0.002\times24}{31.788}$$

$$T_i = 8.060\,J/m$$

The specific strain at the centre of gravity is given as Equation 5.

$$\varepsilon_g = 0.844\times10^{-3}\,\frac{8.060}{0.002} \quad (5)$$

Where T_i $is\ the\ thermal\ impulse\ due\ to\ welding\ (J/m);\ and$ $A\ is\ the\ cross\ sectional\ area\ of\ the\ weld\ (0.002\ m)$

$$\varepsilon_g = 3.40\ m$$

The cross section of the designed butt joint is shown in Figure 1.

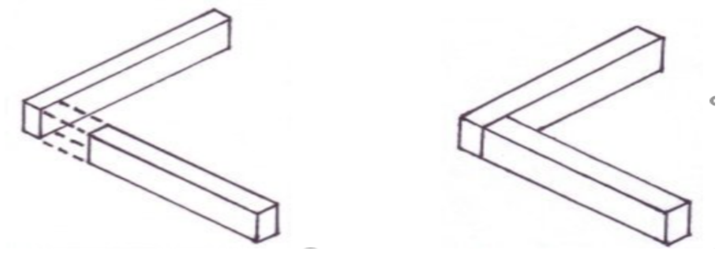

Figure 1: Butt Joint

2.1 Design of Experiment

The Taguchi method was preferred as the modelling tool because it studies the effect individual process parameters as well as the relationship between process parameters on the multi output responses (Pozo *et al.*, 2015) while the RSM was employed to study the interacting effect and influence of process parameters on the welding process. The existing literatures have proven the RSM to be a viable statistical tool for the optimization of process variables as it studies and simplifies complex experiments (Aworanti *et al.,* 2013; Enweremadu and Rutto 2015; Bello *et al.,* 2016). Using the Taguchi method, the designed experiment consists of an orthogonal array of L8, eight degree of freedom (DoF) with the welding parameters in the following ranges: voltage (22-25 V), current (200-250 A), speed (0.003-0.007 m/s) and arc length (0.03-0.07 m) as input variables. The matrix generated nine experimental runs over four levels and five factors as presented in Table 1.

Table 1: Experimental Matrix from the Taguchi Method

S/N	Factor 1 A:A	Factor 2 B:B	Factor 3 C:C	Factor 4 D: D
1.	1	1	1	1
2.	3	1	3	2
3.	2	1	2	3
4.	3	3	2	1
5.	1	3	3	3
6.	2	2	3	1
7.	2	3	1	2
8.	3	2	1	3
9.	1	2	2	2

The process parameters were introduced as decision variables into Table 1 with distortion (mm) as the output response which was determined experimentally as presented in Table 2. The physical experiment was conducted according to Taguchi process parameters combinations presented in Table 2 using the gas metal arc welding.

Table 2: Experimental Determination of the Distortion from the Taguchi Matrix

S/N	Factor 1 Voltage (V)	Factor 2 Current (A)	Factor 3 Speed (m/s)	Factor 4 Length (m)	Actual Distortion (mm)
1.	22	200	0.003	0.03	6.102×10^{-2}
2.	25	200	0.007	0.05	5.567×10^{-2}
3.	24	200	0.005	0.07	5.200×10^{-2}
4.	25	250	0.005	0.01	6.987×10^{-2}
5.	22	250	0.007	0.07	7.340×10^{-2}
6.	24	240	0.007	0.03	3.230×10^{-2}
7.	24	250	0.003	0.05	4.769×10^{-2}
8.	25	240	0.003	0.07	4.986×10^{-2}
9.	22	240	0.005	0.05	8.230×10^{-2}

The statistical analysis of Table 1 produces a model that predicts the distortion during welding processes as function of the independent welding process parameters (Equation 6).

$$Distortion = +0.058 + 9.877\times10^{-3}\times22A - 0.014\times24A - 8.437\times10^{-3}\times200B - 5.737\times10^{-3}\times240B - 7.063\times10^{-3}\times0.003C - 1.367\times10^{-4}\times0.005C - 2.267\times10^{-4}\times 0.03D + 3.127\times10^{-3}\times0.05D \quad (6)$$

where; A is the voltage (V); B is the current (A); C is the speed of welding (m/s); and D is the arc length (m).

The developed model was validated by comparing the values of distortion obtained via physical experiment with the predicted output of the model.

Table 3: Comparison of Distortion values from the Physical and Numerical Experimental

S/N	Actual Distortion (mm)	Predicted value of Distortion (mm)	Deviation (mm)
1.	6.102×10^{-2}	6.00×10^{-2}	0.00102
2.	5.567×10^{-2}	5.557×10^{-2}	0.00010
3.	5.200×10^{-2}	5.320×10^{-2}	0.00120
4.	6.987×10^{-2}	7.0×10^{-2}	0.00013
5.	7.340×10^{-2}	7.540×10^{-2}	0.0020
6.	3.230×10^{-2}	3.200×10^{-2}	0.00030
7.	4.769×10^{-2}	4.07×10^{-2}	0.00699
8.	4.986×10^{-2}	5.02×10^{-2}	0.00034
9.	8.230×10^{-2}	8.105×10^{-2}	0.00125

Figure 2 is a plot of the actual values of the weld distortion from the physical experiment and the numerical experiment from the developed model.

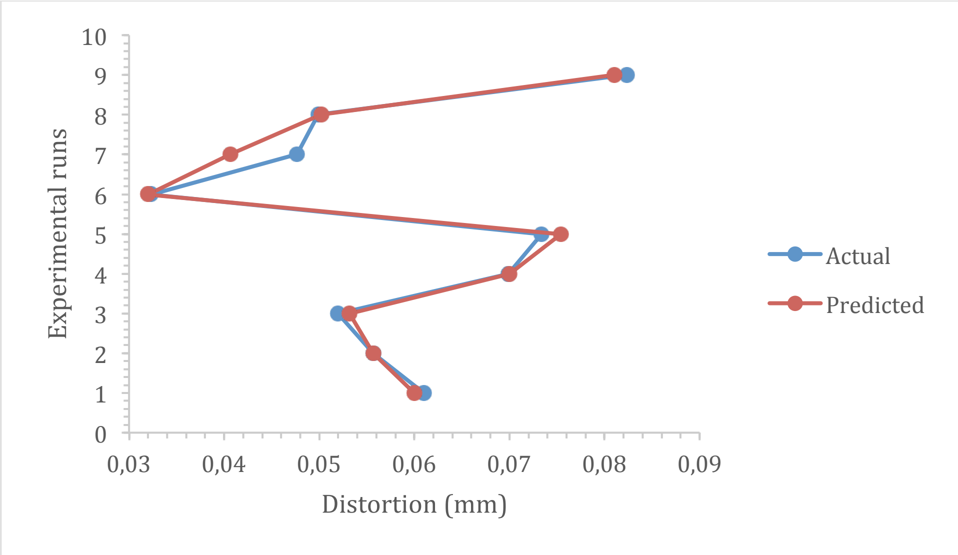

Figure 2: Plot of Actual and Predicted values of Distortion

From Figure 2, the actual values of distortion from the physical experiment agrees significantly with the predicted values of the developed model with negligible error (Table 3), hence this confirms that the developed model can adequately predict the weld distortion.
Figures 3-6 show the convergence and changes in the orientation of the welded components. From Figure 3, the value of current increases as the voltage increase. This agrees with the Ohm's law. Hence, increase in the value of voltage brings about increase in current with increase in the depth of penetration. The depth of penetration is the distance that the produced fusion extends into the base metal during welding. The deeper the degree of penetration, the lower the distortion and vice-versa. When the values of the welding speed and arc length were kept at the values of 0.01 m/s and 0.06 m respectively, the interaction of the current and voltage produces a maximum distortion of 0.06 mm. The value of distortion however decreases to 0.45 mm when the values of current and voltage reduces to 200 A and 22 V respectively. Increase in the values of current and voltage beyond this optimum tends to increase the values of distortion.

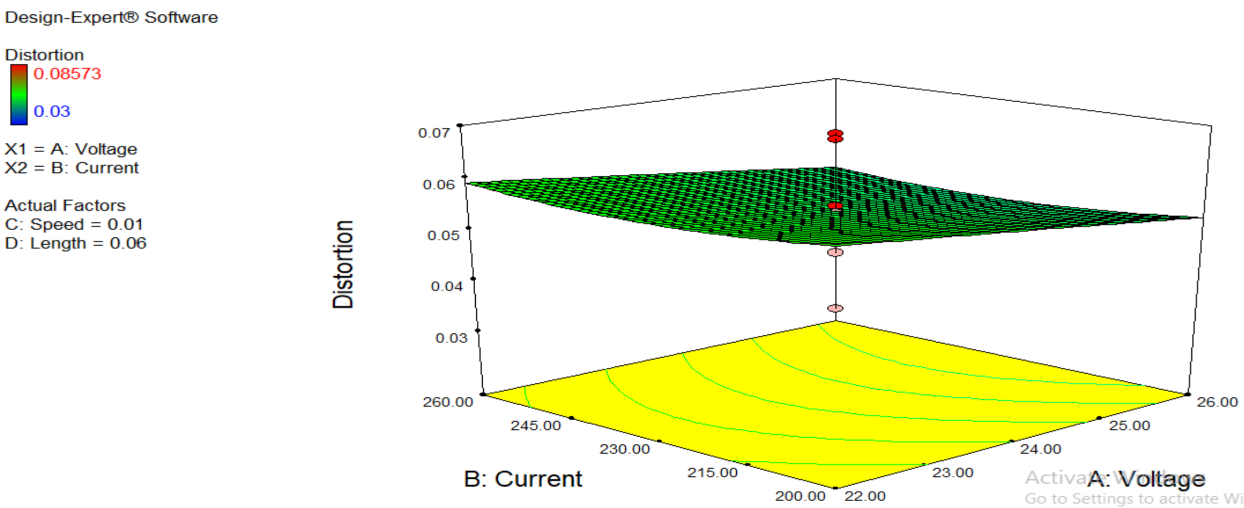

Figure 3: The Cross Effect of Current and Voltage

Figure 4 studies the cross effect of welding speed and voltage. The welding speed is the time it takes the electrode to travel down the joint and transfer the arc energy into the base material at any particular point along the joint. As travel speed increases, welding time decreases with decrease in the depth of penetration. When the values of the current and arc length were kept at 230 A and 0.06 m respectively, the interaction of the welding speed and voltage produces a maximum distortion of 0.0543 mm. The value of distortion however increases from 0.0543 mm to 0.5925 mm when the values of welding speed and voltage increases.

