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Addressing Food Waste and Loss in the Nigerian Food Supply Chain: Use of Lean Six Sigma and Double-Loop Learning

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Abstracts

Food waste and loss (FWL), although a growing problem in the world, there is limited research especially from the developing country context. In this research, we investigate FWL in the processing and distribution stage of the Nigerian Food Supply Chain (FSC). We propose the use of Lean Six Sigma (LSS) tools coupled with Double Loop Learning (DLL) to reduce FWL. Using case study strategy we explored the perception, understanding and experience of the FSC stakeholders on the effectiveness of LSS tools and DLL to reduce FWL in two case companies. We found awareness, identification of root causes of FWL and taking responsibility as the major steps adopted by the case companies to reduce FWL. We provide insights regarding how DMAIC could support Organisational Learning Theory (OLT) while solving FWL issues.

Keyword: Food Supply Chain, Lean Six Sigma, Food Waste and Loss, Organisational Learning Theory, Double Loop Learning, Developing Country

1.0. Introduction

A report by Food and Agriculture Organization of the United Nations (FAO) argues that 1.3 billion tonnes of the World's food products are wasted every year, which is appropriately one-third of the food produce (Gustavsson et al. 2011; FAO 2014; Segrè et al. 2014; FAO 2013). It highlights that in the Sub-Saharan African, significant proportion of food waste is from the pre-consumption stage compared to developed countries, where there are more wastes at consumption stage of the Food Supply Chain (FSC) (Gustavsson et al. 2011). Food Waste and Loss (FWL) is pertinent in both developed and developing countries, although there is a dearth of research on how FWL could be reduced at pre-consumption stage of the FSC. The pre-consumption includes the processing and distribution stage of the FSC (FAO, 2013). Most previous studies had mainly focused on consumption and retailer stages from developed countries' perspective (Principato et al. 2019), thus, there is limited research exploring FWL issues in developing countries, especially in the context of Sub-Saharan African (Kummu et al. 2012).

Myriad of extant literature highlights a need to manage flow of activities for which effective Supply Chain Management (SCM) practices need to be adopted (Dora et al. 2013). However, Supply Chain (SC) activities within the FSC are complex (Daini 2015) and may range from variations in production, delivery time, market uncertainty including supply and demand, storage, and inventory management (Sgarbossa and Ivan 2017). This is due to the high level of perishability involved in FSC products. As a result, there is a growing concern around the world on the strategies that could be used to reduced FWL (Parfitt et al. 2010; Gunders 2012; Lipinski et al. 2013; Reich and Foley 2014; EuropeanUnionCommision 2016; Melo and Pato 2016).

Several opinions could be found with regards to the strategies used in the elimination of FWL, such as; open innovation strategies, reverse logistics, and food sharing (Gollnhofer 2017). Other strategies include the adoption of continuous improvement tools such as Lean, Agile, Six Sigma from the Quality Management perspectives (Abdulmalek and Rajgopal, 2007; Hallgren and Olhager 2009; Wee and Wu 2009; Choi et al. 2012; Gollnhonfer 2017). However, scholars suggest that for SC to be effective, there is a need for the implementation of effective continuous improvement practices, which would not only eliminate waste but also improve organisational processes (Fernandes et al. 2017). Therefore, Lean, Six Sigma, and Lean Six Sigma (LSS) have been evolving in the literature as tools that could be used to improve organisational activities (Hooge et al. 2018). Lean was primarily developed for the elimination of non-value activities in the manufacturing industry (Womack and Jones 1996), other sectors aside from manufacturing have also benefited from the implementation of Lean (Melton 2005). The development of Six Sigma, which focus on the identification and elimination of defects within the manufacturing industry have helped various organisations to increase efficiency (Mishra and Kumar 2014). Lately, scholars have been using Lean Six Sigma (LSS) to detect the root causes of waste, as well as develop improvement strategies that could be used to reduce waste (Drohomeretski et al. 2014).

The research on LSS has focused on the use of Define Measure Analysis Improved and Control (DMAIC), as the tool for its implementation and this has been used in various organisations to achieve LSS objectives (Ibid). Also, several studies have used DMAIC tool in conjunction with model/theories that are aligned with the objectives of LSS, such as Organisational Learning Theory (OLT) amongst others (Savolainen and Haikonen 2007). OLT should be seen as a theory that could be used to achieve organisational goals, promote knowledge creation, solve organisational problems and promote dynamic capabilities (Spender 1996; Antony et al. 2018). Previous studies have argued the need for DMAIC as an LSS tool to be researched from the OLT field more importantly from Double Loop Learning (DLL), a framework within the OLT whose objective is aligned with that of LSS tool (DMAIC). However, there is limited research on how DMAIC promotes DLL and the use of both in solving organisational problems such as FWL. The research aim of this study is to fill this gap by investigating how DMAIC-DLL could be used as an effective solution to FWL at pre-consumption stage. This raises the question of "how DMAIC-DLL could be used to reduce FWL in the processing and distribution stages of FSC?"

Consequently, this research will provide empirical evidence on how DMAIC promotes DLL towards FWL reduction. We contribute to the body of knowledge by extending the Double-Loop Learning (DLL) framework of Argyris and Schon (1974) contained in the Organisational Learning Theory to answer the research questions and to deal with the objective of this study. This paper aim to propose a conceptual framework of DMAIC-DLL based on DMAIC tools and DLL to tackle the challenges of FWL, which have been identified as a problem facing the developing countries. The proposed framework develops operational methodology on the effective application of DMAIC-DLL towards the reduction of FWL, a case study of Sub-Saharan Africa, with interest in Nigerian FSC.

The rest of the paper is structured as follows: in the next section, we present the overview of SCM and review literature in LSS and DLL, followed by the conceptual framework. Methodology including data collection and analysis is followed next. In section 4, we present our key findings in relation to the research questions addressed. In section 5, we articulate our discussion by structuring it around our conceptual framework to highlight the importance of DMAIC-DLL for organisations to tackle FWL.

We end our paper with practical implications and future research suggestions within the conclusion section.

2.0. Literature Review

Due to the significant amount of food wastage in the world, two-thirds of food produced are wasted (Gustavsson et al. 2011). This has captured the interest of many researchers (Darlington and Rahimifard 2007; Buisman et al. 2017). The developed countries have more waste at the consumption stage due to the eating habit of the consumer (Mena et 2011) while developing countries witness more waste at pre-consumption stage due to weak supply chain infrastructure (Buisman et al. 2017). Consequently, some scholars maintained that some of the most effective strategies to reduce FWL is the need for FSC stakeholders to understand how to manage their SC and implement continuous improvement practices aimed at improving FSC activities (Mena et al., 2014). In the next sub-section, we will discuss extant research in the SCM with a focus on FSC.

2.1. Supply Chain Management (SCM)

SCM is defined "as a set of activities conducted by organisations to promote efficient management of supply chain" (Li et al. 2006: 108). In view of this definition, SCM promotes efficient management of supply chain by managing SC flows effectively, through this, a reduction in FWL could be achieved (Dora et al., 2013). Several authors have explained the need for stakeholders to have effective SCM to manage the FSC challenges (Sgarbossa and Russo 2017). Therefore, to achieve SCM objectives, organisations need to implement necessary Supply Chain Strategy (SCS). This SCS should be part of the organisation strategies (Fisher 1997). Scholars like Blackburn and Scudder (2009) claimed that SCS would need necessary continuous improvement practices, such as LSS to function well. Salah et al. (2011) maintained that LSS would improve the activities of SCS by removing non-value-added waste. This suggests that there is a link between SCS and LSS. We provide review of some of the continuous improvement practices in the next section.

2.1.1. Lean

The Lean concept was developed in early 1950 by the Japanese Automobile Market as a result of the crisis in Japan after World War II (Sugimori et al. 1977; Monden

1983; Ohno 1988), for eliminating waste and improving organisational performance. Holweg (2007) discussed the genealogy of lean production, the author argued that the emergence of the lean concept was as a result of the learning process that adopted the strategy from automobile and textile sectors, in response to the environmental need at that time in Japan. As indicated by Staat et al. (2011:377) lean provides a principle of limiting excess workers and inventory or “waste” as against the “buffered” approach used by the automobile. Matthias and Brown (2016) shared that lean encourages elimination of all forms of waste, improves efficiency, and customer service. To achieve the objective of lean, Womack et al. (1996) proposed value, value stream, flow, pull, and perfection principles.

