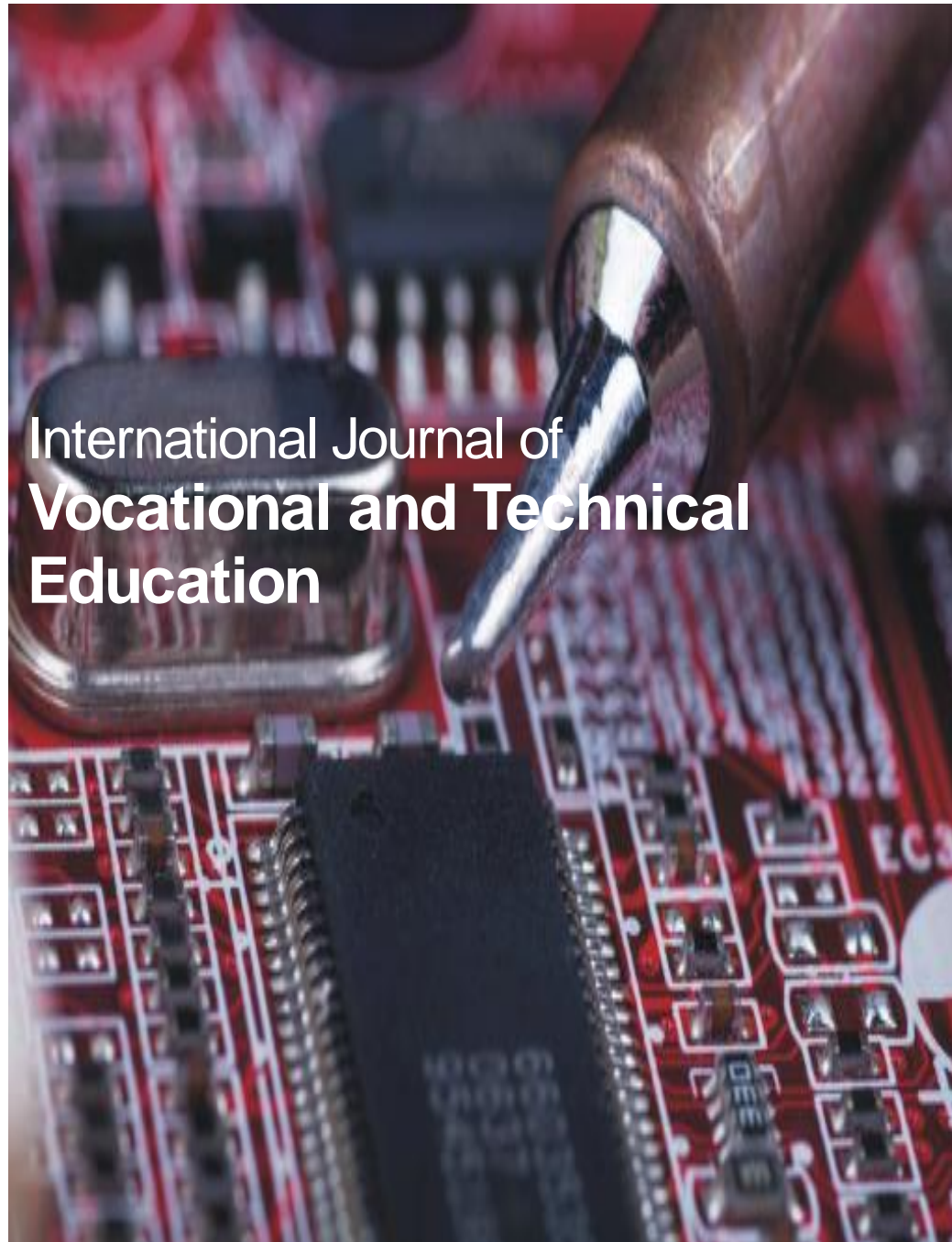


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Full Length Research Paper

Environmental implications of water as a natural resource based business: The case of non-revenue water in Kisumu City, Kenya

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Most water utilities lose significant amounts of water in their distribution systems due to leakages, illegal consumption or accounting errors. These water losses are referred to as Non-Revenue Water (NWR) by the International Water Association. Efforts to reduce water loss levels are centered on the socioeconomic aspect (efficient water provision and profit maximization) while overlooking the environmental aspects because the effects are subtle; hence it is difficult to quantify or ascertain. This study examined the effects of non-revenue water on water quality, quantity and the general environment through purposive sampling of Key informants, Focus Group Discussion and desk review methods. The findings indicated a significant positive correlation between physical water losses and water quality parameters (p-value <0.05, rho=0.872); commercial losses had a moderate but positive correlation at $P < 0.05$, rho=0.432. Further results revealed that from May through October 2019, Kisumu Water and Sewerage Company lost approximately 158,500 cm³ equivalent to 31.17% water loss. Water loss was found to also affect environmental components such as land and soil leading to pollution and degradation. The study recommends the need for bridging the gap between the existing water resources management strategies and their implementation through further studies, capacity building and technological advancements.

Key words: Non-revenue water, water quality, water quantity, water loss, environmental effect.

INTRODUCTION

Water makes up approximately 70% of the earth and is one of the most essential natural resources that interconnect the earth's natural system processes and it is indispensable to sustaining life (Baker et al., 2016). In

2010, the United Nations acknowledged water that is sufficient, safe, acceptable, physically accessible and affordable as a basic human right; however, this is usually not the case as some parts of the world still

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experience acute water shortage due to climate change, poor infrastructure maintenance, population growth, lack of funds and inadequate management making it difficult to extract, treat and distribute this water to consumers. Aside these sets of challenges, the water utilities tasked with the mandate of efficient water provision often experience high levels of water loss that derails their efforts towards meeting the consumers' demands and conservation of water and its related resources (Frauendorfer and Liemberger, 2010). These water losses are often referred to as Non-Revenue Water by the International Water Association and it is a vital indicator of the performance and management efficiency of water utilities (Donkor et al., 2014). The lack of a standardized definition to represent water loss has been criticized over the years making The International Water Association to come up with a recommended international standard water balance with clear definitions of the components of non-revenue water. The water balance technique is vital for water utilities to be able to track their entire distribution systems and discover where, why and how the losses are occurring (AWWA, 2019).