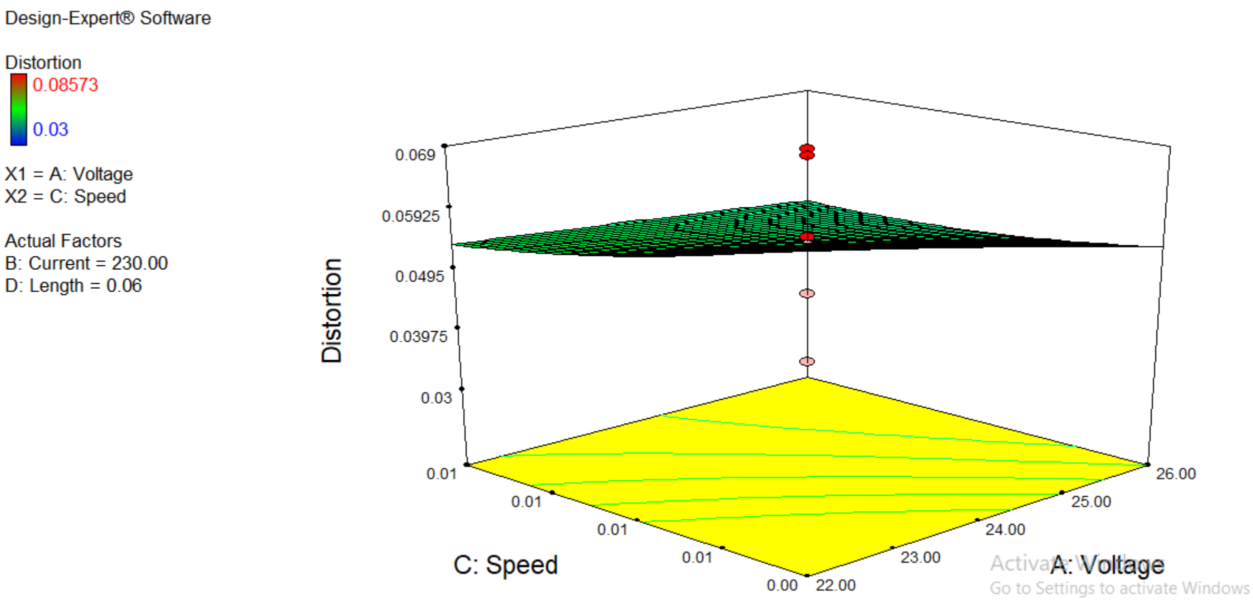

Figure 4: The Cross Effect of Speed and Voltage

Figure 5 studies the interaction between the arc length and voltage. The arc length is the distance between the molten weld pool and the filler material at the point of melting. When voltage decreases, the arc length increases and vice versa. The arc length in turn determines the width and size of the arc cone. As the arc length decreases, the arc cone becomes narrower and the arc is more focused. This result in a weld bead that is narrow and ropy. The level of weld penetration may increase very slightly producing lower distortion. Conversely, as the arc length increases, the arc cone becomes wider and the arc is broader. The result is a weld bead that is wider and flatter and the level of weld penetration may decrease very slightly resulting in greater distortion. When the values of the current and speed is kept constant at 230 A and 0.01 m respectively, the maximum distortion was observed to be 0.05925 mm when the arc length and voltage values were 0.08 m and 26 V respectively. As the value of the arc length decreases to 0.04 m, the value of distortion also reduces to 0.0348 mm.

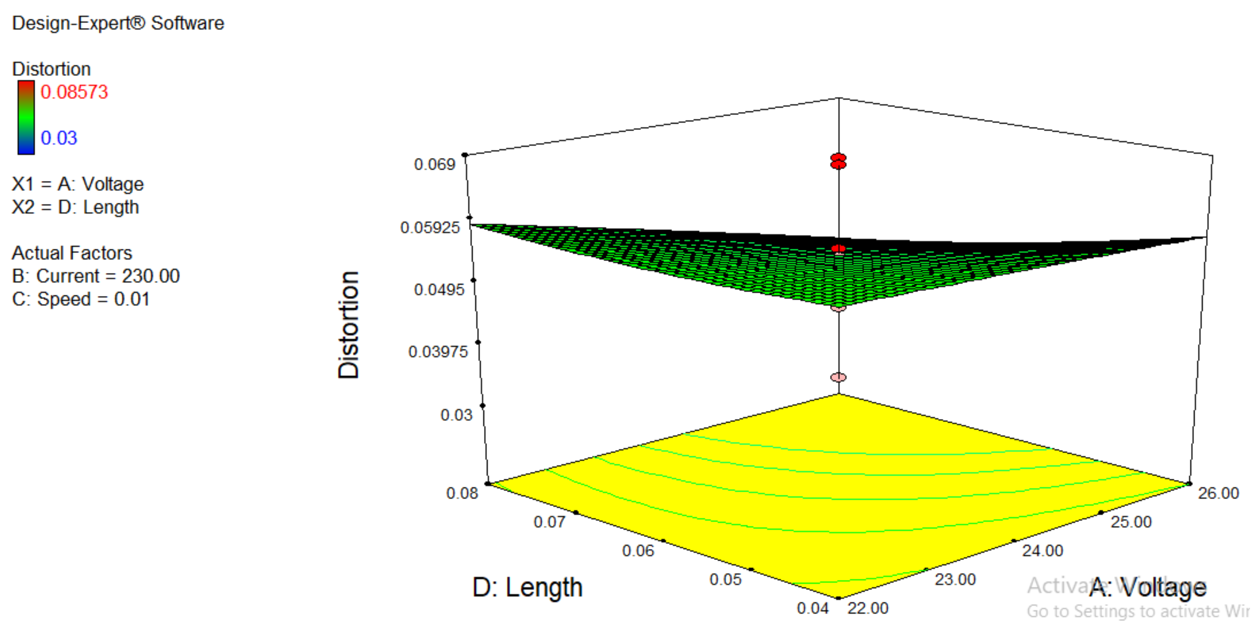

Figure 5: The Cross Effect of Length and Voltage

Figure 6 studies the interaction between arc length and current when the values of voltage and speed were held constant at 24.59 V and 0.01 m/s respectively. The maximum and minimum distortion was found to be 0.570 mm and 0.05075 mm respectively. An increase in the value of the current decreases the arc length and vice versa resulting in deeper weld penetration thereby producing minimal distortion.

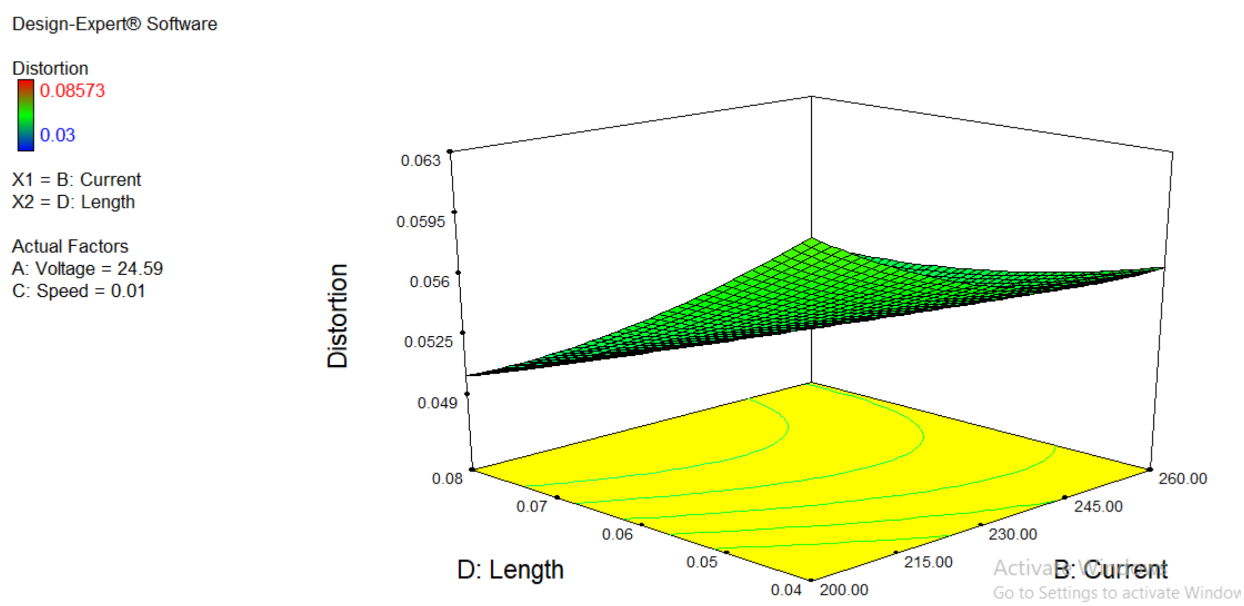

Figure 6: The Cross Effect of Length and Current

4. CONCLUSIONS

The effect of welding process parameters namely; voltage, current, speed and arc length on welding process was studied using the Taguchi method and RSM. The developed model can adequately predict the values of weld distortion judging from the high degree of correlation between the actual and the predicted values. Also, the results obtained indicated that the process parameters were critical as they affect the welding process significantly. The combination of the process parameters that gave the least distortion (0.0348 mm) was found to be; voltage (24 V), current (230 A), speed (0.01 m/s) and arc length 0.04 m. This is essential in the design of welding processes that are fast, reliable, cost effective and safe.

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Nature and composition of ego-centred actor networks for innovation in rural areas: evidence from rural Mopani District, South Africa

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Abstract
There is a glaring absence of empirical evidence on the social dynamics of innovation networks in rural contexts. To date limited work has been done in South Africa to systematically explore actor networks for innovation among rural enterprises. The purpose of this article is to explore the dynamics of actor networks and how they relate to innovation in rural contexts of South Africa. Using evidence from rural based agro-processing enterprises, the evidence reveals diverse characteristics of actor networks. These networks are composed of local and non-local actors including those actors that are not traditionally recognised as innovators in the conventional South African NSI framework. Nonetheless participation of external actors is characterised by a limited number of these actors, the linkages and the practices are often top-down, while local linkages are characterised by locked-in but free movements to search for new knowledge. From a policy perspective, we need to look differently at local innovation networks and not try to squeeze it into the NSI framework. Instead, the empirical evidence reveals a different picture and given the research we need to ask how best policy can support innovation in rural areas?

Key words: actor network, ego network, rural contexts, actors, links

1. Introduction

It is acknowledged that innovation is a network driven process. These networks are complex structures of actors that consider all activities that influence the development, transfer and use of innovative knowledge. As a result learning, information exchange and innovation are affected by the contexts and structures in which the innovating enterprises are embedded in. Moreover the innovative capability, absorptive capability and innovation performance in general is influenced by network structural features (Ferru & Rallet 2016). While networking among innovation actors is recognised as a driving force of innovation process, the social dynamics of rural actor networks remain ambiguous. The limitations remain in the literature about the composition and content of linkages (Jack 2005; Liverpool-Tasie& Winter-Nelson 2012; Lamers *at al*. 2017) and role of different actors in supporting innovation (Hermans*et al*. 2013; Kumar 2014). There is a general limitation in our understanding about the social dynamics within actor networks and networking processes (Huber & Fitjar 2016).