Dora et al. (2013) present a strong case for the adoption of lean in the European food processing industries. They found that rapid improvement of operations was being achieved. Matthias and Brown (2016) investigated the adoption of lean concept coupled with operational strategy in the health sector. The authors argued that, the adoption of lean has been on a micro-level. Filho et al. (2016) found that lean adoption in SMEs has been effective. Although, the common arguments of these studies is on the benefits of lean in the area of cost reduction through the elimination of the seven types of waste proposed by the lean proponents (Holweg 2007; Dora et al. 2013; Panwar et al. 2015; Moacir et al. 2016). The waste includes transportation, waiting time, inventory, overproduction, motion, over-processing, and defects (Singh et al. 2010). Mathias and Brown (2016) shared that the elimination of these identified waste will consequently reduce costs and improve performance. Lean has been criticised for some mixed results in its adoption. The literature highlighted that out of 70% of UK industries that have attempted to implement lean, about 25% of them recorded success (Lyons et al. 2013). Scholars have indicated reasons for the low success in implementing lean such as wrong tools application to sectors that do not require such, leading to failure. Therefore, the concept of Six sigma was developed to revolved some of these deficiencies in lean (Shokri 2017).

2.1.2. Six Sigma

The primary focus of six sigma is to detect variation and how this variation could be controlled (Mast and Lokkerbol 2012). Sin et al. (2015) claimed that six sigma does not only reduce variation, but it has been helping industries to improve efficiencies and customer satisfaction. As indicated by Foster (2007), the common process for the implementation of six sigma is through; Define, Measure, Analysis, Improve, and Control (DMAIC). As a result of this, several studies have considered DMAIC as an essential tool for six sigma (George 2014). DMAIC could help organisations implementing six sigma, through a step by step process of achieving efficiency. As indicated by Kubiak and Benbow (2009), the purpose of "Define phase" is to determine the problem to be investigated, such as waste generation. In the "Measure phase", the teams collect actual data to understand the extent of the problem in question. Arthur (2010) explained that in the "Analysis phase", the potential root causes of the waste are identified and validated. In the "Improve phase", identification of solutions to address the root causes (Lucato et al. 2015). The Control phase involves documentation of procedures, training of employees for new processes, and create monitoring and reaction plans for new processes (Salah et al. 2010). Like some of the failures that happened in the implementation of Lean, failures were also recorded in the implementation of Six Sigma (Albliwi et al. 2014). Monlouis (2013) explained that after two decades of six sigma, the result of the implementation in most companies had been mixed. As a result of this, hybrid method, Lean Six Sigma was proposed as a method that can be used to integrate both lean and six sigma tools and techniques to solve organisational problems. Authors such as Shokri (2017) claimed that DMAIC tool is a reflection of Lean tools, as it incorporates lean tools as well as six sigma. Given this argument, the next section shall provide a critical review of Lean Six Sigma and its adoption in this research.

2.1.3. Lean Six Sigma (LSS)

LSS is a combination of lean and six sigma tools and techniques that began in the late 1990s and is emerging in the literature as a powerful tool that can be used to reduce waste and improve performance (Kalashnikov et al. 2017). The concept was introduced into the literature around 2000 (AlBliwi et al. 2014; Shokri 2017), and several authors have regarded LSS as a disciplined, data-driven methodology used to eliminate/reduce the variation such as product defects and waste. Screedharan and Raju (2016) in their systematic review of the literature on LSS, explained that various authors had classified LSS definition based on approach, methodology, model, philosophy, program strategy, and system. For this research, we adopt the definition of LSS by Furterer (2012) "as an approach focused on improving quality, reducing variation, and eliminating waste in an organisation. It is the combination of two continuous improvement strategies, i.e. “Lean” and Six Sigma. Scholars have viewed the role of LSS as the elimination of waste that may occur during the flow of SC activities leading to FWL reduction and striving for perfection. In view of this, Gremyr and Fouquet (2012) explained that the LSS concept is more efficient than the separate Lean and Six Sigma. The justification for combining the two concepts have been explained in the literature. For example, Salah et al. (2010) and Kalashnikov et al. (2017) claimed that the concept of Lean focuses on the “speed” of the process, and Six Sigma focuses on the accuracy, hence the combination of these two techniques have proven to be powerful tools in driving efficiency and effectiveness in organisations, than relying on lean or six sigma alone (Salah et al. 2010; Kalashnikov et al. 2017). Furthermore, Banawi and Bilec (2014) shared that Lean tools are valuable at identifying the cause of waste, but they often do not provide actual methods to reduce or eliminate waste. In such a case, Six Sigma has the potential to fill this gap created by Lean. Consequently, six sigma tool is proposed as a complementary tool to lean, which has a direct impact on eliminating the waste identified by Lean tools (Bhat et al. 2014). LSS uses DMAIC as the tool to achieve its objective as discussed in the previous section

Table 1: Key processes of DMAIC

Six Sigma Steps	Key process
Define	Define the requirement and expectation of the customers Define the project's boundaries Define the process by mapping the business flow
Measure	Measure the process to satisfy customer's needs Develop a data collection plan Collect and compare data to determine issues and shortfalls
Analyse	Analyse the causes of defects and sources of variation Determine the variation in the process Prioritise opportunities for future improvement
Improve	Improve the process to eliminate variations Develop creative alternatives and implement enhanced plan
Control	Control process variations to meet customers requirement Develop a strategy to monitor and control the improved process Implement the improvement of systems and structures

Source: (Nabhani and Shokri 2009)

Although the importance of LSS for FWL reduction is well justified, many researchers have pointed towards the lack of this tool in the food industry compared to other industries (Amani et al. 2015; Screedharan and Raju 2016; Shokri 2017). Limited studies have adopted LSS in the distribution unit of the food industry. For example, Nabjani and Shokri (2009) investigated the impact of DMAIC in the reduction of defects in the distribution of food products in one of the food distribution SME in the UK. The authors' found that with the help of DMAIC tool, the root cause of defect during loading process was identified, they claimed that with DMAIC, defects were reduced, leading to the reduction of lead time and consequently improved customer satisfaction. The study, however, focused on a single company and one unit of the FSC. Shokri (2014) and Amani et al. (2015) shared that LSS had been widely recognised to provide means by which waste is identified and possible ways of reducing waste. DMAIC is an accepted methodology in solving different types of organisational challenges. De-mast and Lokkerbor (2012) confirmed this and claimed that LSS provides a powerful, specific, and operational solution as it manifests in various aspects of DMAIC. The authors concluded that LSS is a problem-solving tool for organisation. Several authors have adopted the DMAIC tools and have shown it to be effective in eliminating waste and in improving efficiency (Drohomeretski et al. 2014; Lucato et al. 2015).

LSS is the best tool for the reduction of waste and variation, especially in the manufacturing industry (Rajak et al. 2016). However, there are limited studies on how LSS tool could be used to reduce FWL at the pre-consumption stage of the FSC. Therefore, in this study, we will use the DMAIC as the LSS tool to investigate food waste reduction at the pre-consumption stage. This is consistent with the work of Banawi and Bilec (2014) who used DMAIC to understand the root causes of waste and its elimination in the construction industry with the help of other tools, such as learning. To corroborate this, Savolainen and Haikonen (2007), argued that learning is essential during the adoption of DMAIC. Therefore, learning should be seen as a way of promoting organisational goals, knowledge creation, solving-organisational problems, and promoting dynamic capabilities (Spender 1996; Antony et al. 2018). Hence, a need to adopt a double loop learning model from the Organisational Learning Theory (OLT).

2.2. Organisational Learning Theory (OLT)

Argyris (2000: 116) defines OLT as “a process of detecting and correcting errors within an organisation”. This means that detecting and correcting errors produces learning, but its absence may prevent learning. Argyris contends that there is a need for organisations to detect the root causes error in the organisational processes, through this, reflective methods of analysing the root cause and taking responsibility towards the reduction can be developed with the help of LSS tools. Furthermore, various frameworks have been developed within the OLT domain. Some of the key frameworks are developed by Bateson (1972, 1979), Argyris and Schon (1974, 1978, 1996, and 2000), Schon (1967, 1983, and 1985), Kolb (1984), Senge (1990). The underlying assumption of these authors was that people and professionals do not only work formally with their knowledge and their logical or analytical skills but also depend on knowledge from other sources and think in a way that fits their organisational need (Bateson 1972). Our study subscribes to this assertion and adopts the framework postulated by Argyris and Schon (1974) to answer the research questions. Many researchers have investigated the link between this framework with DMAIC in various studies see (Savolainen and Haikonen 2007; Lifvergren and Bergman 2012; Arumugam et al. 2013). Thus, adopting this framework is consistent with empirical practice in the literature.