The water balance described by IWA basically revolves around the system input which is the total amount of water put into the distribution system. The system input is further Classified into two 1) Authorized consumption that has two components; billed and unbilled authorized consumption where - billed (metered and unmetered) results into revenue and unbilled (metered and unmetered) describes a situation where water usage is authorized but not charged such as fire hydrants and other public services. Although this unbilled authorized consumption contributes to the amount of water that is lost, it is not usually characterized as non-revenue water by IWA. Authorized consumption is therefore described by IWA as the amount of water which was used for its intended purposes. 2) Water losses which contribute the most to NRW. These water losses are further divided by IWA into i) Apparent/ commercial losses where water is found to have got to the end-user but there was no payment for it probably due to meter inaccuracies or outright water theft along the distribution line. 2) Physical/ real losses which include overflow of the main storage tanks and pipe burst/leakages in the main distribution network up to consumers' meter as indicated by Kingdom et al. (2006).

Water utilities around the world lose 35% of the water they produce on average but the level in some developing countries sometimes is recorded at 50-60% (USAID and WBI, 2010). A recent study by Liemberger and Wyatt (2019) indicated that the level of water loss has been constantly increasing over the years and is now at 346million m³ and 126million m³ for physical and commercial losses respectively. In Africa however, 45 million m³ of water is lost through pipe bursts/leakages per day while 16 billion m³ is lost due to water theft (commercial losses) (USAID and AfWA, 2015; USAID

and WBI, 2010). In Kenya, the average level of NRW for major towns is 45% and it is, therefore, the National Water Service's aims to provide strategies that will help in reducing NRW to under 30%; whereas the Kenyan vision 2030 however aims to reduce it to under 25% using countries with a success rate of below 20% levels as the benchmark (WASREB, 2019). Despite the rapidly increasing NRW levels, some countries such as Denmark, Germany, Netherlands, Singapore and Japan have managed to reduce the rate of water loss to below 10% which Fraunderfour and Liemberger (2010) emphasize that they should be used as the benchmarks when it comes to water resource management.

Fraunderfour and Liemberger (2010) further state that most water utilities lack the basic understanding of water loss and its components which contribute to the increasing levels of water loss and enhancing their negative environmental impacts. Due to the complexity of NRW components, the International Water Association Water loss specialist Group in their effort towards describing NRW issues and the related solutions provided a document to enhance the management of water resource and reduce water losses. Their documentation on NRW reduction further states that the management of NRW requires proper understanding of the water balance, efficient analysis of physical and commercial losses, and effective pressure management that enables the formation of strategies unique to each water utility for addressing NRW.

It is however important to note that these water losses not only cause huge financial losses for the water utilities but provide avenues or channels for introducing impurities that compromise the quality of water distributed to the consumers (AWWA, 2019). Konikow and Kendy (2005) also elaborated on how continuous water losses make depletion of water resources in the future inevitable as it forces the water utilities to extract and pump more water into the distribution system; the impact of which is often felt from water utilities that extract their water from rivers, streams or underground aquifers. This paper therefore attempts to provide further insights on how these water losses interact with other environmental components and the research was underpinned by three objectives: (1) To examine how water losses affect water quality; (2) To assess the effects of water loss on water quantity, and (3) To identify and discuss other environmental components affected by water losses.

MATERIALS AND METHODS

Study area

Kisumu City is located in Kisumu County (formerly port Florence, Kisumu District, Nyanza Province) along Lake Victoria shores in Kenya. Kisumu City covers approximately 427 km² of land 120 km² of which is covered by water mass otherwise known as Lake Victoria. Also given that it situated on the equator, the county

Table 1. Status of water quality parameters before distribution to the consumers.

Parameter	Units	S 1	S2	S3	S4	AVG.	Approved levels
Turbidity	NTU	2.7	2.58	2.3	1.82	2.35	5
Alkalinity/ pH	PHU	7.49	7.23	7.1	6.9	7.18	6.5 - 8.5
Suspended solids	Mg/l	0	0	0	0	0	30
Dissolved solids	Mg/l	243	110	341	413	276.75	700
Total hardness	TDH	112	76	143	210	135.25	300
Residual chlorine	Mg/l	0.08	0.11	0.04	0.01	0.06	0.10+ -0.05
Bacteria	Counts/100 ml	0	0	0	0	0	Should be absent

Source: Authors

experiences a hot and humid climate with night temperatures dropping to as low as 18% and an average annual rainfall of roughly 1,200 mm which occurs in 2 seasons.

Data collection methods

Desk review

For purposes of qualitative analysis, the researchers used existing data provided by Kisumu Water and Sanitation Company (KIWASCO) to achieve the research objectives. The first set of data were obtained from the meter test bench at Tom Mboya (KIWASCO branch) on all issues related to meter handling; another set of data were obtained from the human resource department to supplement data collected on measures and strategies, the finance department, production and distribution, networking department and the department that deal directly with non-revenue water. Reports on water quality done by KIWASCO laboratory at Dunga beach were also obtained to draw conclusions on the effect of non-revenue water loss on water quality. Other sources of desk review included the water Act 2016 and online resources such as journals and articles on related studies.

Key Informants Interview (KII)

The researcher used semi-structured guidelines for a detailed in-depth face to face to get responses from the key informants (KII) on the status of Non-Revenue Water, how and why these water losses occur and what the water utility has done so far to curb this menace of water loss. Purposive sampling was done during the KII and the participants were voluntarily interviewed. A total of 26 people were interviewed, 16 KIWASCO staffs, 4 residents in Manyatta and Millimani, 2 water vendors, 2 chief representatives, 1 representative from Lake Victoria South Water Services Board and 1 representative from National Environmental Management Agency.