Actor networks and their importance has been a subject of significant inquiry in innovation studies (Freeman 1991). They have been shown by previous research to have a positive impact on interactive learning, knowledge creation and innovation (Gilbert *et al*. 2001; Powell & Grodal 2005) and they are also a foundation for systems of innovation (Esparcia 2014). In essence innovation occurs through an on-going process of learning, searching and exploring (Lundvall 2009; Singh & Bhowmick 2015). As recognised in extensive literature (Powell *et al*. 1996; Bell 2005; Fritsch & Kauffeld-Monz 2010; Knell 2011; Isaksen & Karlsen 2016), networks serve as a locus of learning that caters for both formalised and informal learning processes and sharing of indigenous knowledge and scientific knowledge at all levels of the society. Despite a widespread acknowledgement of the importance of networks, there is still limited empirical evidence that provide insights on the composition of actor networks in relation to innovation (Chaminade & Plechero 2012) and on the roles of diverse actors in networks (Hermans*et al*. 2013; Asheim *et al*. 2016).

It is acknowledged that innovation networking among actors enhance their innovation performance (Powell *et al*. 1996; Fritsch & Kauffeld-Monz 2010; Knell 2011) making it necessary to study the nature and dynamics of networking systems. However, this contribution of research on networks is bearing little relation to the realities of innovation and social relations in poor rural areas. These studies have not explored in depth questions in relation to what kind of network linkages matter for innovation; to what extent such linkages are systemic in nature; and what the roles and functions of different actors are (Chaminade & Plechero 2012; Hermans *et al*. 2013; Kumar 2014; Chindime *et al.* 2016). While previous studies have contributed to the understanding of how actor networks may support the development and introduction of innovations, there is still limited empirical evidence that reveals interplay between actor network composition, the determinants of network emergence and innovation output or change among enterprises in the rural context (Ramoroka *et al*. 2014). In addition, there are gaps in our understanding of the ways in which networks facilitate learning and improve innovation (Bessant *et al*. 2012).

From systems of innovation perspective and network approach it is emphasised that public and private sector actors as well as policy makers are involved in the innovation process (Todtling*et al*. 2009). In addition it is pointed out that universities and science councils are key innovative knowledge producers in the National Innovation System (NSI) approach – the adopted policy framework in South Africa (Kruss 2006; Kruss & Lorentzen 2011). In South Africa as in certain other developing countries, the policy perspective is on innovation carried outby formal organisations within formalised structures which results in the poor being isolated from the process (Hart *et al*. 2012; Lorentzen 2010). This said, there are studies which recognise innovation among enterprises in rural setting and non-formal structures, and observes rural enterprises engage in innovation networks to boost their innovative capabilities and performance (QUNO, 2015).

The research presented in this paper attempts to answer the following questions: what are the compositional dynamics of actor networks and networking behaviour of socially and economically oriented enterprises in rural areas of South Africa? It should be noted that to date no work has been done to systematically explore composition of actor networks and how they link with interactive learning patterns with an intention to identify policy actions that are relevant to resource poor enterprises in rural South Africa. The impetus for this paper emerged from the observation that, while the concept of NSI has existed in the South African policy domain for about two decades, rural network systems are poorly conceptualised and understood. In an attempt to contribute to the empirical gap mentioned above, this study explore ego-centred actor networks to understand the composition of actor networks in relation to innovation using evidence from rural South Africa. Theoretically we draw from systems of innovation, agricultural innovation system and network theory as this research is concerned with rural innovation networking behaviour. Given that there is limited empirical research on network components at a dyad level particularly in rural South Africa, we adopted an open ended exploratory case study approach and qualitative egocentric social network analysis to understand the compositional dynamics of actor networks and networking behaviour in rural contexts.

2. Conceptual framework

Innovation and networking have been studied using different approaches; innovative milieu approach (Maillat 1998), systems of innovation (Lundvall 1992; Nelson 1993), regional innovation systems (Cooke *et al*. 2000), sectoral innovation systems (Malerba 2005), clusters (Malmberg & Maskell 2002; Porter 2008) and innovation networks (De Bresson & Amesse, 1991; Freeman, 1991; Powell & Grodal, 2005). These dominant perspectives, tend to sideline more recent literature on the geography of innovation from the early 2000s which indicate that innovation systems are neither necessarily territorially-bound, nor dependent on proximate relationships; and accordingly involve a broad set of actors part of multi-scalar innovation networks (Asheim *et al*. 2016; Shearmur *et al*. 2016; Tödtling & Trippl 2016).

Nonetheless, existing literature have not paid adequate attention to the nature and dynamics of actor networks in relation to innovation in rural contexts. Since systems of innovation and studies of innovation networks are more explicit on the types of interactions and links (Todtling *et al*. 2009) we adopt them as the basis of the conceptual framework in this study.
In the context of innovation systems in rural areas, networking among innovators has been widely acknowledged (Spielman *et al*. 2011, Esparcia 2014). The paper also draws from the Agricultural Innovation Systems (AIS) which also follows the systems perspective which has influenced the understanding of innovation networks in rural areas. AIS is understood as a system that bring different actors together to bring about different types of innovations and the institutions that influence how actors interact (QUNO 2015). The scope of innovation has gone beyond the technocratic nature of innovation and innovation is now understood as a social process embedded in complex systems (QUNO 2015). Fundamental to AIS is that actors do not act in isolation but collaborate in complex networks.

In recent decades there has been recognition of innovation as complex process that includes both technical and social dimensions (Pereira & Romero 2012). Thus innovation incorporates the traditional R&D processes and the social activities that influence these innovations (Rose & Winter 2015).In the third edition of the Oslo Manual (OECD & Eurostat 2005) innovation is defined as the process of making changes to products, services, processes, organisational structures and making strategies in an economy or society (Neumeier 2011; Pereira & Romero 2012; Singh & Bhowmick 2015). The study adopts the definition of innovation as an outcome of a collective process that is dependent on the social structure in which the actor operates (Singh & Bhowmick 2015).

2.1 The concept of networks

The concept "networks" has emerged as both a theoretical model and practical method within sociological studies of science and technology as well as within economic theory (Tijssen 1998). It has become widely utilised in socioeconomic studies and their application to economic problems (Debackere*et al*. 1994; Murdoch 2000). There are many definitions of actor networks (see DeDresson & Amesse 1991; Freeman 1991). In a seminal paper on networks, Chris Freeman (1991) regarded networks of organisations as institutional arrangements to overcome challenges of access to knowledge and resources in innovation processes. He further referred to innovation networks as "loosely coupled organisations having a core with both weak and strong ties among constituent members" (Freeman 1991: 502). Rappa & Debackere (1992) defined networks as a group of scientists and engineers working towards a solution of an interrelated problem-set and communicate with each other regardless of where they are located. Powell (1990) regarded networks as a viable pattern of economic organisation. In this study we adopt a definition of networks as innovation enterprises working together (see DeDresson & Amesse 1991; Freeman 1991).

2.2 Aspects of network composition in relation to innovation- A conceptual framework

Extant literature in networks (Powell *et al*. 1996; Gulati 1995) has paid attention to network formation at a dyadic level. Knoben *et al.* (2006), at the time of their study, observed that limited attention has been paid to the network process after the network has been formed. Perhaps more specifically, little is known about the dynamics of rural actor networks. The network components such as actors, actor characteristics, links and flows are often overlooked in network research (Knoben *et al*. 2006; Chaminade 2011). In rural contexts, actor networks are often composed of clusters of individuals or enterprises. They are fundamentally social relationships influenced by trust (QUNO 2015). The rural sector comprises of a wide range of actors that often operate in the informal economy. These enterprises collaborate into innovation networks. Networks are formed by different enterprises belonging to different sectors (Corsaro *et al.* 2012). These actors are often involved at different stages of the innovation process. For instance, Iizuka (2012) highlights that, some of these actors are not directly involved in production networks. Murdoch (2000) points out that, rural networks are largely based on high trust relations. The formation of rural networks tends to be influenced by the socio-economic and natural entities embedded in local contexts.

A distinction is made between formal and informal actor networks (DeBressen & Ammese, 1991; Head, 2008; Shearmur 2011; Huggins *et al*. 2012; Klerkx & Aarts 2013). Formal networks are those collaborative practices and activities based on a contractual basis (Van Aken & Weggeman 2000). They can be formed with a deliberate action or goal. Examples of formal networks include strategic alliance and joint ventures (Van Aken & Weggeman 2000). The contractual agreements in a formal network setup specify the objectives of the network, the anticipated contribution by each actor and the goal as well as network life (Van Aken & Weggeman 2000). Formal networks consist of regulations, contracts and rules that link actors and activities with varying degrees of constraint while informal ones are mainly informal in nature, linking actors through open chains and very difficult to measure (Freeman 1991).
Unlike formal networks, informal actor networks are not based on any spelled out contractual agreements. They can emerge at any time and level in an innovation process. Informal innovation networks have an emergent character, they are not created with a deliberate action but emerge organically as a result of interactions of enterprise representatives (Van Aken & Weggeman 2000). However, in some instances, informal networks emerge as a deliberate action by the mobilising actor (Van Aken & Weggeman 2000). Actors often collaborate into informal networks based on mutual trust. In informal networks, collaborative activities have loosely defined boundaries.

In both formal and informal collaborative arrangements, we can observe unilateral exchange of innovation know-how, bilateral and multilateral exchanges. According to Van Aken and Weggeman (2000) in some cases knowledge is exchanged for financial gains and in some cases knowledge is exchange for knowledge. The latter shows the importance of reciprocity in network relations particularly in bilateral network relations.

3. Research approach and methods

According to Yin (2006) research design is about the logical sequence up to conclusions in a study. In innovation and actor network research, both quantitative and qualitative approaches have been applied and their choice is often guided by the research question. However, both of these approaches have their advantages and limitations. In order to gain more and detailed insights into the role and functioning of actor networks for innovation in rural development, it is best to adopt the methodology that allows the exploration of self-organising and interactive practices of actors (Neumeier 2011; Shearmur *et al*. 2016). In this sense, case studies are suitable to understand complex social phenomena (Yin 1994; 2013) such as the nature and types of actor relations and patterns of innovative learning. In addition, exploratory case study approach can provide holistic descriptions and interpretations of innovation activities and actor network mechanisms (Sørensen 2004). The key factor for considering multiple case study approach is that this approach enables one to explore differences within and between settings (Baxter & Jack 2008). It is also apparent to highlight that innovation is understood as the implementation of new or significantly improved products, process, organisational arrangements and marketing strategies in this paper. The innovation must be new to the enterprise (Zitek & Klimova 2016).