2.3. Double-Loop Learning Model

Argyris and Schon (1974) proposed the Single-Loop Learning (SLL) and Double-Loop Learning (DLL) framework. The former is the detection and correction of learning within a given governing variables, whilst the latter involves changing those variables to solve organisational problems (Savolainen and Haikonen 2007). In the application of SLL, detection of errors and corrections may occur based on the laid down rule and regulations within the organisation but does not allow modification or involvement of external knowledge (Tagg 2010). However, Argyris and Schon (1974) explained that, for organisation to improve systems and modify policies, DLL is needed. This allow organisation's stakeholders to change policies and procedures in use, which might result in developing a new approach to work (Jaaron and Backhouse 2017). DLL incorporate explicitly the engagement of all staff to provide valuable information by asking the questions related to the awareness problems, origin, and causes as well as the consequence of the problem, thus generating a flux of knowledge to address the problems. Figure 1 shows the DLL framework as proposed by Argyris and Schon (1974).

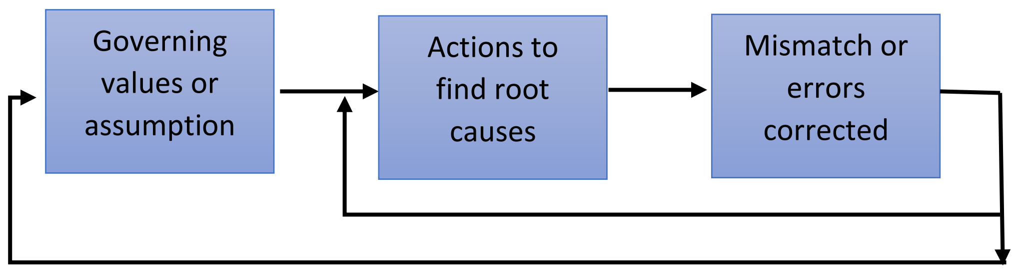

Figure 1: The Double-Loop Framework

Source: Argyris and Schön (1974)

Argyris and Schön (1974) proposed three stages of DLL, which include: governing values/assumptions that need to be questioned, actions to find the root causes of the problem and take responsibility to solve the problem. These three stages support organisations to change underlying false assumptions, causing underperformance while enabling the detection and reduction of root causes (Wong and Wong 2014). However, there are no tools that can be used to achieve these stages. Previous scholars have suggested DMAIC as a tool to achieve DLL (Savolainen and Haikonen 2007). For example, Arumugam et al. (2013) argued that DMAIC can be used to achieve the objective of DLL as both focused on problem-solving and organisational improvement. Furthermore, empirical evidence by Shokri et al. (2016) confirms that DMAIC is needed for the operationalisation of DLL. Therefore, the consensus is that internal and external stakeholders' inputs are essential in the promotion of DLL, which can be achieved through DMAIC. Hence a need to adopt DMAIC to achieve the DLL stages.

2.3.1. Conceptual Framework: Integration of DMAIC and DLL in this study

Both DMAIC and DLL although have similar objectives, the latter is used to promote OL while the former promotes continuous improvement activities (Savolainen and Haikonen 2007). For example, DMAIC is used to detect the cause of a problem and improve processes by eliminating every form of waste, and it deals with the internal stakeholders (Chakravorty 2009) while the constructs within DLL can as well perform the same function with DMAIC but with the inclusion of internal and external feedback (Lifvergren and Bergman 2012). Although, DLL does not have a specific tool for its implementation, therefore, tools within DMAIC could be used to achieve DLL objectives (Jaaron and Backhouse 2017). The conceptual framework could be achieved through five stages as shown in Figure 2 below:

Stage one of the framework is the awareness of the FWL problems within the DLL. This stage can be achieved through the “Define” phases of the DMIAC where the problem is being defined with the help of project charter tool. This allows organisation to identify the problem being faced. Project charter has been used by scholars to define organisation problems and scope of such problems (Nabhani and Shokri 2009)

Stage two of the framework shows that organisation needs to understand the extent of the problem being faced. This stage is achieved through the DMAIC “Measure” phase. Various measurement tools can be used to achieve this such as, brainstorming, reporting, chart, and graph including waste log. Authors such as Hung and Sung (2011) used different charts to know the extent of the organisational problems.

Stage three of the framework helps organisation to identify the root causes of FWL. The “Analysis” phase of the DMAIC will be used to achieve this step. Mena et al. (2014) used one of these tools to find the root cause of FWL in the UK. This “A” stage requires the input from stakeholders to get holistic views of the root causes of FWL. However, the root cause diagram can be used to achieve this objective.

Stage four of the framework considered various improvement actions that can be taken by the organisation to eliminate the root causes identified in stage three. This stage can be achieved through the “Improvement” stage of the DMAIC. The “I” phase deals with possible solutions towards the reduction of FWL were is consistent with the work of Banawi and Bilec (2014) who used same to find lasting solutions to the problem of waste in the construction industry, including sustainable strategies. Also, it is consistent with the work of Krueger et al. (2013) who identified proper production planning, information sharing among stakeholders, marketing planning and so on as improvement strategies to eliminate organisational problems.

The last stage of the framework, **stage five,** enables the internal stakeholders to reflect on possible ways to sustain the improvement actions. This stage is based on the “Control” aspect of the DMAIC (Dora et al. 2013). The desired outcome can be achieved following these stages within the framework. It is good to note that each stage of the framework gives room for learning, which is promoted by information sharing and collaboration through the feedback given by the stakeholders of the FSC. This is the aspect that will be addressed by DLL in the DMAIC-DLL framework. The framework will be investigated in this study.

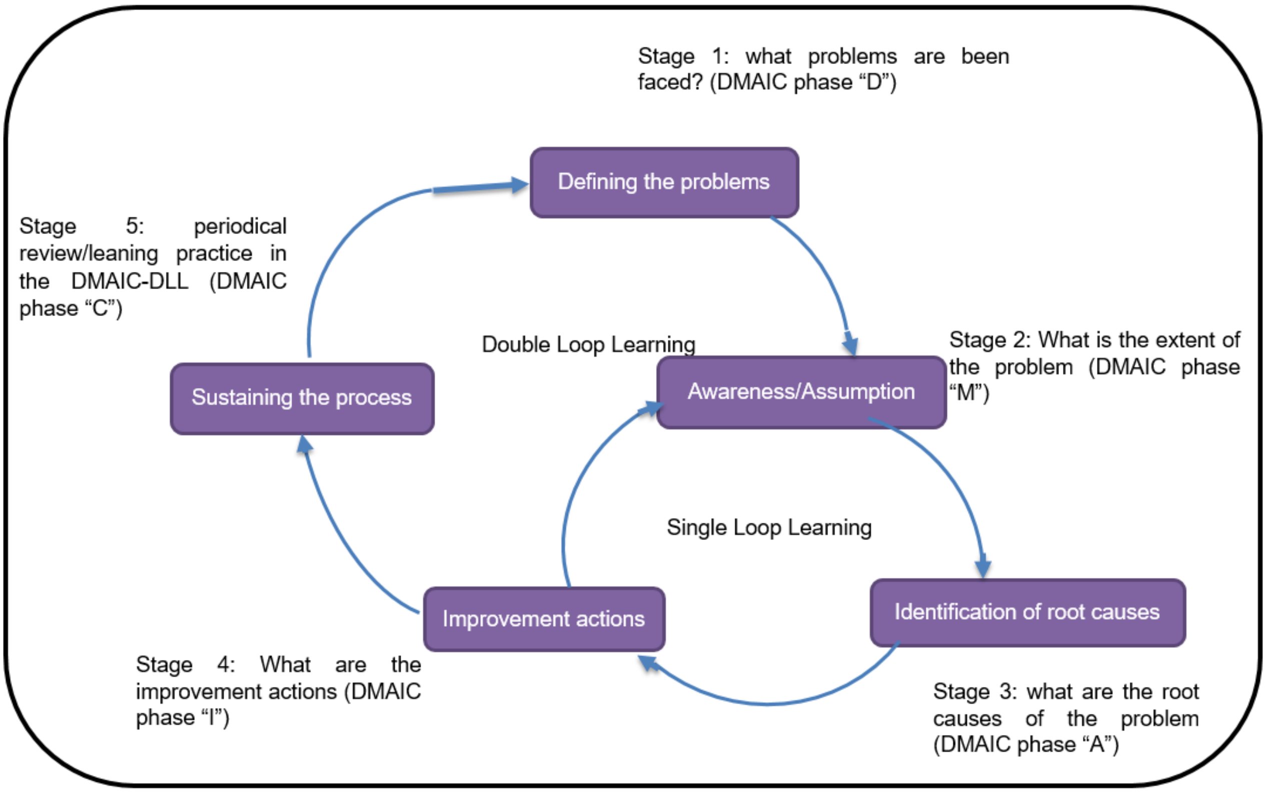

Figure 2: DMAIC-DLL Framework

To conclude our literature review section, here we have established that FWL is a global problem facing every nation of the world, and there are preventive measures that have been suggested in the literature such as the use of LSS. However, it was observed that adoption of DMAIC-DLL to reduce FWL in the literature still lacks in some ways. Also, previous studies have focused on how DMAIC could be used to achieve continuous improvement practices but not on how to promote learning through the adoption of DLL framework while reducing FWL.The review shows that DMAIC tools can be used to eliminate waste but the uses of the combination of tools within the DMAIC-DLL to understand the root causes and provide improvement actions towards FWL reduction have remained scanty in the literature. Though, the work of Mena et al. (2011 and 2014) and Dora et al. (2019) attempted to identify the causes of FWL. Their studies empirically investigated the root cause of FWL from the developed countries perspective and not based on the application of the use of DMAIC tool and DLL. Given this limitation, Mena et al. (2014) advocated for more contextual studies that will aim at exploring the root causes of FWL. Therefore, a conceptual framework was developed in this paper with a proposed hybrid model that integrated

DLL and DMAIC to address this shortfall in the literature with focus on Sub-Saharan African countries.