Focus Group Discussion (FGD)

Two focus group discussions were conducted with 9 and 7 participants totaling 16 participants in Kisumu City. In the FGDs there were gender and age considerations, that is, 6 male and 10 female participants in the age bracket of 18 - 65 years. Opinions from water consumers on the effects of water losses due to non-revenue water were obtained and used to supplement data from KII and desk review. Participants at the FGDs were selected voluntarily based on the participants' consent and the discussions lasted not more than one hour. The FGDs were held in a non-intrusive environment to make the participants feel comfortable and

confident during the survey.

RESULTS

Effects of non-revenue water on water quality

Water utilities' main mandate of extraction, treatment, storage and distribution of clean and safe water basically revolves around water as a natural resource based business. This makes it the main environmental component affected in terms of Non-Revenue Water. The study therefore first started by examining how water quality is affected by these water losses. The water quality standards used to measure the fitness of water in Kenya are set by the Water Services Regulatory Board (WASREB) based on the World Health Organization guidelines. The WHO outlines the following as the main water quality parameters; turbidity, alkalinity, suspended solids, dissolved solids, hardness, residual chlorine and bacteria. Therefore, any negative changes in these parameters will compromise the quality of water. Before water is distributed to consumers it is subjected to physical treatments which involve techniques such as filtration and screening to remove the solid matter and chemical treatments through coagulation, flocculation and chlorination to remove toxic organic and inorganic compounds. KIWASCO (Kisumu Water and Sanitation Company) has two water treatment plants. The main being Dunga treatment plant which extracts its water from Lake Victoria and the other being Kajulu water filter which extracts a substantial amount of its water from river Kibos. KIWASCO then does a 2-h interval water analysis to ensure that these parameters are always at par with the WASREB recommended levels in the storage system before distribution to the consumers. An analysis of these main parameters therefore indicated that they were all within the acceptable levels implying that indeed the water distributed by KIWASCO to its consumers is of quality standard and is fit for human consumption. Table 1 shows the status of water quality parameters before distribution to the consumers.

Analysis of four samples from different points of the

Table 2. Changes in water quality parameters after physical/ real losses.

Parameter	Unit	S 1	S2	S3	S4	AVG.	Approved level
Turbidity	NTU	6.82	4.58	5.35	5.82	5.64	5
Alkalinity/ PH	PHU	7.93	7.12	8.9	8.15	8.03	6.5-8.5
Suspended solids	Mg/l	37	40	35	38	37.50	30
Dissolved solids	Mg/l	312	441	218	506	369.25	700
Total hardness	TDH	97	81	282	115	143.75	300
Residual chlorine	Mg/l	0.16	0.17	0.15	0.19	0.17	0.10 +/- 0.05
Bacteria	Counts/100ml	20	15	25	20	20	Should be absent

Source: Authors

Table 3. Correlation between physical/ real losses and water quality.

Physical/ real losses	N	Non-revenue water	Pearson rho
		P-value	
	12	0.000	0.872**

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

Source: Authors

distribution system where physical losses occurred indicated that some of the water quality parameters such as residual chlorine, turbidity, suspended solids and the amount of bacteria were well above the required limits. These findings are as stated below: -

Residual chlorine

The recommended level of chlorine by WASREB to be consumed is 0.10mg/l because chlorine is a widely used method of water purification not only by water utilities but also in the household. The water samples analyzed however indicated that residual chlorine was 0.17mg/l which does not comply with the set standards of 0.10mg/l.

Turbidity

No guidelines are provided for turbidity other than the fact that it has to be acceptable to the consumers. WASREB on the other hand recommends turbidity of not more than 5 units to be fit for consumption. The level of turbidity however can also be attributed to age and material of the pipes as corrosive pipes release iron oxides into the water thereby compromising its quality and therefore it can not only be attributed to leakages. The samples analyzed showed that the average level of turbidity was 5.64 NTU.

Suspended solids

Total solids of 30mg/l are recommended as they

represent the water's natural contact with soil, rocks and other inorganic salts. The study however found the average level of suspended solids to be 37.50mg/l indicating that it surpassed the required limits and hence consumption of this water can be harmful to the consumers over time.

Bacteriological quality

The water utility's analyses report should indicate "no ecoli/100ml" which is the level recommended by WASREB; however the samples collected indicated the average level was as high as 20/100ml which indicated that the water was not fit for consumption as it would have serious health implications on the consumers and cause diseases such as diarrhea, anemia and urinary tract infections. These changes in water quality parameters due to physical water loss are as shown in Table 2.

The study found that there was a significant positive correlation between physical/real losses and water quality parameters (p-value <0.05 and rho=0.872). The results of this correlation are as shown in Table 3.

Effects of apparent/commercial losses on water quality

Commercial/ apparent water losses as contributors to NRW were also investigated by the researcher to determine its effects on water quality parameters. The samples used here were taken from consumers who

Table 4. Change in water quality parameters due to commercial/ apparent losses.

Parameter	Unit	S 1	S2	S3	S4	AVG.	Approved level
Turbidity	NTU	5.82	4.28	5.61	5.94	5.41	5
Alkalinity/ PH	PHU	7.85	7.31	7.98	8.35	7.87	6.5 - 8.5
Suspended solids	Mg/l	14	19	18	18	17.25	15+
Dissolved solids	Mg/l	27	31	38	35	32.75	30
Total hardness	TDH	300	298	467	510	393.75	700
Residual chlorine	Mg/l	111	96	128	214	137.25	300
Bacteria	Counts/100ml	0.18	0.18	0.15	0.16	0.16	0.10+ -0.05

Source: Authors

Table 5. Correlation between commercial/apparent losses and water quality.

Commercial/ apparent losses	N	Non-revenue water	
		P-value	Pearson rho
	12	0.000	0.432**

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

Source: Authors

have illegally reconnected themselves to the network after disconnection, those who have illegally connected themselves to the main distribution channel, and those who have cases of meter tampering or vandalism and the points from which these illegal connections are connected to the main distribution system. The researcher also noted that these areas are prone to leakages because the pipes are not fitted properly or according to the standards required by KIWASCO. The findings indicated that turbidity 5.41NTU > 5, the amount of suspended solids 32.75mg/l > 30, residual chlorine 0.16mg/l > 0 and bacteria 2.75/100ml > 0/100ml were the parameters most affected by cases of apparent water losses because their units were higher than WASREB's recommended levels (Table 4).