3.1 Case study and data collection

In multiple case study research, a sample would normally be four or five cases (Arthur 2011). Qualitative research largely uses small samples that are selected purposefully (Williamson 2006). The rationale for purposefully selecting cases is in selecting cases that are information rich for in-depth analysis. In addition exploratory case studies require detailed analysis for a subject. For these reasons four cases were selected and investigated in this study. These four cases are from the agricultural sector and involved in agro processing of different commodities and on biogas production. The four cases for part of the on-going research on rural innovation undertook by Human Science Research Council. The selection was influenced by the interest of the study and the perceived richness of information that can be collected from these for cases for an in-depth study.

For primary data collection, in-depth semi-structured interviews were conducted with key informants within the focal actor. A purpose sampling method was used to select interviewees. Purposive sampling involved criterion by the researcher and convenience sampling. Purposive sampling can also be used, where for example key informant (such as managers) from an organisation will provide a list of individuals to be interviewed based on their job responsibilities and involvement in the subject being researched (Noor 2008). Innovations within an enterprise need different persons to be involved: a person/s with specific technical knowledge to change existing production processes, as well as a person/s higher up in the hierarchy who backs the changes in the internal rules and systems (Hermans *et al*. 2013). This assertion was relevant in this study because the types of innovations, size of enterprises, and nature of operation varies among the four cases selected in this study. For the purpose of this study, key informants were selected at different levels within the enterprise to provide detailed information on innovation activities, networking, learning and exchange process. Therefore, the focus of the study was not based on individual perceptions within the enterprises but rather the dynamics of actor networks and innovation. For this reasons, the number of key informant interviews within the enterprises varied. Another reason that influenced the number of interviews was the referral approach that was adopted in the study.

3.2 Research methods

SNA has developed as an approach for studying relations between actors employing various quantitative and qualitative methodologies (Edwards 2010). Despite the current dominance of quantitative network analysis, there is also a tradition of qualitative driven SNA in network analysis (Alexander 2009; Edwards 2010). The choice of the appropriate measure in SNA is guided by what the researcher intends to reveal (Coulon 2005). In this sense, the study adopted qualitative driven SNA that considers the configuration and dynamics of networks (Alexander, 2009).

Qualitative driven SNA is exploratory and summative, therefore and egocentric approach to network analysis is appropriate (Alexander 2009). Egocentric approach is one of the methods in SNA (Crossley *et al*. 2015). It was adopted to examine the network components of a focal actor, unlike 'sociocentric' approach (whole network analysis) that focuses on the structural patterns of the network of a whole network (Alexander 2009; Leavy 2011). Egocentric approach in SNA was adopted in this study to understand the compositional dynamics of actor networks. Egocentric approach refers to actor-centred analysis also referred to as ego-net. An ego-network is a network that forms around a particular actor in a social space (Crossley *et al*. 2015). According to Alexander (2009) egocentric approach present a bottom up perspective to studying networks at a dyad level. For this reasons this method provided an appropriate framework to examine network activities, actor roles, content of linkages and functions in actor network. Ego network research focus on how the success is a function of an individual (actor)'s social ties. This looks at how network ties facilitate access to resources and support (Borgatti*et al*. 2013). Ego network approach is often carried out at actor level and it takes into cognisance the characteristics of actors and how they influence the composition and structure of networks. Egocentric approach enables the exploration of the composition of actor networks (Rice &Yoshioka-Maxwell 2015).

4. Findings – cases

Case A- Description and ego network of NBef organics

NBef organics is involved in the production of organic vegetables and processing of moringa leaves. NBef organics plant, harvest the leaves, dry and grind the leaves into powder for human consumption as nutrient supplement. Moringa powder is packed into sold as powder and capsules. A 100g of moringa powder is sold between R80-00 and R120-00. The innovative idea of moringa leaves processing was learnt through interactions with external actors. NBef had introduced organisational and product innovations at different stages of processing of moringa leaves into powder and capsules, which resulted from the formation and interaction with external actors. Thus, NBef did not innovate in isolation but through interactive learning and exchange processes as reiterated in the innovation literature.

NBef's ego network was composed of public/ state agencies, private enterprise from both formal and informal sector, non-government organisations and associations. The state agencies included Limpopo Department of Agriculture (LDoA) and Department of Rural Development and Land Reform (DRDLR). The involvement of NBef with the two institutions was contractual. LDoA has contracted NBef to provide training to CPAs, establishing formal linkages. The department have contracted NBef to provide training for farmers in different practical and technical skills, including moringa production. NBef also interacted with extension service officers who offered agricultural advices as part of the mandate of the LDoA. The linkages with extension service officers presented an opportunity for NBef to learn about moringa and have access to information events and exhibition organised by the department. NBef's involvement with DRDLR was resource based. The enterprise leased land from the department. The linkages between the two enterprises were purpose built as NBef approached DRDLR to seek infrastructure support. The DRDLR has provided support by assisting this enterprise to access a moringa leaf powder capsule packaging machine. The packaging machine could be regarded as external knowledge as it was been developed outside the locality and NBef adopted and used the machine in their on-going activities. By the time the machine was introduced the enterprise was already involved in moringa leaf processing for human consumption.

NBef had a relationship with two product associations, namely the Moringa Development Association of South Africa (MDASA) and the Cassava Growers Association (MORCASA), The linkages with Moringa and MORCASA was formal through a membership contract. NBef paid a membership fee to become a member of this association. MORCASA provided a platform where farming enterprises could exchange information and knowledge and also provided knowledge and information to members, particularly on moringa and cassava production. NBef established informal linkages with the MDASA and was a non-registered member of the association but did not acquired formal membership. MDASA was a local moringa association that intended to promote the use and production of moringa in South Africa through collaboration, research, training and information sharing. NBef interacted with MDASA members through a social media platform, namely a WhatsApp chat group, whereby members exchanged information and knowledge, and sought advice when facing production challenges.

The enterprise also exchanges information on moringa oil extraction with Knysna, a Cape Town based enterprise trading in moringa oil. The relation between the two enterprises was driven by the need for Knysna to purchase oil from NBef. The enterprise also engaged in promotion and market-driven relations with Letsitele Moringa. Letsitele Moringa was a local moringa distributing enterprise and a well-branded retail and distribution outlet that sold powder, tea and capsules. This enterprise actively participated in product exhibitions and road shows. NBef has put some of the processed moringa products on the shelves of Moringa Letsitele. NBef was involved in group marketing to meet demands of the farmers from the Communal Property Association on an ad hoc basis.

NBef received institutional and regulatory standard support from CBI, based in the Netherlands, and BCS, which was German-based. BCS was an organic production certifying body that conducted inspections and certifications of operators in countries of the third world. NBef received organic certification for moringa from BCS. The involvement with CBI, a centre that specialised in the promotion of imports from less-developed countries, was informal. CBI provided the enterprise with training on how to participate in export markets for moringa products. The LDoA assisted NBef to obtain a food safety standards certificate by providing information to the Hazard Analysis and Critical Control Points (HACCP).

Case B- Description and ego network of Wolkberg fruit processors

The WFP factory is located in the Nkowankowa Industrial Park, next to the Nkowankowa location in one of the impoverished rural district municipality called Mopani in the Limpopo province. The factory is specialising in mango processing into juice pulps and dried fruits. WFP processors engaged in innovation and interactive learning processes with a host of enterprises from different localities but limited sectoral variety. These actors included state agencies, farmers, processors, civil society and households. The factory received start-up funding from DST. The factory was involved with the Limpopo Economic Development Agency (LEDA), which leased a building to the factory at the industrial park in Nkowankowa area. The factory also engaged traditional authorities who provided support and assisted in getting buy-in from the community in the area. This relation was used to create awareness and encouraged small-scale farmers and households to grow more mangos and supply the factory for processing. The interaction with civil society was particularly important for social support and building more social structures to facilitate the supply of fruits to the factory. The factory hired labourers locally as a way of contributing to the local livelihoods. Such behaviour has strengthened the links and trust between these actors.

The factory had limited interaction with the local municipality to facilitate access water and electricity. This relationship was not reciprocal as the enterprise only visited the municipality if they experienced problems with water and electricity supply. At the supply and storage stage of the processing, there were increasing interaction with local actors who produced mangoes. The linkages were reciprocal because the enterprise needed the supply of mangoes while alters or network partners were in search for markets which they can supply to. However, learning activities between these actors were limited. The linkages were established for fruit-supply purposes. The actors in the ego network that supplied mangoes to the factory, included CPA farmers, commercial farmers, “bakkie traders”, and households who grew mangoes in their gardens and back yards. The factory had an informal relationship with most of these farmers, particularly the non-commercial farmers.

Contractual supply linkages were established with Ledzee Estate, a commercial mango grower that concluded contracts with the factory to supply mangoes. There was also evidence of knowledge and information exchange between WFP and Ledzee. Ledzee provided training on handling the fruit delivered to the enterprise and project management. WFP had accessed services and product specifications for quality and consumption safety at the small Letsitele branch of QMS laboratories. The relation was service-based and not formalised. The factory paid a fee for the quality assessment services.

WFP also established linkages with three other mango processing enterprises located at the Nkowankowa industrial park. These linkages could be interpreted as competitor linkages as these enterprises competed for the supply of mango fruit for processing. The linkages were these enterprises were regarded as more beneficial as indicated by the manager, since these linkages also served as a market for their juice pulps and dried mango fruit. BNS purchases surplus dried fruits from WFP and both Bronpro and Granopasse bought its surplus juice pulp. BNS, Bronpro and Granopasse are private entities that were strict on HACCP regulations and did not acquire mangoes from informal traders, sucyh as CPA farmers, “bakkie traders” and households.

Case C- Description and ego networkof Mpfuneko rural biogas

The rural biogas enterprise is a locally based non-governmental and non-profit organisation that constructed and operated biogas digesters to produce ready to cook biogas. It was founded in 2007 after receiving donor funding from Dutch based organisation to pilot test the use of ready to cook biogas in rural areas. Its aim was to improve the standards of living in households in rural areas by introducing the use of biogas for cooking to rural communities. These biogas-digesters enable households to cook using the produced gas instead of the traditional fuel wood cut from the forests. The biogas enterprise is based in Gawula village and the first biogas digester was constructed and operationalised as experimentation and demonstration site in Gawulavillage.

Mpfuneko collaborated with different enterprises to bolster their operations. This enterprise joined into non-contractual relations with the municipal district office, the local municipality and the local department of agriculture. These linkages contributed to awareness of ready-to-use biogas in the local area. Furthermore, the enterprise interacted with the district municipality to access water to produce gas. The traditional authorities played a key role in offering land to Mpfuneko. Traditional authorities also acted as gate keepers in different areas, which created ease of entry and trust in the communities. Another form of partnership arrangement was between households and the enterprise. This was a contractual relationship whereby the households sign the ready-to-use contract. The households committed to paying a fixed fee on a monthly basis and the enterprise ensured the digesters were filled with cow dung and produced gas for cooking.