3.0. Methodology

We adopted interpretivism as suggested by Biggerstaff and Thompson (2008) to investigate the interpretation of the social actors on how DMAIC-DLL could be used to reduce FWL. Interpretivism recognises that reality is constructed based on the social actor's opinion and experience through social interaction (Saunders et al. 2009; Scotland 2012). Furthermore, we use qualitative approach which deals with the study of a situated world, considering phenomena in their specific macro and micro, social, institutional, political, economic, and technological contexts (Parker 2003; 16). The adoption of qualitative method aims to interpret the natural setting of how DMAIC-DLL has been used by the FSC stakeholders to reduce FWL. Therefore, stakeholder's experience, understanding and opinion are vital elements of qualitative research (Bryman 2015).

The research within DMAIC as LSS tool has primarily utilised quantitative research methods, using statistical techniques with focus on positivist philosophical stance (see Drohomeretski et al. 2014; Prashar 2014; Shokri et al. 2014). However, there are limited studies that have been carried out using qualitative research (Krueger et al. 2013). Screedharan and Raju (2016) advocated for more qualitative research within the field of LSS using DMAIC tool. Hence we take the subjective view to explore the adoption of DMAIC-DLL rather than the objective view which has characterised most of the previous study on DMAIC (Peters et al. 2013). We thus, use DMAIC as a problem-solving methodology. This methodology provides various tools that could be used to address the objective of DLL in order to reduce FWL. In this research, we do not aim to carry out the implementation of DMAIC in the case companies but used each of the phases of DMAIC to achieve the objective of this research, that is, DMAIC phases were used to answer the research questions. The methodology provides improvement process that enables FSC stakeholders to reduce FWL. As shared by Thomas et al (2008), DMAIC methodology is effective to implement LSS to provide process improvement tools for organisations. This is linked to case study approach as shown in the next section.

3.1. Case Study Approach

We used a case study approach as an exploratory and descriptive methodology, consistent with the work of Marinez-Jurado and Moyano-Fuentes (2014). A case study is exploratory when the phenomenon required a deeper understanding and the variable are not known (Yin 2014) and where the questions of "how" and "why" are used. Consequently, a multiple case study is adopted to explore the issues of FWL and how DMAIC-DLL could be used to reduce FWL. In the case study, there is a need to place boundaries on a case to avoid deviation from the study objective (Yin2014). Therefore, research questions should be the main determinant of defining a case relating to a particular organisation, social group, etc. (Yin 2014).

For validity, accuracy, and credibility, two ranges of complementary samplings techniques were employed including purposeful and snowball sampling (Bryman 2015). As often with qualitative case studies, a purposeful sampling technique was chosen as a primary sampling strategy (Creswell 2012:206). As such, participants who were believed to have experience, information, and knowledge about the FWL issues within the processing and distribution units of the proposed case companies were purposefully included in the study. For example, members of staff within the processing and distribution unit of the case companies, this is consistent with the similar techniques used by Viio and Nordin (2017). In addition to purposeful sampling, the snowball sampling technique is used when a researcher samples initially a group of participants based on the research questions, and these sampled participants propose other participants, who have had the experience and knowledge that is relevant to the research problem (Bryman 2015:424). Thus, further participants for the research were recommended by the internal stakeholders of the case companies to gather the opinion of the external stakeholders (Nastasi 1999).

3.1.1. Selection of Cases

Before delving into case selection, it is worth highlighting why we chose to focus on Sub-Saharan African region and especially Nigeria. In the literature, there is limited evidence on the strategies to be used in reducing reduce FWL from the perspective of developing countries, most notably Nigeria, a Sub-Saharan African country (Afun, 2009). For example, the adoption of DMAICL-DLL to reduce FWL in Nigeria has not been shown empirically in the literature. Hence, the need for this research. Nigeria as a country has a large market share for most foreign and local goods, including food products due to the growing population. The population of Nigeria as presented by the World Bank (WB) who put the people of Nigeria above 182 Million as of 2016 and claimed that this population would double by 2050. Given the claim by World Bank (WB) (2016), Nigeria is a good ground for investors that may wish to invest in FSC due to the availability of markets for food products as a result of growing population which will increase the demand for food commodities. However, the more the population in Nigeria grows, the need for increase in the food supply, and if care is not taken the percentage of FWL at processing, and distribution stages will keep growing due to the poor infrastructure in the country and poor knowledge of FWL reduction strategies.

Drawn on the work of Farquhar (2012) and based on the objective of this research, two in-depth case studies were conducted to gain an in-depth understanding of FWL reduction. This guide against bias provides robustness, reliability, and triangulation (Mathias and Brown 2016). The two case studies were selected based on the production of ambient food drawing on the work of Mena et al. (2011) who suggested that ambient food include food products such as bread, biscuits, fresh vegetable, fruits, and other ambient food, e.g. oil, pasta, rice, etc. Moreover, Cicatiello et al (2016) confirm that more than 70 percent of waste occurs in ambient food production. Oladepo et al. (2015) added that due to lack of updated equipment in the developing countries waste in the production and distribution of bread has been on increase. Hence in this study, we will focus on FWL in the companies focusing on ambient food which is one of the fastest moving food products in Nigeria, and many wastes are being generated through these products (Kummu et al. 2012). Chosen case companies who had knowledge of DMAIC and also had a major market share in the Nigerian food sector were chosen.

The chosen companies produce and distribute biscuits and bread. Case A has been in the production of ambient food such as biscuits, and bread since early 1960. The products are characterised by a short shelf life with approximately 5 days for bread and a month for biscuits. The company produces around 17, 000 tonnes worth of the product every month. The company is one of the largest producers of bread and biscuit not only in Nigeria but also in other West African countries. They generate more waste in their processing unit compared to the distribution unit of the FSC. The company's Distributors are over 3,000 across the countries with more than 10,000 Retailers.

On the other hand, Case B is into the production of bread and biscuits since early 1980 and has since expanded its distribution to other West African countries. The company produces around 14,000 tonnes of both products every month. The company's distributors are over 2000 while retailers are more than 10,000. The company like case A generates more waste during the production of foods compared to the distribution unit.

3.2. Sampling and Data Collection Instrument

The participants were recruited through the Manufacturer Association of Nigeria (MAN), an umbrella of food industry in Nigeria. An email and letters were sent to the participants who were engaged in DMAIC activities through MAN, soliciting their consent for participating in the research. In the email, we introduced ourselves and the project after which the aim and objectives of the study were shared with the participants then the researcher invites them to participate. A consent letter was attached, primarily to ask them to sign if they wish to give their consent to participate in the interview. The researchers explain to them their right to anonymity and confidentiality as well as the right to withdraw from the interview at any point they may wish to. The participants were informed that the interviews would need to be recorded with a voice recorder for easy analysis of the interview.

A semi-structured interview is adopted to explore the understanding, experience, and perception of the participant on how DMAIC-DLL could be used to reduce FWL. However, for triangulation purposes and to understand how DMAIC tools were used, the company's documents, annual reports, graphs, charts, and observations were used alongside the semi-structured interview. 30 interviews were conducted in the food processing and distributing units of the case companies. The interview was conducted with tactical, operational, strategic staff, and distribution staff because they have more knowledge of how FWL is being generated in the units as well as improvement actions to reduce it. The respondent consisted of four top management staff, eight middle-level management staff, eight tactical staff, and six wholesalers/distributors as shown in Table 2. The interview was conducted between

30 and 60 minutes. The interviews were recorded with the permission of the interviewees.

Table 2: Distribution of Interviews across the Cases

Participants	**Position**	**Numbers of in-depth interviews**		**Total interviews**
		Case A	Case B	
Internal FSC Stakeholders	Senior manager	4	4	30
	Operational Staff	4	4	
	Tactical staff	4	4	
	Distributors/retailers	3	3	

Interview questions were drafted based on the five phases of DMAIC as shown in Appendices A. For ethical reasons and for the fact that FWL is considered sensitive issues to the food industry, confidentiality was agreed with the participants and case companies including participant's names were anonymized. We used Case A and Case B for company names and I1, I2, 13…...I30 for the interviewees.