A Pearson's correlation coefficient computed on relationship between commercial/ apparent losses and NRW indicated that it has a moderate effect on water quality parameters ($\rho=0.432$). Therefore, an increase in the level of commercial/apparent losses can also compromise water quality to moderate strengths. These results are as shown in Table 5.

Effects of water loss on water quantity

Water loss is one of the major factors that contribute to declining water volumes in the reservoirs especially if the source of water is streams and rivers which can sometimes be seasonal. Water loss coupled with other factors such as climate change and rapid population increase is described by the International Water Management Institute IWMI (2017) as why the world is fast approaching water crisis in the near future. The

findings of this research show that in May, June, August, September and October the level of water loss in KIWASCO was recorded as 36.96, 29.41, 36.51, 28.99 and 33.33%, respectively all of which are higher than recommended levels. In July however, the level of water loss was 21.79% which was within the acceptable levels. On average, from May through October 2019, the water utility lost some 158,500m³ of water which is equivalent to a 31.17% of NRW contributing on a global scale to the 48.6 billion m³ of daily water loss as described by the World Bank. The results of these findings are shown in Figure 1.

Effects of non-revenue water on the general environment

Continued discussions in the FGDs and during the KII introduced some very interesting opinions on how these water losses aside compromising water quality parameters and reducing the volume of water (water quantity) also have effects that are visible in the general environment. These effects discussed in the FGD and KII were grouped by the researchers according to the various environmental components such as soil, land, air and the social environment.

DISCUSSION

Effects of physical losses on water quality parameters

The findings of this study indicated that the distributed

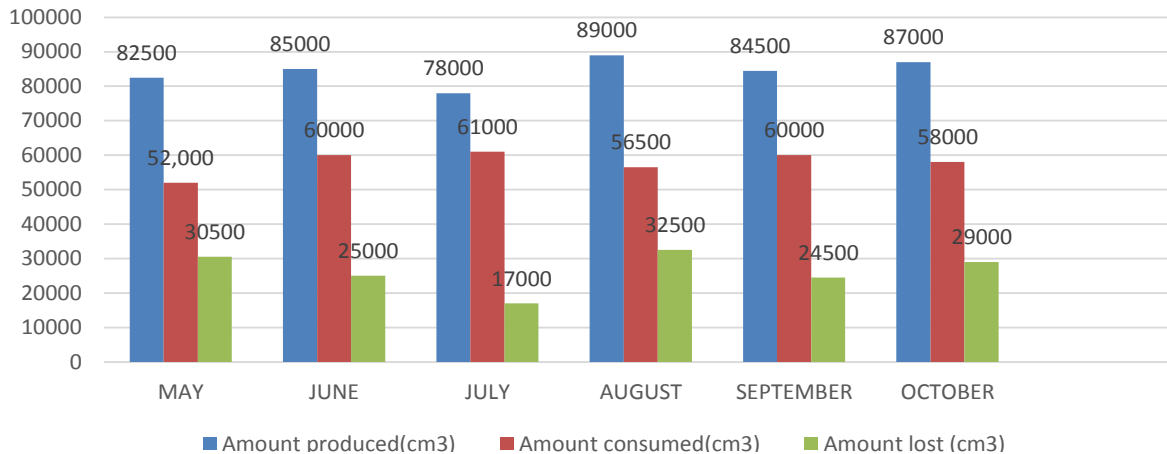


Figure 1. The amount of water loss at KIWASCO.
Source: Authors

water subjected to physical losses such as leakages/pipe bursts had noticeable changes in the level of residual chlorine, turbidity, suspended solids and the amount of bacteria making it unfit for human consumption. The correlation analysis between physical water losses and water quality parameters also supported these findings where $p\text{-value} < 0.05$ and $\rho = 0.872$, indicating that an increase in the rate and amount of physical/ real losses will increase the level of parameters beyond the recommended levels, hence compromising water quality. This can also be supported by the fact that after severe pipe bursts and leakages, KIWASCO usually closes the main water valve for a period of time to allow the contaminated water to drain out and re-treat the water before distributing it to the consumers again. A similar research by Awopetu et al (2013) also indicated that turbidity, chlorine levels, suspended solids and E-coli are the most affected water quality parameters within the water utilities distribution network as a result of constant leakages. This study however indicated that the chemical and physical parameters are easier to manage as compared to the bacteriological aspect which remains to be a challenge for water utilities especially in Kisumu's informal estates such as Nyalenda and Manyatta that are characterized by high density and poor sewerage connections. It is however important to note that the intensity of change in these water quality parameters varies depending on the duration of water loss and pressure in the distribution system as described by Fontanazza et al. (2015); they stated that when the pressure is low, instead of water being forced out through the parts of the pipe that are cracked, water from the surrounding areas like the ground water that has contaminants get sucked in and remain on the pipes until it reaches the consumer. This is owing to the fact that the materials used for and around the distribution systems may contain bacteria and viruses from human wastes.