Mpfuneko also collaborated with funding institutions through special programmes. SANEDI provided funding for training of local people and subsidising the construction of biogas digesters in the households in Gawula. SANEDI has subsidised the construction of 55 biogas digesters in Gawula. Energy and Environmental Partnership Programme (EEPP) also provided funding for training of local people and subsidising the construction of biogas digesters in the households in Mniginisi and Siyandani. EEPP is a special programme jointly funded by international stakeholders. The key objective is to contribute to the reduction poverty by promoting inclusive and job-creating green economy and by improving energy security in the southern and East Africa regions while mitigating global climate change.

With an intension to make the biogas for cooking scalable, the enterprises formed an organisational arrangement with Tivarixaka disability project and cattle owners as partner organisations. The enterprise also interacted with a Cape Town based biogas enterprise called Gender CC on ad hoc basis through workshops. Gender CC has demonstrated biogas digesters using plastic material than bricks and cement. ZZ2 in mooketsi popularly known for producing tomatoes has an enterprise that concentrates on livestock production. ZZ2 has entered into a verbal agreement with the Mpfuneko to acquire cow dung. The relationship was entirely on access to cow dung to curb supply shortages in Giyani area. The relationship was fruitful in and during drought season as many cattle died of hunger resulting in shortage of cow dung. Mpfuneko joined the Greater Giyani local economic development (LED) Forum.

Case D- Description and ego network Ledzee estates

Ledzee is a privately-owned entity that specialises in mango production, sales and processing. This enterprise has established close and loose ties with different enterprises within the local area and outside. Kgogongwe bricks and mango depot was one of the key network partners that interacted with Ledzee at the level of supply and storage of mango fruit. Kgogongwe specialises in buying green mangoes and selling them to big commercial archar producers in the area. When Ledzee experienced a shortage or a surplus of mangos, Kgogongwe would assist Ledzee. This linkage was a kingship tie, i.e. the owners of the enterprises had family ties with each other. Ledzee also had an annual renewal contractual agreement with WFP.

Ledzee also interacted informally with Morokolotsi Archar, which is one of the big commercial archar producers in the Tzaneen area in Mopani district. Ledzee exchanged knowledge and information using informal patterns with network partners. Morokolotsi Archar is also the biggest mango buyer. As part of the services offered to farmers, DRDLR interacted more frequently with Ledzee through extension service support as per mandate of the department to assist local agribusinesses. Another extension services and support relation was with Agri SA.

At the time when Ledzee experimented with new mango products like jam and Minute Maid, the Letsitele branch of QMS laboratories played a key role in offering information and services at a fee. The mango jam samples were taken to the laboratory for quality and safety testing. Ledzee also had a relationship with small-scale mango farmers in the area. In cases where there was a need for more mango fruit supply at WFP, Ledzee mobilised local farmers to increase the supply to the factory. Ledzee also interacted with the DST through their involvement at WFP, which provided an opportunity to learn more about mango processing from DST-supported enterprises.

5. Discussions- actors, links and flows

Extant literature acknowledges the fundamental role of actor networks in innovation, learning, and competence building. At the crux of this article is the nature and composition of actor networks for innovation. To explore the compositional dynamics this article pays attention to network the following aspects; actor attributes, linkages and flows (resources exchanged). We contrast here the nature and forms of actor networks in rural areas based on four cases of enterprises engaging in innovation in agro processing in rural South Africa. The findings from the four cases illustrate the diverse characteristics of actor networks and innovation processes in rural contexts. The findings further illustrate that actor networks are formed by actors from different locations (local and non-local) and sectors. This is in line with literature which indicates that innovation networks, particular those in peripheral areas, include a broad range of local and non-local actors (Corsaro *et al.*2012; Asheim *et al*. 2016).

Innovation networks are composed of actors with varying actor type characteristics (Conway & Steward, 2001) which may influence the composition of these networks. We observe that actors in the four cases included state agencies, NGOs, civil society, consultants, private enterprises, product/ producer associations and special programmes. These networks are dominated by local actors and there is limited participation of key NSI actors such as universities. Across the cases we further observe that these actors are from both local and non-local space. This dynamic is in line with the notion in geographies of innovation that innovation systems are neither necessarily territorially-bound, nor dependent on proximate relationships (Asheim*et al*., 2016; Shearmur *et al*. 2016; Tödtling and Trippl 2016). Actor networks are made of different actors with different roles and interest corresponding to the literature which point to the importance of institutional actors within networks which drive innovation and change including social entrepreneurs, government agencies, funding organisation and NGOs which act as change agents (Feola & Butt 2017).

The evidence also reveals that egos depend on few key actors for resources and innovation know-how. This is consistent with Spielman *et al*. (2011) that found that small holders relied on a limited number of actors for production inputs, credit and information. The findings also show rural actor networks are dominated by local actors than non-local actors. Even though that being the case the results seem to suggest that the type, nature and relevance of an actor to the activities matters more than a high number of actors in a network with less relevance. Huber and Fitjar (2016) for instance assert that local network linkages are often not very useful in promotion innovation in contrary to non-local network linkages.

The nature of linkages between two actors may take varying forms such formality and informality of the ties. All the four cases illustrated that actor networks are predominated by informal linkages and less formal linkages. Formalised linkages are established on contractual relationships such as alliances, project, contracts and cooperative arrangements. The findings also reveal that actor interactions are mostly driven by a need for new knowledge, resources and access to market that is relevant to the current activities. Fitjar and Rodrigues-pose (2017) refer to such linkages as purpose built relations. According to Fitjar and Rodrigues-pose (2017) these linkages results from an assessment of needs and possible opportunities. Purpose built linkages are found between both local and non-local linkages. Nonetheless voluntary linkages play a key role in accessing knowledge and they can still lead to innovation. The explored networks contained both formally and informally structured enterprises.

The findings illustrate the diverse network contributions and the roles and functions of heterogeneous actors. Actors undertook various activities to influence innovation and innovation process. These roles can be categorised as i) providing access to resources and knowledge ii) business development and network mobilisation iii) capacity building and iv) Supporting and enforcing institutional change. The latter suggest that enterprise level innovation, particularly in developing economies and peripheral contexts, requires more than just scientific knowledge and technology diffusion to fulfil their innovation activities (Kilelu*et al*. 2011; Rodríguez-Pose &Wilkie 2016). Institutional actors contribute to innovation by fostering integration and interaction among enterprises in rural contexts. Moreover different network actors require different kinds of support including technical, financial, infrastructure and social support. In the same vein Sotarauta (2017) using the concept of agency, emphasise that the need to understand the micro-level dynamics and how they link with institutions. His argument is that institutions are not uniform for different actors and systems.

Public actors' role is limited to provision of information and resources and they have contributed in creating product market linkages. This finding is consistent with the study on livestock innovation systems and networks in Ethiopia by Asres *et al*. (2012) which found that public sector agencies were able to provide smallholder farmers with information, inputs and credit but were unable to assist smallholders to have access to the market. Private sector actors in agro-processing played a limited in all the four cases. However even though they are regarded as competitors, it was found that they are good sources of relevant production and market information and knowledge. Asres *et al*. (2012) also found that private sector actors played a peripheral role in smallholder farmers' networks. Civil society actors had relatively strong relations with egos. For example the traditional authorities and community based organisations played a fundamental role in the support of the introduction of ready to cook biogas in rural Gawula. The innovative capability of civil society actors lies in their ability to reach the grassroots and interact with the marginalised communities.

Actor networks take different forms and enterprises retain their separateness and independent entities. The latter is proven in the current study. DeBresson and Amesse (1991) distinguished different types of networks that are based on more formal agreement such as contractual and those that are based on less formal arrangements. These two types of actor networks are revealed in the cases that are being studied. However informal networks types are dominant. Formal network arrangements are observed in infrastructure and finance driven networks and market driven and supply driven networks. Other forms of networks observed in the cases are shared experience based relations, short term collaborations to accomplish a task, project based, strategic alliance and gate keeping relations. These forms of networks are in line with those identified by Powell and Grodal (2005).

In the ego networks, informal linkages are predominant however such linkages are not voluntary and unplanned interactions, they are purpose built to access particular information and resources. Unregulated or informal linkages have no clear boundaries. Actors interact and collaborate on ad hoc basis. In informal linkages, rules and routines gradually develop and guide the activities. Nevertheless some of the linkages are formal and contractual and they are purposely established to address a specific challenge or opportunity (Musiolik 2012). For instance Mfuneko rural biogas collaborated with SANEDI to address the issues of renewable energy access in rural areas. However such contractual arrangements are often temporary and project based. An observed dynamic within the networks is that cooperation and coordination among enterprises is not well developed. Network actors rarely take joint decisions. This dynamic conquer with the evidence that was found in a study of wildsilk enterprise conducted in the North West Province in South Africa (Ramoroka *et al*. 2014). The study found that the network was characterised by bilateral and infrequent engagements. Within these networks some actors undertook broker roles. In the presence of poorly developed cooperation and coordination, Common rules and norms in networks are not completely non-existent however they are gradually developing in collective interactions among enterprises.

In purpose built linkages the resources of partners are important and they influence the strength of the linkages. Thus flows (object of exchange) influence how the receiving actor perceives the partner in a network. Enterprise representatives perceive resourceful actors such as government departments as the most important. Moreover the object of exchange must be relevant to the conditions and current activities of the innovator. This indicates that knowledge and resource structure is important for innovators in poor areas. In the same line Grillitsch and Nilsson (2015) argued that regional knowledge infrastructure is necessary for small firms with low internal competencies.

6. Conclusion

The evidence shown that, there are diverse characteristics of actor networks and innovation processes in rural contexts. Rural actor networks are composed of local and non-local actors including those actors that are not traditionally recognised as innovators in the conventional South African NSI framework. The actors in the rural space included public agencies, NGOs, civil society, consultants, private enterprises, product/ producer associations and special programmes. Among these actors, civil society which promotes social entrepreneurship plays a central role in local network systems. Whilst local government and other key NSI players have limited participation in these network systems. We also observed that the prerequisites of innovation go beyond the generation of scientific knowledge and diffusion of technologies. Innovation emerges among heterogeneous actors when factors such as infrastructure, funding, markets, innovation capability and institutional support are present. According to Kilelu *et al*. (2011) the process of innovation involves interplay between scientific, technological, social, economic and institutional arrangement. Thus the use of both local and external knowledge aid innovation process.

Rural actor networks are relatively loose and diversified. Enterprise engaged in both formal and informal network linkages. The most prevalent interactions between actors are informal and weak. It is observed that while local-level network systems are dominated by local actors which are of little value for innovation, relevant external network linkages are critical for promoting innovation. The potential of local-level network systems or rural innovation systems have not been adequately developed as most of the relations between the ego and alters are not reciprocal.