3.3. Data Analysis

All the interviews were transcribed and analysed using Nvivo 11 qualitative software program. The software allows the researcher to bring out different codes which later formed emerging themes. Multiple cases were used to provide a comparison and differences between the two cases. These comparisons were carried out using the themes that emerged in both cases (Creswell 2012). The following section presents the findings based on the DMAIC problem-solving methodology.

4.0. Findings

The findings were structured using the five stages of DMAIC. These five stages were used as a process of achieving DMAIC-DLL framework to reduce FWL.

4.1. Defining the Problem (DMAIC Phase "D")

We found that one of the major issues the case companies were facing, was the problem of FWL in both their processing and distribution units. The project-charter tool of DMAIC was used to provide a qualitative summary of this problem. With project charter, the boundary and scope of the research were clearly defined for each of the cases. The participants' opinions were used to provide information in the charter based on the excerpt from I1, I4, and I17 as shown in Table 3.

Table 3: Project Chartered

Defining the problem (Project Charter)	
Case A: Case A has been into the production and distribution of food for about 6 decades. The company is one of the oldest food industry. Based on the documents made available from January 2015 to Dec. 2016. It was found that the company produces an average of 17,000 tonnes of bread and biscuit monthly. As per the annual report of the company and observation of the daily report by the researcher. However, the interview revealed that the major challenges faced by the company is the rate at which food waste occur during the production and distribution of food products. **Case B:** Case B has been in the food industry in Nigeria for more than 30years. Based on the documents made available from January 2015 to Dec. 2016. It was found that the company produces an average of 14,000 tonnes of biscuits daily. As per the annual report of the company and observation of the daily report by the researcher. However, the interview revealed that the major challenges faced by the company is the rate at which food waste occur during the production and distribution of food products.	**Problem statement**: Food processing at the case companies contributes to about 70 percent of FWL, while distribution of food contributes to the remaining 30 percent **Goal statement:** To check how the case companies were able to reduce the FWL at processing and distribution units.
	Strategy: DMAIC-DLL

4.2. Awareness of the Problem (DMAIC Phase "M")

The analysis of the case companies shows that both cases are aware of the extent of the FWL being generated daily, this was the initial action in identifying the root causes. We found that the uses of charts, graphs, input, output analysis, and waste log was used to understand the extent of the FWL and to detect the hotspot of FWL in both cases. One unique thing about this was that charts and graphs were displayed daily on the notice board in the factory for employees working in these units to see the extent of the waste been generated.

For example, we found that the input-output analysis was used to understand why the input is not yielding the expected output, and to what extent? Therefore, these tools allow the companies to know the level of FWL, and this has helped both cases to analyse the root causes of the waste. This was confirmed by I30 one of the management staff in Case A:

I30: *We carried out daily reports' reconciliation, though, it is tedious to carry out daily inventory reconciliation. It helps to know the differences in input and output.*

Furthermore, the researchers were taken to the production room, where some charts were shown to them from the previous production activities. At the room, it was observed as stated by I24:

I24: *These are charts on the wall, where the production staff filled daily. The chart shows the number of goods produced during a certain period and the numbers that have resulted to waste.*

As shown in Appendix B and C the daily waste log reported by the case companies, highlights significant FWL.

4.3. Root Causes of FWL (DMAIC Phase "A")

There are similarities in the root causes of FWL being generated in both cases. This is because they are into production of homogeneous food products. It was found that for improvement actions to take place, the companies need to analysis the root causes of wastes. We found that the quality management team in case A, was responsible for the identification of errors that could lead to waste, while it is the responsibility of all staff working in both processing and distribution units in case B to identify errors that could lead to waste. Though, the quality management team are responsible for the analysis of any errors in both cases. The cause and effect diagram has been one of the major tools being used in both cases to identify the root causes of FWL. This was confirmed by two of the participants in both companies as shown in the excerpt below:

I5: *We adopted some of the statistical tool to identify the root causes of FWL in our processes such as cause and effect diagram*

I15: *For us as a company, to reduce FWL, we need to ask ourselves what is the causes of these wastes? In doing that, we usually adopt some analytical tools*

We identified four root causes of FWL in both cases as shown in the cause and effect diagram in Figure 3. The root causes were identified as transportation issues (yellow colour), factory errors (cream colour), human factor (light blue colour), and management practices (pink colour).

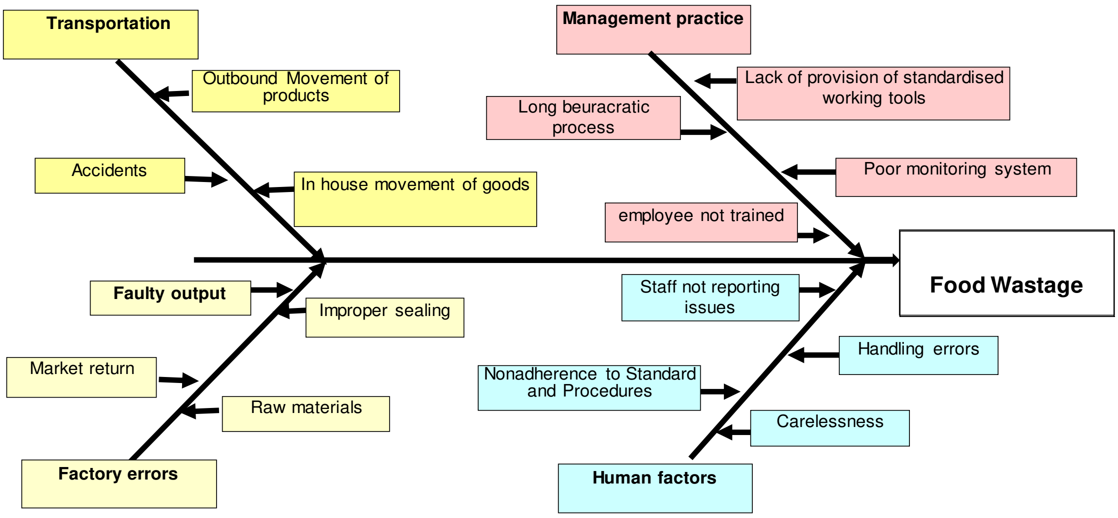

Figure 3: Cause and effect Diagram

4.3.1. Transportation Issues

We found outbound and inbound movements as a way by which FWL were being generated in both cases. Most times, products are squeezed in the process of outbound movement to distributors. This might be due to mishandling on transit or cause by accidents, due to the poor condition of the road networks in the country of operation. As confirmed by I4:

I4: *In the process of moving the product via trucks* to the final destination, accidents might occur, leading to destruction or squeezing of our products*.*

We found that the highlighted issues of loss from outbound movement does not affect case B, because the company outsource the distribution section of the company to the 3rd party. However, during the in-house movement of products, FWL might occur as asserted by I11:

I11: *Moving products from the processing unit to the warehouse; damages might occur as a result of errors from the staff or the machines used in moving the products.*

4.3.2. Factory Errors

We found that improper sealing and faulty output, which includes product contamination, were sometimes caused by errors due to faulty machine and human factors.

Improper Sealing

From the finding, market return is one of the results of improper sealing and this happened in both cases. The finding shows that products that were not correctly sealed are sometimes distributed, due to the inability of the companies to detect such error at the processing level before distribution, the products are returned leading to waste as shared by I7:

I7: *Product that are not well sealed are returned to us and by the time it gets back, might lead to discarding of such products*

In Case B, it was found that bread might not be well sealed due to sealing errors from the factory are set aside by the distributors and will be returned to the factory.

Faulty Output

Another problem that was found in both cases was faulty output. This happened when the number of biscuits in a pack supposed to be four pieces, but at times the pieces comes out in two or three. This might not be detected at the processing level, until after distribution and the product will be returned. Further finding shows that such products cannot be recycled but might be sent to animal feed. Also, we found that changes in the colour of biscuit could make the product to be returned to the factory by the distributor. The excerpt by I9 and I13 confirms this:

I9: *When the number of biscuits in a pack is not up to the expected, the distributors will sometimes send such products back*

I13: Changing in the colour of biscuit or bread usually lead to waste of such products

Also, it was found that contamination of products during processing could lead to waste of food materials. This occur when unwanted particles found its ways into the raw materials that are being processed. It was found that machine oil could loose and mixed with products, if this is detected, the product will be dislodged from the machine and flush out.