Findings by Saria (2015) emphasized on this by pointing out that pressure determines the extent to which these water losses affect water quality because when leakages occur during low pressure it provides an avenue for bacterial contaminants to be siphoned into the distribution system thereby compromising the quality of water. Similarly, the FGD participants also agreed that pipe burst/leakages have significant negative impacts on water quality where one of the discussants stated that *"whenever a pipe burst occurs, the pressure with which that water is running will determine how many foreign particles will be washed away and infiltrated in the distribution channels; this also makes it easier to mix with the untreated sewer water and overflowing latrines thereby compromising water quality."* The KII however indicated that the quality can also be compromised when the pressure is high as this may corrode the distribution pipes and increase the intensity of the contaminants; the metallic taste that consumers sometimes feel/ smell when they drink tap water is as a result of this corrosion. Repairing of pipe bursts/leakages and installation of district metered area involves closing boundary valves which creates dead-ends that consequently affect the water quality. This can only be alleviated through flashing in order to restore water quality; hence the importance of warning the consumers when there is an ongoing pipe repair/ maintenance to beware of dirty water. Saria (2015) further explains that whenever there is a pipe burst/leakage, the re-installation of these pipes always make the water dirty and in some cases residents have reported noticing contaminants such as sand or charcoal from their tap water even after KIWASCO has done a flush program. At the FGD, some respondents however thought that pipe bursts/leakages had negligible effect on water quality and more on the surrounding environment. One of the discussants argued that *"pipe bursts or leakages results in flooding of the immediate surrounding*

depending on the magnitude of the water lost. This is a major cause of pollution in urban centers and many instances of stagnant water and such situations distort the general aesthetic quality of the city". IWA (2018) also states that the reduction in water loss can improve water quality due to less contamination and achieve environmental excellence.

Effects of commercial losses on water quality parameters

The IWA water balance describes commercial/apparent water losses as those that occur due to unauthorized consumption (illegal connection/meter by-passing/water theft) and metering inaccuracies caused by meter vandalism and meter tampering. The findings of the study indicated that the distributed water subjected to these commercial losses recorded slight changes in the water quality parameters where turbidity was higher by 0.41NTU, amount of suspended solids by 2.75 mg/l, residual chlorine by 0.16mg/l and bacteria by 2.75100 ml. Discussions in the Focus Groups supported these findings where most of the discussants argued that the reason this form of water loss affects water quality is because the consumers who practice these forms of illegal consumption have little to no knowledge on how the distribution system should look like as opposed to the trained KIWASCO engineers. This therefore, causes some consumers to end up putting their networks next to the sewer systems or making them overlap in such a way that their water is compromised because of its close proximity to the sewers, a situation described by KIWASCO as spaghetti connections. Further discussions also indicated that in cases where the consumers have attempted to connect themselves to the main distribution channel, they often do not do a proper cleaning of their pipes which may contain suspended particles. Also, sometimes, the type of materials that they use is not properly treated or is substandard and therefore reacts with the water as they are corroded by the chlorine. It is however important to note that billing/ accounting errors as a form of commercial/ apparent water loss does not affect the quality of water. Water that is lost through accounting and billing errors usually occur when water utilities miscalculate or misinterpret the information relayed by the meters and therefore does not represent the appropriate amount of water used. The KII and FGD respondents also agreed with these findings by stating that these kinds of errors are usually due to computer glitches or wrong readings and therefore have nothing to do with quality of water. These computer errors however sometimes lead consumers to using other sources of water which may not be fit for consumption or employ illegal means of accessing water. The consensus from the participants in the FGD was that the influence of this type of water loss is more on economic/ revenue and less

on water quality and the environment. The KII informants on the other hand argued that some of the accounting/ billing errors are caused by corrupt staff who colludes with consumers to tamper with the meters by introducing impurities or boiling the water meters in order to miscalculate the actual readings. Therefore these crude methods were described as ways that could provide avenues for contaminants to get into the water. This in result interferes with the water quality parameters at the reading points which could still be harmful to the consumers.

Effects of water loss on water quantity

The World Bank report stated that water loss of 21-60% could otherwise be used to serve populations that do not have access to water and that the world water demand in the near future will be higher than the supply by at least 40% leading to an increase in the number of unserved population. Furthermore, WASREB recommends 20-25% of non-revenue water to be acceptable while below 20% to be good. This is contrary to the findings of the research where a 31.17% level of water loss was experienced within a period of only six months. This shows that in those 6 months KIWASCO lost water that was 6.17% more than the recommended amount. The KII however expressed their sentiments that this 31.17% of water loss may have less impact on water utilities that extract their raw water from larger water bodies such as Lake Victoria; but detrimental effects could be imposed on those that extract water from rivers or streams such as River Kibos which is the main water source for Kajulu filter in Kisumu. During the dry months of January to March most Kisumu residents who are supplied by KIWASCO water from Kajulu filter can go for weeks with dry taps because the volume of water in the river is so low that it cannot be pumped. A report by the Environmental Consulting & Technology Inc. (ECT, 2016) also noted that the impacts of water withdrawals can have detrimental effects if the rate of withdrawal exceeds the rate of replacement of the said water. Therefore, it does not matter how big of a source the water is, its continuous and unsustainable use will affect these sources over a period of time and make the water resource even scarcer than it already is. Also, in places where water is pumped from underground aquifers, depletion of these resources is considered to be inevitable as the economy strives for their people to live a comfortable life with an ability to access clean water for their daily use (Konikow and Kendy, 2005). The depletion in these ground water aquifers also directly or indirectly impacts the surface water making both water sources unsustainable especially in the face of the rapidly growing population according to Liu et.al, (2020). They further explain that the impacts of groundwater abstractions on stream flow depletion is often underestimated as the water utilities are only focused on meeting the demand.

These ideologies are also supported by some of the discussants in the FGD where it was observed that KIWASCO increases the water tariffs in cases where water is lost to make up for the unaccounted for water and improve their revenue collection while also increasing the level of supply to meet the demand regardless. The FGD participants also argued that in trying to reduce water loss, KIWASCO should consider them as the major stakeholders and put their needs first.

Effects of water loss on the general environment

Soil, the effects of which included soil erosion where the participants argued out the fact that during pipe bursts/leakages, the water not only carries wastes into other water bodies but also carries away the top soil if the pipe burst occurs in a steep place during high pressure; hence contributing to the level of soil erosion that eventually leads to increased sedimentation in nearby water bodies. Increased levels of sedimentation also interfere with the flow regime of the water thereby reducing the quality of water for downstream communities.

Land, the effects of which included destruction of the water catchment areas through over abstraction of water in order to make up for the amount of water lost and meet the demands of the population. Also, water losses in areas with poor drainage lead to an increase of the patches of stagnant water, hence creation of artificial wetlands that reduce the general aesthetic value of the environment.