Mainstream innovation network literature particularly in rural contexts have focused on technology diffusion and adoption (Hermans et al., 2013), but struggled with self-organising practices and agency, linked to the compositional dynamics of actor networks and the micro-level perspective of the system. The findings indicate that the practices that characterised rural realities are directly linked to the process of developing new or improved types of innovations. Key highlights from the network analysis indicate an absence of NSI players and poor interaction between system actors.

Overall, innovation in rural contexts is a social act embedded in socio-economic structures. These social structures are dynamic and complex and they influence the direction of innovation processes. The rural innovators acknowledged the roles that network activities played. In terms of networking, it was found that certain social aspects had influenced learning and innovation, namely the type of an actor; the nature of linkages; and the exchange of content as follows:

Type of actor: actor attributes and features, roles and agency could hinder or enhance learning and innovation, for example, support institutions were often embedded in cooperative relations as part of their mandate and service provision.

Nature of linkages: formal linkages are often contractual and therefore a restrictive, one-way power relationship, for example, funding institutions and rural innovators.

Exchange of content: the object of exchange, value addition and relevance influence learning and innovation.

Based on the findings and prior studies, the South African NSI is inadequate to contend with the developmental challenges facing rural communities. The study suggests that in cases where there is institutional support, there is an outwards movement of know-how from big formal enterprises to local actors. Participation of external actors is characterised by a limited number of these actors, the linkages and the practices are often top-down, while other local linkages are characterised by locked-in but free movements to search for new knowledge.
An important observation is that key players in NSI of South Africa such as universities and research councils are missing in the local or rural innovation systems. The findings also reveal poor integration and interaction among actors and broad public-private sector interactions and development programmes. There is a limited participation of key NSI players in rural innovation networks. Consequently in rural contexts institutional support for innovation is lacking and in some cases non-existent. From a policy perspective, we need to look differently at local innovation networks and not try to squeeze it into the NSI framework. Instead, the empirical evidence reveals a different picture and given the research we need to ask how best policy can support innovation in rural areas? What is the appropriate policy response? How can individual actors be supported?

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THE EFFECT OF PREMATURELY FAILING COMPONENTS IN RAIL INDUSTRY

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ABSTRACT

A railway industry is the industry that operates trains in the form of making business. This industry can be either private or public company. Train has highly costing components like an engine, bogie and traction motors. The key challenging that facing South African rail industry these days when components fail prematurely is maintenance planning schedule, permanent component damage and workload for the work force. The railway industry has many businesses activities to sustain its operations like all other businesses, but maintenance of the freight train has challenges. Prematurely failed components are those components that failed prior their life span that have highest to the railway industry. Monte Carlo simulation tool used to deal with inefficiency maintenance rate and to predict risks in the near future. Logical Process Flow (LPF) used to deal with prematurely failed component in the railway industry. Moreover, the Virtual System Management (VSM) recommended being the best technology that will show positive turn around in the freight train in dusty. In generally, failed components affects delays to customer deliveries. This paper conclude that the proposed Monte Carlo and LPF can assist in eliminating prematurely failing components effects and can introduce the new technique to drive maintenance.

Key words: Prematurely Failed; LPF, Maintenance, Freight train, Virtual System Management

1. Introduction

According to Zyngoer et al.(2018); rail system familiarized in the 19th century to play a crucial role in conveying society from one point to another. South African (SA) railway industry consists of various categories including passengers and freight trains. South African railway industry comprising of product focused businesses in manufacture, upgrading conversion, repairs and maintenance of railway rolling stock, as well as spares and associated transport equipment. South African rail industry is equipped with the International Standards Organization (ISO) certified factories and skilful labour force. Freight train in SA have been the one that is expanding and modernising the country's rail, port and pipeline infrastructure almost a decade to promote the country economic growth. Maintenance found to be the major challenge in freight train for various reasons.

Maintenance of passenger and freight train are not the same, freight train requires much of engineering maintenance than train but both are the railway industry assets. Some of the reasons why freight trains demand engineering maintenance is because they are performing heavy duties in a long distance journey and high costing components including compressors, traction motors and cylinders. Rail industry reported to be the main to the continuous expansion of developed nations, nevertheless the sector working environments and social performance requirements are different to other businesses (Singh and Kumar, 2015). Currently, South Africa rail industry discovered maintenance to be the one that expensive to manage.

Between 2010 and 2017, South African railway industry experienced high level of premature failing component. Prematurely failing components are components that fail before their life span. The prematurely failing component has become the major challenge facing rail industry in South Africa, where major components just fail before their time and schedule maintenance date. In the past, research conducted show that brakes assembly and wheel sets had gain the more focus since they considered the most frequent identified incidents of maintenance mistake (Singh and Kumar, 2015). Freight train business is losing productive hours due to cancellation of freight train and returns to the shading area, and stand in a risk to lose the customer because of failing to meet the expected demand. Maintenance department with the business faces challenges of planning the schedule and unscheduled maintenance, which lead to annual maintenance plan changes. Labour also experience high level work pressure by trying to accommodate the prematurely failed components that lead to an early return of locomotive in a shading areas. Early failing of components will lead to permanent failing of them. The components such as compressors which are not highly stocked, because of inventory costs are not always available for high-level prematurely failed component.

Although Colledani et al., (2018); highlighted that preventive maintenance preserves the equipment against degradation, thus reducing the need for complex and expensive corrective action. However, this does not address the issue of inventory cost, maintenance plan, and customer expectation that affected by the unexpected prematurely failed components. In the past few years, South African rail industry lost service time to redundancy caused by early failed component. The application of simulation model such as Monte Carlo to address the ineffective of compressor maintenance in the rail industry and predict the next maintenance of compressor to eliminate these predominant challenges in the rail industry cause by early failures in South Africa. Furthermore, implementation of Virtual System Management is highly recommended to improve technological side of South African rail industry.

The remaining challenging issue is limiting the applications of opportunistic maintenance outlined by (Colledani, et al., 2018). The early return of locomotive is not business profiting, therefor we have to identify the loop whole of the maintenance in the rail industry when maintaining mature components. There many reason for the component to fail before time but this paper has to give clarity to understand the challenges that leads to prematurely failing components. The main objective of this article is to diminish the prematurely failing of components in SA rail industry. The attainment of these objectives will assist the rail industry to increase its turnaround time and utilise the resources that are scarce and hard to manage. This paper is organised as follows: Section two deals with the literature view to acknowledge other researchers on the same stream of work. Section three; clearly outline the methodology that used to deal with the challenge of prematurely failing components in the South African rail industry. Section 4 is results and discussion, which help to understand the impact of the model used. Section 5 concludes the work on this article.

2. Literature review

French railway industry funding industry intend to show that access pricing is driven by budgetary concerns and not economic principle by Ivaldi and Pouyet, (2018). The role of access pricing to provide the right economic signals to rail operators was the concern, which leads French railway industry to simulate the impact of variations in access price. Utilization of Monte Carlo simulation to overcome upcoming challenges in the railway industry in order to eliminate certain challenges like prematurely failing components facing South African railway industry.

Zyngoer et al., (2018); pointed out those more classy strategies, for planning, scheduling and controlling railcars over the system have been increasingly required assumed the high exploitation of rail lines and enlarged pressure on reducing emissions, assets and operational costs of rail organization. They also utilize the optimization-based approach for real-time schedule may be leveraged for uses such as quick determination of feasible train schedules and recovery from unforeseen events in the rail system among them which have common view as the logical flow process tool used in this study but technological irrelevant to the study.

Cardenas et al.,(2018); discovered British railway organization there are multiple failure mode happening in large numbers from a variety of biologically discrete assets. They also build linear model that estimate material cost associated with maintenance activity cost. The author further acknowledged that labour cost and each hour task could be calculated distinctly when commerce maintenance cost where scheduling and planning permits estimates of task duration. The accurate cost savings valuation is challenging because of the massive number of factors involved but 10% will signifies considerable saving and smooth railway operation by (Cardenas et al., (2018).

The reduction of maintenance cost by evaluating infrastructure sites within. Cost for wages, tools, fixtures, rent, energy, cutting fluid, cost for poor quality and down time are the most recognised maintenance cost pointed out by Bengtsson and Kurdve, (2016). This never addressed prematurely failed components in in railway industry and challenges facing railway business.

In dealing with some maintenance challenges, Bengtsson and Kurdve, (2016) proposed centralising cutting fluid system to reduce the man-time cost for fluid maintenance, but never pay attention in meeting the planned schedule target when dealing with unscheduled maintenance. The major factions for real-time diagnoses are management of hardware, man-time and interface, signal processing, damage detection and presentation of diagnostic results announce by Hang et al., (2014).

Since no one can deal with the constant flood of information Gorman et al., (2014); thought it is vital to realise that these conditions change thousands of time per day. The authors further outline that equipment pool arrangement; parochial arrangement reduces effective rail car ability. The question of early delivery to the customer is affect by the dynamic changes that take place in maintenance. Bengtsson and Kurdve (2016); noticed that the suppliers that are the challenging part in maintenance estimate cost acquisition and reconditioning spare parts and possibly energy.

Many customers pool of equipment, which negatively affected asset utilization, disbanded to maximise the model effectiveness from the commercial viewpoint analysed by (Gorman et al., 2014). The manual task reported to be the one that enhance human error and the key part to reduce railroad cost is to improve safety by Singh and Kumar, (2015).

3. Methodology

The researching individual reached South African railway industry, planning department and none of them refused to participate. The data extracted from the monitoring system of a rail industry through face-to-face interview with rail industry expert in South Africa. Developed and administered by senior rail industry employee and researcher. The main objective was to obtain the actual components failed before their time in South African railway industry and collect feedback maintenance. The planning department mailed the number of failed components to the researcher as part of study survey and maintenance also submit their maintenance procedure for all levels of maintenance.

The 34-class of freight train was prioritized because it was the facing the high failure rate according to the South African industry. The 20-freight train information where received out of 26 locomotives in the rail industry, These 6 freight trains were not included where phase off by the SA railway industry. This resulted to 77% respond rate of 34-class freight train.

The data was analysed using Monte Carlo simulation model because it useful tool that is strong allow the analytical of historical data on excel. Shebani and Iwnicki, (2018) used feed forward to predict non-linear system in wheel and rail maintenance. The system that is available in South Africa is linear system and that why Monte Carlo and Logical process flow is relevant. Data was analyse through excel. The advantage of Levenberg-Marquardt algorithm that used by Shebani and Iwnicki, (2018) has high convergence and will need training, which make it not preferable to this instance due to the time of training people it will take. Hence, our Logical process flow only needs people to follow the steps.

The LPF sent to the SA rail industry for implementation phase to test the respond on the freight train after maintenance. With a belief that it will improve the safety to the rail industry and it reported positively. An important part to diminish railroad costs is to advance safety said Singh and Kumar, (2015).