4.3.3. Human Factors

Human factor is one of the significant reasons why FWL occurs in both cases. This is due to various negative attitudes of the employee especially in the developing countries where monitoring activities is very low. The following were found:

Carelessness

In both cases, staffs tend not to be reporting issues that could lead to wastes of products during the discharge of their duties. As shown from the analysis, due to the carelessness of staff, issues that may affect performance are often not reported to the management. For example, a machine that have been showing signs of fault but instead for the staff to lay complaints about the machine, so that it will be repaired or management will stop the use of such machines, staff might keep using it, until it stops working while in use. If this happens, the products in the machine while being use might result to waste. Excerpt by I8 confirms this:

I8: *Sometimes staff do not report faulty machines on time and by the time the problem is detected, it might be during the processing, and the machine might stop suddenly. The products in the machine might lead to waste because the case was not reported on time.*

Non-adherence to Standard and Procedures

Both companies have sets of standards laid down for product formulation in line with their company's production standard during products formulation stage. The finding shows that the inability of staff to follow the laid down procedures and rules had led to wastes in the past. This suggests that when staff do not diligently follow procedures during processing, FWL might occur. The same issues also prevail in the distribution stage when staffs chose not to follow the stacking procedure while loading the products on the distributing trucks. This non-adherence to standard often leads to wastes of products as I11 highlighted:

I11: *Staff that do not followed the company procedures during the processing are often sources of FWL*

Handling Errors

Poor handling from the staff during processing or distribution is found to be one of the root causes of FWL in both cases. The findings show that staff might be following the required standard that has been laid down by the company but decided to handle the products poorly then wastages are inevitable. As a result, some inevitable mistakes could be because of error from the staff, in house accident is one of the examples that emerged in both companies

I28: *Mistakes are sometimes inevitable and could lead to waste*

We found that staff mistakes are inevitable in both processing and distribution units.

4.3.4. Management Practice

Poor management practice such as poor monitoring, lack of information sharing system, lack of provision of standardized working tools, inadequate training, and long bureaucratic processes were found to be the root causes of FWL based on management negligence.

Poor Monitoring and Lack of Information Sharing System

Although staff were expected to be monitored during the discharge of their duties, in Case A, we found that staffs were not adequately monitored during products formulation stage and this had resulted in many incorrect formulations of products, leading to waste. We found that weak monitoring system gives opportunity to staff to act in a manner that does not accede with the company standard. This was confirmed by I6:

I6*:* *Poor monitoring system allows staff to behave as they like which has been one of the sources of waste*

Although in Case B, monitoring system was very robust compared to Case A, the major problem with Case B was weak information sharing system, whereby the flows of information were not sufficient. Staff were not allowed to share information without formal approval from necessary authorities and this led to waste of raw materials during processing. It was found that delay in information sharing and failure to make information available to employees resulted in the use of trial and error ideas which has been one of the sources of FWL.

I22: *Some of this problem could be solved amongst the internal staff assuming the right information was given, but the management prefers to invite external persons to attend to problem that will know we could solve.*

Lack of Provision of Standardised Working Tool

The finding shows that loaders in the distribution stage in Case A, are not always provided with equipment and necessary training, that was needed to help their skills when carrying out loading duties. As a result, they were subjected to the use of manual handling in loading products to trucks; in the process, wastes are generated. However, when manual handling is used, damages mostly occur in the process. The staff member carrying out this task may fall by mistake and the product that is being carried might get damaged. Consequently, when management refused to provide the needed working tools to the staff, FWL will be generated. In Case B, it was found that there were adequate working tools that enabled the staff to perform their duties without the need to delve into using manual methods of carrying out their jobs.

Inadequate Staff Training

In both cases, there was inadequate knowledge by staff to perform some functions, which was due to the inability of management to provide appropriate training and standardized procedure to aid the staff. When staff were not supplied with the needed resources and skills, they tend to carry out their duties in an unprofessional manner which may produce negatives effects which leads to FWL. The staff in these cases shared that, if wastes are generated because the company management did not provide the needed materials, such wastes should be seen as management negligence and not that of the staff.

4.4. Improvement Actions (DMAIC Phases "I")

The root causes of FWL have been determined, therefore the DMAIC phase "I" aims at identifying various solutions that could be used to eliminate or reduce the root causes while reducing FWL. Appendix D shows some of the identified improvement actions taken by the case companies as shared by the interviewers.

4.4.1. Use of 5S tools

We found that both cases make use of 5S tools to help ensure the quality of the duties discharged by the employee and allowed them to carry out their roles through the required standards to afford waste. The company top official in Case A shared that they have over the years adopted an aspect of Lean management features, that is, 5s and has been used to organise the factory area and distribution unit as stated below:

I1: *We adopted 5s which involved sorting help to discovered and remove all unnecessary items from the factory ", "you see we have to set everything in order, that is the case level of the "s", the third "s", involved us to make sure everywhere is cleaned including our machine because at times if machine is not clean is a problem that can cause breakdown of such machine, leading to FWL. The fourth "s", make us have a standard of how things ought to work in the workplace and while the last "s", help us to continue to monitor and continue to improve all our activities*

In Case B, we found that Gemba Walk was adopted which allowed top management staff to make an unscheduled inspection to the processing and distribution unit as shared by I19:

I19: *Aside from the supervisors, there are other teams from the management side that can come to the factory or where we are loading at any time to check what we are doing*

Gemba walk allowed the management team to see things for themselves, leading to proactive action on how to mitigate any challenges being faced by the staff during the inspection.

4.4.2. Supervision/Monitoring

Supervision was being used as a monitoring mechanism to ensure that necessary supports are provided to the staff during the discharge of their duties. We found that supervision was to ensure coordination and ensuring efficacy. This appear to be the case in both cases. Supervisory role was being carried out by the most experienced and more knowledgeable staff members. I13 shared that:

I13: *Our staff are monitored at every stage of their work. The supervisor monitored those under him, and he is responsible for any fail out.*

As such the supervisor would be careful to ensure his/her subordinates perform as expected. The company had a mechanism in place that monitors the rate at which food are being wasted during processing and distribution stage. In a situation, whereby the rate of FWL are more in a particular unit, the supervisor in charge of the unit would be queried. Therefore, the case companies ensure that information sharing is being promoted, availing staff the opportunity to have access to needed information.

4.4.3. Improved Collaboration

The finding shows that collaboration and knowledge sharing are important in both cases. To achieve knowledge sharing, there are diversity in the range of expertise employed by both companies, which is a necessity for the development of collaborative ideas and knowledge sharing in the organisation. It was found that collaboration and knowledge sharing help the companies to cope with complex problems and improved organisational learning. The ability of the individual employee to collaborate productively with one another was crucial for individual learning development and organisational competitiveness. This is confirmed by I7 and I21:

I7: *Relationship with our stakeholders is very important to us.*

I21: *We have a team of people that are saddled with that responsibility of relating to our stakeholders.*

From the findings, collaboration comes before knowledge sharing. This suggests, when collaboration is not allowed, knowledge sharing might be difficult. It was found that stakeholder's engagement through team meetings and information sharing are effective ways of knowledge sharing methods, that have helped to improve knowledge of how poor handling, unruly staff behaviours, and incorrect formulations could be eliminated.

4.4.4. Learning Practices

We found collaborative, experiential, and training to be effective in reducing wastes that occur as a result of human and non-human errors in both cases. The three-learning process has been effective in the case companies as confirmed in the excerpt below;

I2: *We learn through different means, training, learning from experienced staff and learning from information shared among the team*

As shown in the analysis, collaborative learning allows the employee to learn from each other. This could be in form of learning from shared information which involves dissemination of new ideas or knowledge. This could involve team of the employee coming together to learn best way a job can be done. This was confirmed by I27:

I27: *Joint learning activities are allowed in our company. Staff can come together and put their mind and thoughts together to solve a problem, and in the process, they will improve their skills*

4.5. Sustaining the Improvement (DMAIC Phase "C")

We found both cases do not aim to reduce the FWL at a particular period alone, but to sustain the improvement process that has been discovered to be useful in the elimination of the waste. Therefore, different control process was taken by the case companies. For example, in case A, the company invest more in staff training to improve the knowledge of the staff. Also, there is a monthly review of the improvement process in the case company. This is to check and re-check that the company is in control of their improvement activities. This was confirmed by I1, the Executive Director of the Case A:

I1: *We ensure that every month we check our improvement strategies, to ensure we are on top of our ideologies. If we notice more waste than expected, we go back to identify the root cause of waste.*

For Case B, we found that there is quarterly review of these processes starting from questioning every stage of the processing and distribution unit in order to check for unwanted wastes. If the level of FWL has not increased, then the company will maintain status-quo. In case, there is an increase in the level of waste compared to the last time the continuous improvement was undertaken, the company will go back to identify the root causes with the corresponding solution, while adding new skills to the organisation in form of learning. This was confirmed by I20:

I20: *we review our processes every three months to check if there are no wastage than expected*.