Air – Water utilities use a lot of energy to extract, treat and distribute water to the consumers. The use of non-renewable sources of energy for pumping water was flagged by the International Water Association as a major contributor to the greenhouse effect as the pumps are always left running. Increase in the levels of water loss therefore contributes to global warming as the water utilities will need to pump more water into the distribution network to make up for the amount of water lost and meet consumers' demand. This water pumps on non-renewable forms of energy that emit environmental pollutants such as carbon dioxide, methane and nitrous oxides that trap heat into the atmosphere thereby contributing to the level of global warming over time. A report by IWA further stated that *“increase in the energy use by the water utilities to meet the population demand and make up for the water lost contributes to the carbon footprints robbing us of a cleaner, better world stating that between 2005 and 2013 there was a total of 21,000t CO₂ emissions in the production, treatment and distribution of water to consumers by the water utilities.”*

Effects on the social environment – this involves the human aspect which is mostly impacted by water logging and increased decline in water quality. When pipe bursts/leakages occur in areas with poor drainage, the water stagnates there for quite some time creating temporary

breeding sites for disease vectors such as mosquitoes, hence the increased cases of malaria in the surrounding areas and bilharzia snails which are harmful to general human health. Also the decline in water quality due to leakages will lead to an increase of other water-borne related diseases such as typhoid and cholera especially in the high density estates where there is no proper sewerage system and thus the water that is lost through leakages may easily come into contact with wastes and become polluted. Pollution was also the most common effect identified by all the participants where one of the discussants stated that *“as an expert in community development, the issue of pipe bursts and sewer systems is a real problem especially in low income neighborhoods where there is a lot of congestion and poorly structured social amenities.”* Again, depending on the intensity, pressure, size of the pipe and duration of the leakages, water from these leakages may carry wastes along the way and deposit them in nearby water bodies such as river/ streams hence pollution. The compounded impacts of these water losses also affect the social well-being of the consumers in that the water shortage created by these water losses leads to decline in sanitation and the general standards of living on the consumers. Sometimes, the water service providers also increase water tariffs so as to make up for the revenue lost. This becomes a problem to individuals who cannot afford it and they therefore seek alternative ways of accessing water for their daily use which usually involves stealing of the said water.

Conclusion

Non-revenue water loss has significant effects on water quality parameters which are majorly attributed to the physical water losses such as leakages, pipe bursts and overflows in the storage tanks that create avenues through which contaminants get into the distribution network. Continued water loss that exceeds the rate of renewal also leads to the decline of the said water at source and also affects other environmental components albeit some of the effects being hard to detect and quantify. These impacts could range from the mere fact that the water lost can be used to supply people with limited access to water hence reduced level of water shortage to cumulative impacts such as increased amount of carbon footprints. This is because more energy is required to replace the water that is lost to meet the supply and demand curve, hence increase in the emission of greenhouse gases.

Recommendation

Quantifying environmental effects may prove to be a challenge and therefore there should be detailed analysis of factors such as the change in the water catchment

areas over a period of time by using GIS systems to map the effects of the rates of water withdrawal at source. There is also need to ascertain whether these environmental changes are solely due to the water loss experienced by water utilities or if they are enhanced by other external factors. The enhancement of water quality by water utilities requires the use of technological advancement and modernized equipment to improve water distribution.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Assessment methodologies and determinants of employability and skills level among Technical and Vocational Education Training (TVET) graduates in Central Uganda

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Globally, unemployment persists because skill levels and learner capabilities are not in tandem with job market requirements. Using logistic analysis, the present study probed determinants of employability of 150 graduates of Technical and Vocational Education Training (TVET) in Central Uganda and further predicted factors influencing their skills level by applying Tobit regression. On a 1 to 5 scale, skills averaged at 3.3. Employability depended on the skills level, age, gender, possessing a national award and disability status whereby the disabled had less likelihood of being employed. Class size, the training period, age and gender of the graduate significantly explained skill level of graduates. It was reported that the main methodology used to assess the graduates was class-based written testing. The paper argues that administrators of training institutions originate a special training and assessment methodology for the disabled. Class sizes should also be small and manageable for learners to be adequately trained and assessed. The study further proposes that the training period be longer and learners attend for the entire period to acquaint themselves with work-world demanded capabilities.

Key words: Employability, skill level, assessment, Logit model, Tobi model.

INTRODUCTION

In many world economies, education systems restructuring tends towards Technical-Vocational Education and Training (TVET) for generation of employable skills (Kasozi, 2001). Robinson (2000) also asserted that the real problem is to find workers with employability or job readiness skills. For Africa, TVET delivery systems are characterized by low quality training which emphasizes theory rather than skills acquisition and proficiency testing. In Uganda's case, the system is

also overly academic, theoretical and examination-oriented. Thus, many who graduate do not possess employable skills required to initiate livelihood ventures (Kanyandago, 2010; Openjuru, 2010). Therefore, to ameliorate the TVET requires promotion of vital indigenous technology and objective assessment of those who graduate through the system (Jjuuko, 2012). TVET should prepare learners to be appropriate and relevant in the world of work (Astrid and Naing, 2009)

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because gaining skills does not only improve life chances, but also their respect, self-confidence and personal pride (Cuthbert et al., 2015). It is a means to empower individuals sustain their livelihoods. In Africa, it is envisioned as a means to help in achieving a prosperous Africa by the Africans themselves (AU, 2007). Vocational and Technical Education is vital in the acquisition of marketable business skills but also enhances decision making and generates knowledge to make informed decisions (Moses, 2007). Elsewhere, TVET is synonymous with occupational education, workforce education and workplace education. It also likened to human resource and skills development and the ultimate goal is to avail skills and knowledge requisite for the work workplace. It is the training for a specific skill or particular work; and is aimed primarily to make a trainee (self-) employable (Akande, 2011).