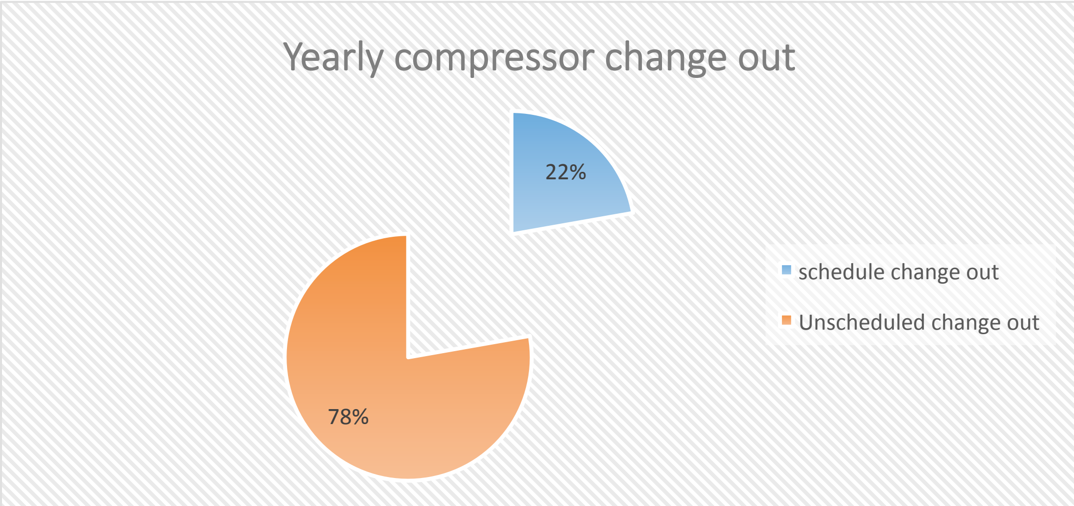
4. Result and discussions

Conducting Monte Carlo simulation model to analyse the possibilities of components to fail before their expected date using the historic information obtained from planning department and maintenance department. One class was taken and simulated through excel using Monte Carlo model. The data arranged in descending order to obtain a proper range and risk analysis of the components and Locomotive number needs more attention.

Table 1: Major challenges on the compressor.

Loco No	Date installed	Date failed	Duration/Period In Use	Defect/Failure	Cause of Failure
D34056	Beyond SAP Begin dates	17/06/2014	Over Life Cycle	Scheduled Change-Out	Scheduled Change-Out
D34109	Beyond SAP Begin dates	07/04/2014	Over Life Cycle	Scheduled Change-Out	Scheduled Change-Out
D34910	17/08/2012	19/08/2014	2 Years	Defective	KRP Seals Leaking
D34414	08/10/2012	15/09/2014	2 Years	Compressor Noisy	Bad Knock Inside Compressor
D34456	04/05/2011	23/05/2015	4 years+	Compressor Broken	Wear and Tear
D34109	07/04/2014	25/05/2015	1 year+	Compressor Smoking	KRP Seals Leaking
D34444	19/11/2009	15/06/2015	5,5 Years	No Main Air	Compressor leaking
D34458	21/05/2012	03/08/2015	3 Years+	No Main Air	HP Cylinder Head Broken Off
D34476	06/12/2012	20/08/2015	±3 Years	No Main Air+Vacuum	HP Cylinder Head Broken Off
Total Compressor Change OUT	9				

Table 1 represent the number of challenges facing compressor in the rail industry on South Africa. Yellow coded defect is the one that has been available (well-known cause) in the decade and green coded results represent the causes that already dealt with. The non-highlighted results represent newly found and monitored internally.



Graph 1: Graphical presentation of schedule and unscheduled change out.

Data presented in **Graph 1** clearly shows us the previous damage to the business when comes to maintenance department due to prematurely failing component. The unscheduled change out put pressure the maintenance team, which might human error. The unscheduled is very high by 78% compare to the schedule of 22% in SA railway industry, particularly to the freight train compressors. This clear indicate the challenge facing South African railway industry when comes to maintenance and planning department. The two department have instability to it line of work. Hence, 22% represent the probability of a customer to receive good service in rail industry. Every business's goal is to exceed the customer expectation to increase profit is what the railway industry prepared for and gets unexpected challenge, which prevents railway industry in attaining it, business goal. However, the control limit is the optimal in minimising maintenance cost according to Li et al., (2017); when dealing with single service virtual machine (VM). The safe stock also become unproductive when comes to this massive increase of change out. Hence, Muller et al., (2018); reported that cost of acquisition and reconditioning, spare parts and possibly energy estimated by suppliers. With this case, business of railway industry will not make profit.

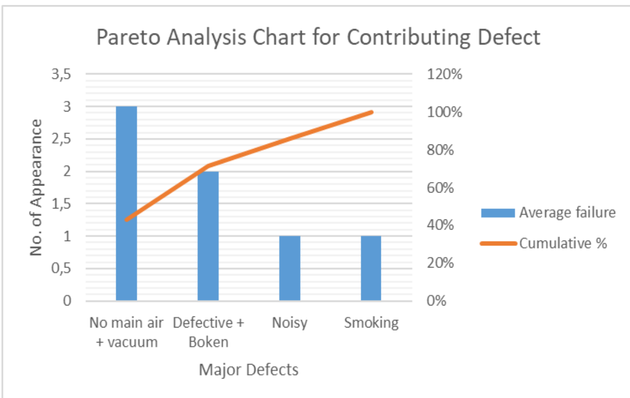
Common failures mostly found to compressors, in table and graphical form.

Table 2: Common compressor failure cuases

Compressor defect	Average failure	Defect %	Cumulative %
No main air + vacuum	3	43%	43%
Defective + Boken	2	29%	71%
Noisy	1	14%	86%
Smoking	1	14%	100%
Total	7	100%	

Graph 2:Pareto Analysis of component

Failureure



Bengtsson and Kurdve, (2016) proposed the bird-eye view of cost, which is not investment valuable only but can be used and update equipment life cycle. In preparation of unexpected change out, cause of failures to the compressor component was analysed through the Pareto analysis as shown in Table 2 and in Graph 2, to show each defect contribution to railway industry of South Africa. A noisy and vacuum shows a high 43% probability to be the cause of compressor failure. The freight train business have to address this major contributor to failing of compressor by involving everyone involve to this business. This high failing rate can lead to component unusable. Defective and Broken (D&B) are classified as major defect because the maintenance they need will involve welding. Welding also reduce component value. The cause of this 29% to D&B is vibration when the freight train is in motion and bolt are not tighten properly. Bengtsson & Kurdve, (2016) once said Mean time to Recovery (MTTR) does not only rest on to design for maintenance it also depend on skill and availability of maintenance employees.

Noisy and Smoking compressor are both contribute 14% to the failure rate analysis. If measures to deal with these contributors were address to the customer, they could have been not part of the contributors. Hence, the probability of them is not that effective to the main component by they need attention.

Simulated result on Compressor in different maintenance state.

Figure 1:Compressor failure effects

before maintenance.

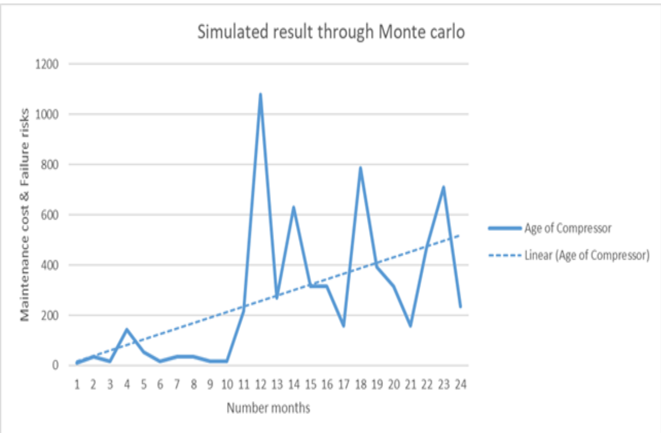
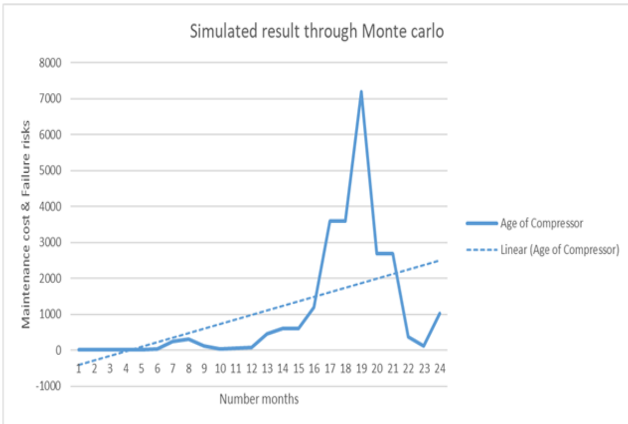


Figure 2: Compressor failure effects

before maintenance (Retested)



The Monte Carlo simulated results of compressor maintenance represented in Fig 1-4 and Fig 6. In these figures, the vertical axes represent maintenance cost and risk level, whereas horizontal axes represents period in months. The linear line in these graph represent the gradual maintenance and risk level in month's proportion, whereas solid line represent actual simulated results.

Fig. 1 and Fig. 2 are the results of compressor installation before any performed maintenance. Fig. 1 predicts that within a year of compressor installation the will failures that force an early return of freight train several times. Hence, Fig. 2 predicts early components failure. They both show a major effect to the railway industry, more component sick maintenance attention the more maintenance cost will increase. In addition, the less it failed it more it show a very high maintenance cost and risk of components not to recover. These results showed the high risk of compressor failing very earl and rising the maintenance cost from zero to the maximum of R2000, what is unpleasant with these results is the high-level variation of failing from period 11 to 24 months.

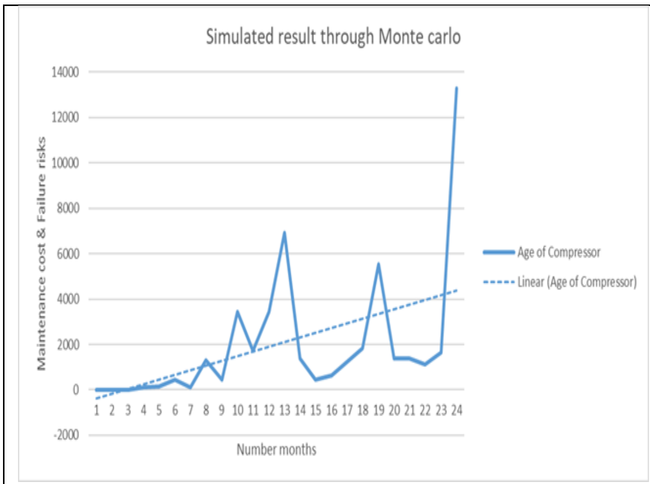


Figure 3: Compressor maintained once failure rate.