5.0. Discussion

To address food wastage and loss (FWL) especially in the pre-consumption stage of a developing country context, we adopted DMAIC tools as a process to achieve the DLL to reduce FWL in the processing and distribution units of the Nigerian FSC. We found that for DLL to be achieved, five stages will be required as shown in Figure 4. We extend Argyris and Schon (1974) framework. Argyris and Schon (1974) highlighted three constructs for achieving DLL- governing values/assumption, taking responsibility to identify root causes, and taking responsibility to solve the problem, however, we found five stages which include, defining the problem, awareness/assumption, identifying root causes, improvement actions, and sustaining the improvement actions as a more effective way to achieve DLL. Savolainen and Haikonen (2007) argued that DLL could be better explained by DMAIC, but without providing empirical evidence. Our research contributes to the knowledge by empirically showing that DMAIC could be used to achieve the objective of the DLL especially in reducing FWL at processing and distribution stage, which are at the pre-consumption stage in the food supply chain. The findings suggest that DMAIC is an enabler of organisational learning through its different phases.

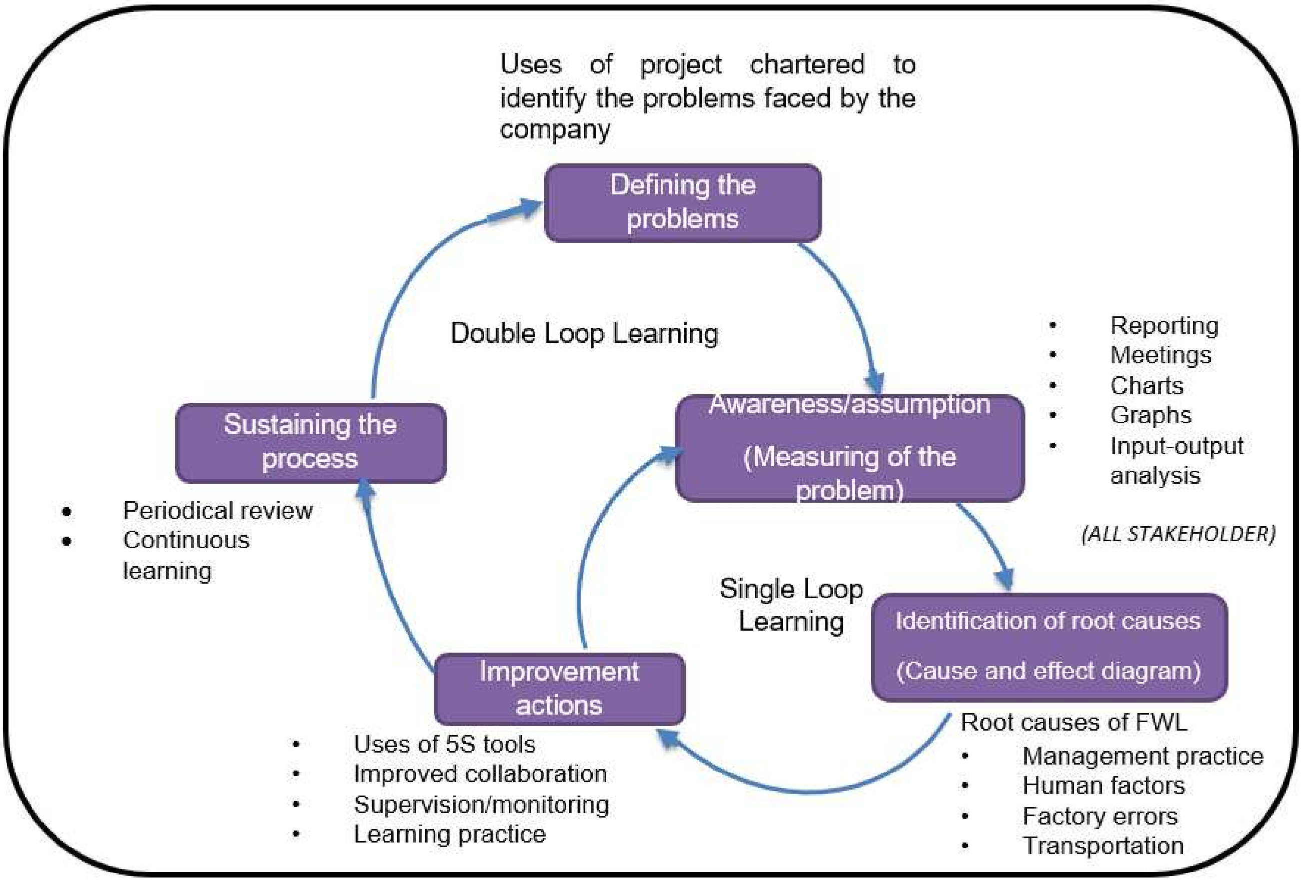

Figure 4. Modified DMAIC-DLL Framework

Based on our findings we structure our discussion around these five stages to further elaborate how the five-stage DMAIC-DLL could be used to address FWL.

5.1. Define the Problems

The first stage of FWL reduction is to define the problem. We found that the project charter of the defining aspect of the "Define" phases of DMAIC was used to identify the problem being faced by the FSC. Also, the charter tool was developed based on the interpretation of the stakeholders on what they considered to be the major challenge of the organisation. This is consistent with the previous research by Ben Ruben et al. (2017) who used this aspect of the DMAIC to identify the problem of defects in their study. The authors used the project charter to identify the problem of growing defect as the major problem facing the case company (Guan et al. 2020).

5.2. Awareness and Assumption about FWL

In the second stage of the framework, we found that FSC companies need to be aware of and know the extent of the FWL problem in both units. We, therefore, found that to know the magnitude of FWL the "Measure" phase of the DMAIC will be needed. This enabled the case companies to identified governing values that might need to change for the problem to be addressed. Furthermore, we found that without understanding the extent of the problem, the root causes may not be found. This research confirms the work of Arumugam et al. (2013) that "the Measure phase" is otherwise known as "knowing what". Therefore, "knowing what" help organisation to know the magnitude of waste in both processing and distribution stage of the FSC. As a result, some of the Measure tools such as charts, graphs, input, and output analysis were adopted (Liao and Marsillac 2015). However, our study found waste log as shown in Appendix B and C to be effective in understanding the extent of FWL in both cases. Furthermore, Marabelli and Newell (2014) argued that creating awareness about the organisational problem is the first step towards learning on "knowing what". Therefore, for learning to be effective, stakeholders need to know the extent of the errors, this will lead to identifying the causes of such error.

5.3. Identification of Root Causes

The third stage of the DMAIC-DLL model suggests that organisation needs to take responsibility to identify the root causes of errors (Argyris 1977). We found that management practices, human errors, factory errors, and transportation were found as the root causes of FWL in both processing and distribution stages of the FSC. Human errors are caused, due to lack of concentration and attention to details, especially during the processing and distribution stage. Marais et al. (2017), in their study, shows the impact of lack of concentration of restaurant staff towards FWL generation. This study is line with their finding that lack of concentration and attention to details could lead to FWL at the processing and distribution stage of the FSC. We found that factory errors and transportation are the root causes of improper sealing and faulty output (Dora et al. 2019).

The proponent of the DLL model did not suggest any tools that can be used to achieve this aspect of their model. However, this study found that some of the tools within DMAIC "Analysis" phase can be used to achieve this stage of the DLL. We found that cause and effect diagram was a tool that helps the case companies to analyse the root causes of FWL. The cause and effect diagram had previously been used by scholars in the field of quality management (Sarkar et al. 2013). For example, Mishra and Sharma (2013) used the cause and effect to have a clear picture of the parameters affecting the shrinkage process in their study. Our findings thus extend the work of Mena et al. (2015) that management practices also cause waste in both the processing and distribution interface as well as shown in the cause and effect diagram. This suggests that management practices impact staff behaviour. Other authors such as Liljestrand (2016) concur with the argument by Mena et al. (2015).

5.4. Improvement Actions

In our study we found that improved collaboration amongst stakeholders is a major way by which the case companies was able to reduce FWL. As it led to improve in information sharing as well as staff morale. This is what Eksoz et al. (2014) termed as collaborative methods of FWL reduction. This collaborative effort was used to identify the essential ways by which FWL can be reduced based on the identified root causes.

Supervision and monitoring system ensure that all activities that are being carried out by the staff are well supervised and adequately monitored. This has helped to reduce human errors and factory errors. Machines are well checked as at when due. These findings agreed with the previous study on the effectiveness of monitoring systems in reducing FWL (see Bent et al. 2000; Capaldo et al. 2017). Our finding extends the work of De Steur et al. (2016) that supervision and inspection of staff involved in the processing and distribution of food are some of the effective ways of limiting human errors. Also, Gemba Walk by the management staff help to reduce errors from the staff as well as take proactive actions on faulty equipment. Scholars have argued that Gemba walk is one of the human resources tools that ensure right things are done by the staff (Suárez-Barraza et al. 2012). Therefore, this stage of the DLL was addressed through “Improve” phases of the DMAIC similar to the “knowing-how” proposed by Arumugam et al. (2013). We also found that learning in both cases started with the everyday experience of the employee, training and collaborative activities at each stages of the framework. These are learning process that can be achieved through the adoption of the DMAIC-DLL (Kolb 2014;Kayes 2002).