Even then, for TVET to bear positively on employability and poverty, it requires streamlining in many dimensions including assessment (MoES, 2012). The skilling Uganda strategy 2012/2013 - 2021/2022 strongly recognizes that an assessment component will play a critically crucial role to produce a whole trainee adequate in skill, knowledge and attitude desired at the workplace (MOEs, 2012). As such a national TVET assessing body - Uganda Business Technical Examination Board (UBTEB) was born in Uganda, purposely to streamline assessment and give credible awards to TVET graduates. But much as effective assessment should ensure that competencies associated with specific occupations are developed and are actually present within a graduate (Ward et al., 2006), UBTEB is young and national assessment is a relatively new phenomenon. Some institutions are just beginning to adopt national assessment.

Therefore to enhance graduates' quality and ultimately augment their self-worth, productivity and social mobility, this study attempted to answer questions about the level of skills among recent graduates, their employability and approaches that were used in assessment. It was undertaken to determine predictors of employability and skills level and describe assessment approaches.

Skill abundance in Uganda

Uganda's education system according to Cuthbert et al. (2015) does not deliver required skills for integration in the labour market and other livelihood opportunities, yet they are required to help learners get, keep and even do well on job (Matthew, 2000). This suggests that alternative innovations are required both in training and assessing the learners. The world over, lack of or inappropriate skills, explains poor labour productivity (Okwelle and Deebom, 2017).

Uganda's BTVE Act of 2008 recognizes lack of skills

and daunting youth unemployment (MoES, 2012). Bennedy and Oteng (2018) study on youths' empowerment in North Eastern Uganda also found that 94% were lacking skills even after their Vocational Training. The dismal skills level among Ugandans is actually not a new phenomenon because even African Union (2007) has confirmed huge numbers of poorly educated, unskilled and unemployed youth and suggested new strategies to revitalize the TVET. The AU further cites presence of a huge number of educated graduates who remain unemployed due to lack of skill. But whether graduates actually lack required skills, or their assessment has not adequately morphed to realistically and objectively measure them is unclear. This study therefore derives essence as it documents innovations in assessing the Uganda's TVET graduates, their skills level and employability.

The Uganda Government paper (1989) on review of education policy also indicated that industrialists often complained about quality of TVET graduates. It asserts that graduates in vocation education were not performing as required in the world of work, blaming it on the training that offers mediocre skills. Uganda also has been affected by the skills mismatch. Agaphin and Sulaeman (2013) also noted that a large share of current working-age population and most especially the youth do not satisfactory exhibit entrepreneurial skills at the world of work. Thus, inquiring into assessment should not be overemphasized.

TVET assessment methodology

The training outcome assessment should inform methodology and innovations that assessors should pursue. Assessment bodies are urged by African Union (2007) to measure the efficiency and equity of the training the graduate underwent through. Graduates should be assessed on such parameters on a predetermined scale before their release to the market. Equally important is a measure of the trainees' satisfaction of the training and the extent to which they participated in their predestined industry before graduating to the job market. This suggestion should be incorporated in current systems of field outreaches conducted by national TVET assessors.

Bennedy and Oteng (2018) suggest the employment-oriented methodology. It is yet another innovation assessors of TVET graduates should undertake in order to release a complete graduate. It works on the principle of (pre-) determining proportions of trainees to be in gainful employment before and after training. The duration the graduate would take to be (self-) employed, and expected satisfaction to offer to the employer are parameters of relevance both to assessment actual employment as suggested in this assessment approach.

Another important assessment innovation dimension is the social dimension. Assessors should extend to the

social dimension whereby the citizenship character, sustenance and perception of the citizenry towards them matters. In this approach the graduate ought to be measured through participation in social dynamics and (Maddala, 2008).

The true skill level is unobservable and is a latent variable democratic processes.

$$y^* = \alpha'X + \mu$$

METHODOLOGY

The study adopted stratified random sampling and obtained data by using questionnaires obtained data from 150 learners who completed their TVET courses. Predictors of employability were determined by a binary response model – the logistic regression since a graduate is either employed or not. Determinants of skills level among the graduates were elucidated by estimating a Tobit model censoring skills level between 0 and 1. Assessment approaches and graduates’ demographics were analyzed by descriptive measures.

Modeling employability

The *i*th graduate is either employed or not. Assuming $y_i = 1$, if employed and $y_i = 0$, if not, the probability of $y_i = 1$, 0 given the characteristics of the graduate and other factors lies between 0 - 1.

If the occurrence of y_i is associated with a probability μ , then:

$$Pr \{Y_i = y_i\} = \mu^{y_i}(1 - \mu)^{1-y_i} \quad \text{for } y_i = 0, 1 \quad \text{and} \\ Y_i = \beta'X + \varepsilon \quad (1)$$

where X is a vector of covariates that predict employment likelihood, β' is the vector of coefficients $\beta_1, \beta_2, \beta_3, \dots, \beta_n$ to be determined in the model, and ε is a stochastic error term. The odds ratio is given by Green (2003) and Gujarati (2008) as:

$$\frac{Pr(y_i=1/x)}{1-Pr(y_i=1/x)} = e^{x\beta + \alpha}$$

Specification of the model for employability of the TVET graduates

$$D = \beta_0 + \beta_1skil + \beta_2 In Age^2 + \beta_3nataward + \beta_4gen + \beta_5trainqlty + \beta_6wrkword + \beta_7disability + \varepsilon$$

where β_0 is the model constant and $\beta_1 \dots \beta_7$ are parameters to be estimated from the binary response model.

Modeling the level of skills

In practice, the level of skill of the graduates is considered a continuous distribution. Censored between 0 and 1, the study customizes that $Y = 0$ has no skill and $Y = 1$ excellent skill, conditional on quality and period of training, personal attributes, etc.

Where the level of skills is censored, the Tobit model is appropriate. The probability of the *i*th graduate having a value of was measured:

$$Y_i = \begin{cases} 0 & \text{if } y^* \leq 0 \\ \alpha'X + \mu & \text{if } y^* > 0 \end{cases}$$

Specification of the model for the level of skills of the TVET graduates

$$Y = \lambda_0 + \lambda_1 In classize + \lambda_2traingperd + \lambda_3 In Age^2 + \lambda_4 Gen + \lambda_5 Expe + \lambda_6 satisf + \mu$$

where $\lambda_1 \dots \lambda_7$ are parameters to be estimated from the censored regression model, given the data and λ_0 is the model constant.