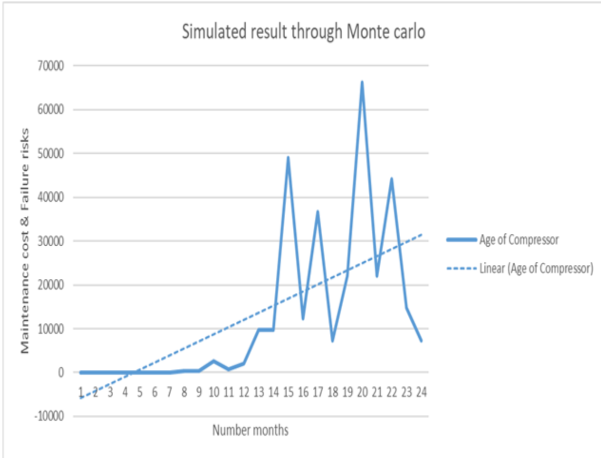


Figure 4: Compressor maintained once failure Rate (Retested).

In addition, another results obtained in Fig. 3& Fig. 4 and they show an early stage of failing of compressors with many variations after installation. Suppressing the linear line show a very high cost of maintenance in Fig. 4, which shows failure at later stage. In addition, this had high cost of maintenance. These result combined showed that if the component can still be fixable can cost the organisation an almost amount of R7000 upward for maintenance cost. Prematurely compressor failure predict high damage to the business of rail industry. Muller et al., (2018); reported that side effect are concern for nearly all-opioid maintenance treatment and they do not appear to accumulate with age or length of treatment when researching side effects of medication. Even here, in the freight train business there is maintenance after maintenance in the same freight train due to side effects.

Logical Process Flow (LPF) for improvement

The LPF model implemented to overcome the high seen risk of locomotive components to fail before their expected time. The aim was to monitor maintenance process of the major part that highly experience prematurely failing component. Baji et al., (2017); once said an efficient maintenance structure is required in order to maintain safe and economical operation of the infrastructure. Therefore, LPF has the very objectives.

Logical process flow to monitor performance and eliminate risk of compressor failure.

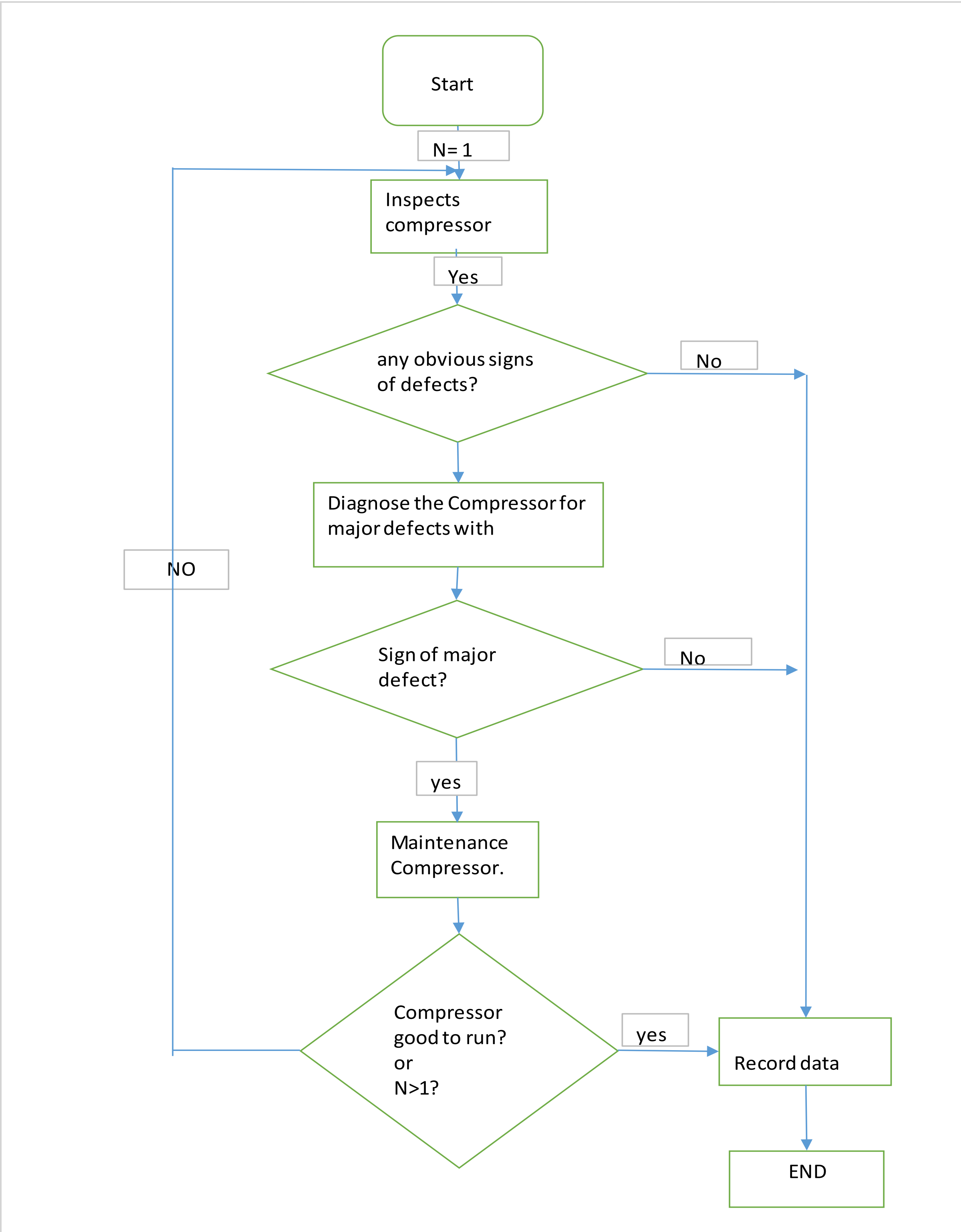


Figure 5: Logical process flow.

Simulated results after application of LPF model

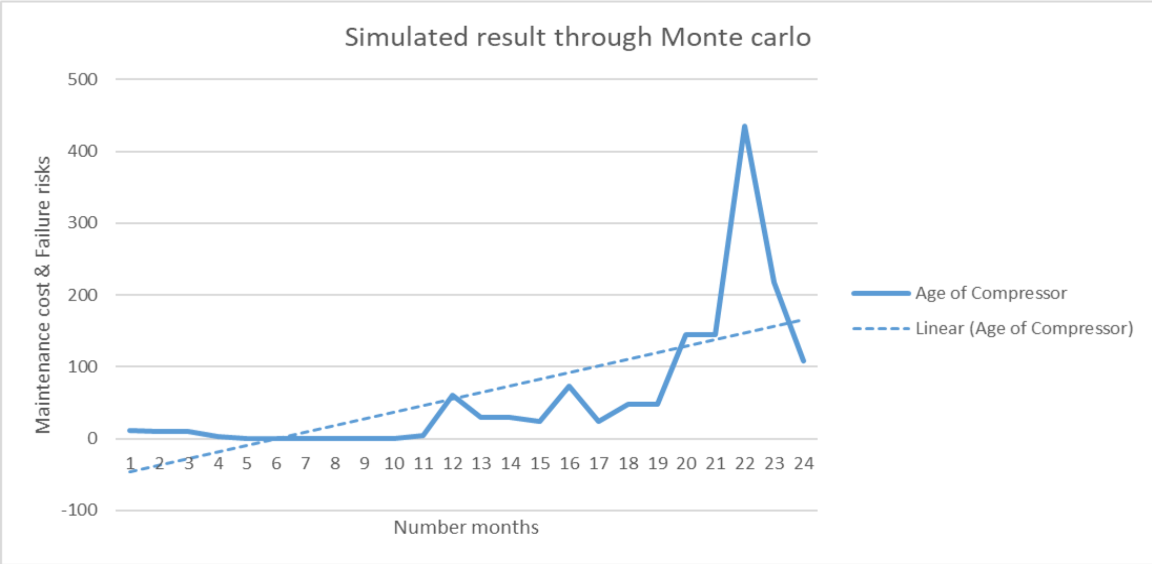


Figure 6: Results of simulated after LPF.

Discovering the simulated result from Fig. 1-6 the introduction of Logical Process flow (shown in Fig.5) to monitor the performance of compressor in the railway industry. The proposed technique predict the improvement of reducing these prematurely failing components to the SA railway industry during discriminative control developed by contingencies association Lynch and Keenan, (2018) found that there is a need for maintenance procedure when the game is removed. It meant to direct maintenance and monitoring of compressor in the rail industry. After number of Freight train results, where simulated after introducing the LPF and positive result where obtain and presented in Fig. 6. These results show that maintenance cost can be only R500 or less. It also shows reduction on maintenance cost by 72% (high cost After/high cost before).

5. Conclusion and recommendation

In this article, the development of detailed Logical process flow, which extremely exceed the maintenance plan method the South African railway industry, have. The propose LPF model is flexible and can be applied to all prematurely failing components in the rail industry. In addition, the LPF assist in the planning department and maintenance. The employment of Monte Carlo simulation to screen $CaCO_3$ and $CaSO_4$ tendency to absorb in growth scale crystal by Elkholy et al., (2018); to demonstrate the flexibility of the tool. Using LPF and Monte Carlo simulation, the positive results obtained. Initial the prediction demonstrated the failure rate of more than 70% to the freight train compressor components within a year. In addition, after implementing the LPF to the simulated results it shows the reduction of 50% or more. "Scheduling and planning passes estimates of task duration, therefor labour cost and each hour of the task could be calculated separately" (Cardenas, et al., 2018).

The LPF is similar to the algorithm for maintenance strategy optimisation proposed by (Baji et al., 2017). This model is much simpler and allow the use of technology together with work force to improve the maintenance in the railway industry.

The industries are now moving to industry 4.0. The Virtual System Management (VSM) would be most appropriate technology. VSM will ensure the reduction of time and ensure safety in troubleshooting. It will also improve technological skills to operators. The effective maintenance sustainability of rail industry still need to be research in the near future in order to overcome maintenance challenges.

Acknowledgement

The Authors will like to thank the Tshwane University of Technology, particularly the Department of Industrial Engineering for providing Industrial Engineering Lab to conduct research. The Authors are thankful to South African railway industry for providing major component data verification.

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The Raspberry Pi, Hadoop, and its Clusters

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ABSTRACT

In today's present advancement and quest to discover, explore and learn new things, we as a modern society have come to create large amounts of data, known as “Big Data.” Moreover, therefore, traditional computer systems cannot handle the mining and analytics if these data, thus pushing us as individuals on a quest to turn to systems like Hadoop, which are great in analyzing millions of information and at very fast speed for greater value. Also, as companies push to advance and promote their systems to their specific need, clusters of Hadoop system came into place to increase productivity and value. As such this paper will be centralized towards the management of very large amounts of data, while also using very cheap computer systems like the Raspberry Pi, for small, cheap and effective experimentation.