5.5. Sustaining the Responsibility to Reduce Waste

This aspect ensures that organisation maintains their success in the reduction of FWL. As a result, the case companies ensure that their process are standardised with development plans (Aman et al. 2015). Furthermore, documentation to ensure that the process of reducing FWL reflected in their policies and procedures. Monthly and quarterly review of the process were identified as a continuous improvement process that needs to be taken seriously. Staff are mandated to report any issues that might lead to waste during the discharge of their duties. Training were mandatory for staff in both units to guarantee that staff knowledge are up to date (Gijo and Anthony 2014).

5.6. Contributions

We contribute to the OLT by using some of the DMAIC tools to achieve DLL, which aim at reducing food wastage. Through this research, we extend the literature on both the DMAIC and DLL. The research contributes in terms of reinforcing the establishment of how the tools within DMAIC could be a powerful paradigm for achieving DLL, that will lead to continuous improvement practice. We believed; we are the first to apply the concept of DMAIC paradigm in achieving DLL towards the reduction of FWL. The integration of both DMAIC and DLL allows this research to establish five stages by which double-loop learning could be achieved. Thus, this research fills a gap in the understanding of how different stages in the DMAIC-DLL framework interact to achieve DLL to reduce FWL.

Prior to this study, there was a dearth of knowledge about how DMAIC-DLL could be used to reduce waste in the food supply chain industry, particularly in Sub-Saharan African. Despite the importance of the topic to Nigeria and the global economy, there is little knowledge about how the framework could be an effective tool at reducing FWL while promoting learning. Therefore, our study made a significant contribution by advancing knowledge in the use of the DMAIC-DLL framework to promote continuous improvement using the case of the Nigerian FSC. Our study contributes to the ongoing debate on the root causes of FWL in Sub-Saharan African countries.

Our contribution is not limited to the extension of Argyris and Schon (1974) framework and its application in the food supply chain context for reducing food wastage. We contributed to the methodology literature; we have identified process by which the tools within DMAIC could be used qualitatively without implementing DMAIC process but adopting some of the tools to answer the research question. Based on our knowledge, our research is the first study that had used qualitative research methods to achieve each phase of DMAIC, while promoting organisational learning.

6.0. Conclusion

We explored “how DMAIC-DLL could be used to reduce FWL in the pre-consuming stage in Nigerian FSC. Based on the semi structured interview with 30 participants, we propose our five stage DMAIC-DLL framework, we found that each stage of the DMAIC could be used to achieve the objective of DLL. These five stages were used to identify, the problem, the extent of FWL, the root causes, improvement actions as well as how organisations could sustain the DMAIC-DLL process.

Through this study, managers will have full knowledge of the process by which FWL can be reduced. The findings suggest that FSC managers can adopts all or some of the five stages of the framework to understand how organisational problem could be defined, as well as the extent of the problems. This will give full understanding of the root causes of such problems and provide improvement actions that would be used to eliminate the problems. This will provide opportunities for organisation to be more proactive in their problem-solving skill. Furthermore, each of the stages provide steps by step by which organisational learning could be achieved. This is because at each of the stages, collaborative and experiential learning are being promoted. Therefore, research in other sectors could adopt these stages within the DMAIC process to solve organisational problem without necessarily implementing the process.

The study is limited to the Nigerian FSC particularly for the pre-consumption stage of processing and distribution. Future studies could consider investigating how other units within the FSC could be used to achieve these stages. Moreover, future research may replicate the process outlined in this research to solve other organisational problems. This research depends only on a qualitative research method, future research could consider the use of different methods, during the adoption of the five stages of the DMAIC-DLL framework.

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Appendices

Appendices A: Interview Protocols to Operationalise DLL and DMAIC in the Case Companies

Construct from the DMAIC and DLL	Definition of construct	Sample Questions (Refer to interview guide)	Purpose	Academic reference to support the research questions
Awareness ("D" and "M" aspect of DMAIC)	The awareness of the FWL is based on the research problem that has been identified in the literature. Thus, it suggests there is awareness of the FWL based on the evidence from the literature.	I'd like to start by having you tell me your background. What is your role in this company? What are the major problem facing your processing and distribution unit? What is your understanding of FWL? How does it start? How well are you informed about this problem? How aware are the other member of your units aware of this problem? Do you have any documents to show the extent of the FWL?	*To be certain that respondents have full awareness of the research problem and have met the criteria of being part of the key participants to be interviewed.*	Viio and Nordin (2017) Neff et al. (2015),
Honesty to find the root causes ("A" aspect of DMAIC)	Based on the awareness of the FWL problem. The next stage of the double-loop model is to know the root causes of these problems.	What products generate more waste base on your understanding? What are the reasons for FWL in these products? What do you think are the root causes during processing of those products? etc.	*To understand the subjective view of the participant on the root cause of FWL in processing and distributing units.*	Mena et al. (2011) Mena et al. (2014)
Taking responsibility to solve the problem ("I" and "C" aspect of DMAIC)	Having understood the root cause. The last stage is to now understand the strategy that can be used to solve the problem based on the subjective view.	I will like you to tell me some of the supply chain improvement activities that you put in place in your organisation. How effective are these mentioned improvement actions? How are these processes being sustained? Etc.	*To understand the opinion, experience, and understanding of the participant on the improvement actions as well as how the case companies are sustaining the actions to control FWL based on the identified root causes*	Ingram et al. (2013) Aschemann-Witzel (2015)

Appendices B: Waste log in case A (FWL Measuring tool)

Production months	Number of production (tons)	Types of waste (tons)						
		Processing			Distribution			Total wastes
		Scraps	Spoilage, incorrect formulation..	Other waste	Loading errors	Storage and packaging	Other wastes	
January 2016	17,089	3,000	910	1000	500	400	200	6010
February 2016	17,089	2500	900	850	670	445	259	5624
March 2016	17,089	3500	950	900	700	400	200	6650
April 2016	17,089	3670	1000	940	710	480	316	7116
May 2016	17,089	2230	980	780	700	600	400	5690
June 2016	17,099	2500	750	690	700	400	400	5440
July 2016	17,100	2190	500	800	700	500	400	5090
August 2016	17,906	2570	980	900	590	400	400	5040
September 2016	17,089	3789	500	700	300	400	350	6039
October 2016	17,089	3600	750	670	400	350	350	6120
November 2016	17,089	3100	900	750	400	340	450	5940
December 2016	17,089	3500	1000	690	400	350	400	6340

Appendices C: Waste log in case B (FWL Measuring tool)

Production months	Number of production (tons)	Types of waste (tons)						
		Processing			Distribution			Total wastes
		Scraps	Spoilage, incorrect formulation, etc	Other waste	Loading errors	Storage and packaging	Other wastes avenue	
January 2016	14,000	1400	970	300	200	800	200	3870
February 2016	14,000	1500	900	858	688	690	409	5045
March 2016	14,000	1500	555	909	750	700	245	4659
April 2016	14,000	1500	700	840	900	600	616	5156
May 2016	14,000	1500	800	806	760	780	470	5116
June 2016	14,000	1500	807	790	790	480	500	4867
July 2016	14,000	1450	300	900	750	600	400	4400
August 2016	14,000	1370	760	900	690	660	670	4390
September 2016	14,000	1300	400	770	560	600	350	3980
October 2016	14,000	1500	700	670	490	350	450	4160
November 2016	14,000	1500	800	650	500	403	550	4403
December 2016	14,000	1500	700	690	450	650	490	4480

Appendices D: Improve actions for eliminating root cause of FWL in both cases

Improvement actions	**Process/methods**	**Corresponding effect on FWL reduction**
Use of Lean and other management tools	• 5s • Gemba walk	• Factory area are well organised • reduced level of damaged products • reduced factory errors • reduce staff trial and error
Improved collaboration	• stakeholder's engagement • team brainstorming • effective information sharing • uses of social media platform to share knowledge	• enable staff to report equipment showing faulty sign • enable information sharing • reduce level of incorrect formulation • reduce improper stacking • reduced level of products damage
Supervision/monitoring/	• staff supervision • management inspection • close observation	• improved staff knowledge • enable the provision of needed working tools • help in understanding the root cause of FWL
Learning practices	• experiential learning • on-job and off job training • collaborative learning	• learning through experience to reduce errors • increase staff knowledge on how to carry out tasks to afford mistakes