Respondent characteristics

The respondents were aged 24 years on average and had spent fifteen years in formal schooling (Table 3). Their skill level is above average and had interacted eight times with the world of work before their graduation (Tables 1 and 2). Majority respondents were males, employed and had offered courses at a certificate level (Figures 1 to 4). Automotive mechanics dominated as the field of training, offered by 39 out of 150 respondents.

Although the graduates were assessed by several methods, class-room based written examinations were the dominant methodology used (Table 4).

RESULTS AND DISCUSSION

Determinants of employability among the TVET graduates

Condition on various characteristics, TVET graduate is either employed or not. Therefore, employability was estimated using binary response model - the Logistic regression (Green, 2003; Maddala, 2008). Such estimation has been applied before by Martina et al. (2009) to study employability in Slovakia. Logistic regression was also adopted and included seven variables five of which disability status, age, gender, skills level), significantly explained likelihood of employability of the TVET graduates.

The estimated coefficient of 3.762 on skills level implies that students with higher level of skills are approximately four times more likely to be employed than those with lower skills (Table 5). Jacquelyn (2010) agreeably argued that employability or job readiness skills help graduates fit into and remain in the work environment. It can also be concluded that older TVET graduates are three times more likely to be employed. The finding contradicts that of Ali et al. (2011) where in their study on Swedish labour market found that younger individuals are more likely to be employed, especially in restaurants and as sales assistants. Their study provided evidence that on average, the younger

Table 1. Definition of the variables used in the employability model.

No.	Variable	Definition and measurement	Expected effect
1	<i>skil</i>	Level of skill of the TVET graduate measured on a continuous scale of 0 -5	+
2	<i>Age</i>	Number of years of the graduate	+
3	<i>nataward</i>	Possession of a national award. Measured as a dummy, D = 1 if the respondent has a national award, otherwise D = 0	+
4	<i>gen</i>	Gender of the respondent, D = 1 if male, otherwise D= 0	+
5	<i>trainqlty</i>	Training quality underwent as rated by the TVET graduate themselves, measured on a continuous scale of 1-5	+
6	<i>wrkword</i>	Number of times the graduate interacted with the industry they would serve while still at school	+
7	<i>disability</i>	Disability status of the TVET graduate, measured as a dummy where D = 1 if disabled, otherwise D=0	+/-

Source: Author

Table 2. Definition of variables used in the skills level model.

No.	Variable	Definition and measurement	Expected effect
1	Classize	Number of TVET learners in the class attended	+
2	Skilev	Level of skill attained, measured on a 1-5 scale	+
3	Trainprd	Number of years of formal training in TVET	+
4	Age	The age of the graduate given in years	+
5	Gan	Gender of the respondent, D = 1 if male, otherwise D = 0	+
6	Expe	Number of times the graduate interacted with the industry they would serve while still at school	+
7	<i>Satisf</i>	The level of satisfaction a graduate obtained from training at their institution, measured on a scale of 1-5	+/-

Source: Author.

applicant received over three times more responses from employers, implying higher employability likelihood.

Results indicate that possessing a national award significantly affects employability. Graduates with a national award were 3.418 times more likely to be employed than those who do not have it. This implies that employers recognize national awards. Thus, students undertaking TVET should enroll only in training

centers where national examinations are conducted.

The findings further suggest that male graduates are slightly more likely to be employed than the female counterparts. The estimated coefficient of 1.103, translates into a 101.3% more employment likelihood in favour of male gender. The UN (2004) also noted a continuing disadvantage faced by women in both gaining access to employment and in

particular access to quality employment. Therefore, employment policies should restructure to mainstream gender.

The estimated coefficient of 0.056 on the variable disability status means that the likelihood of employment of a disabled graduate is 0.056 times that of one without (those without disabilities are 94.4% more likely to be employed). In agreement Song et al. (2011) in their enquiry into employers'

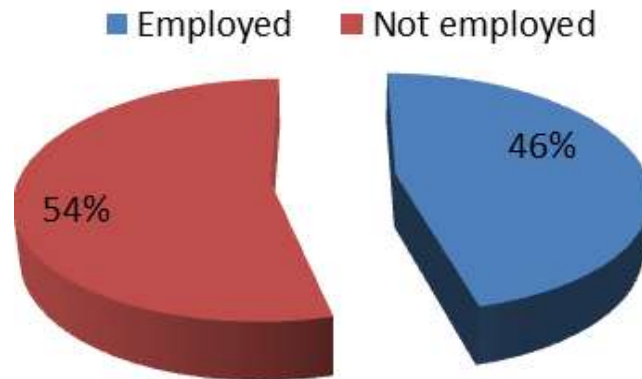


Figure 1. Distribution of respondents by employment status
Source: Author

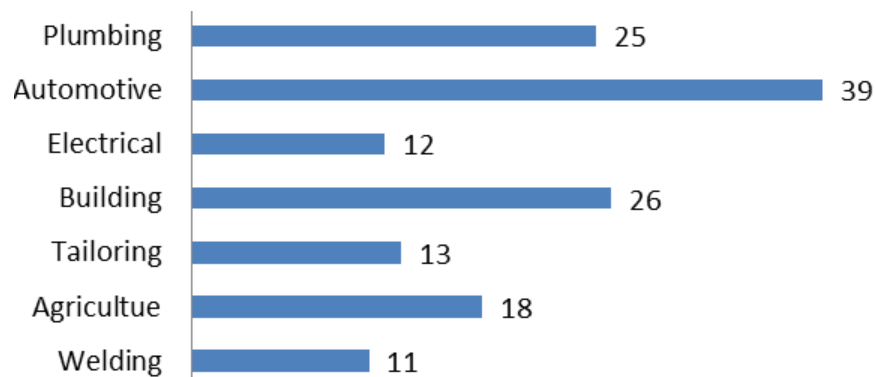


Figure 2. Frequency of respondents by training field.
Source: Author.

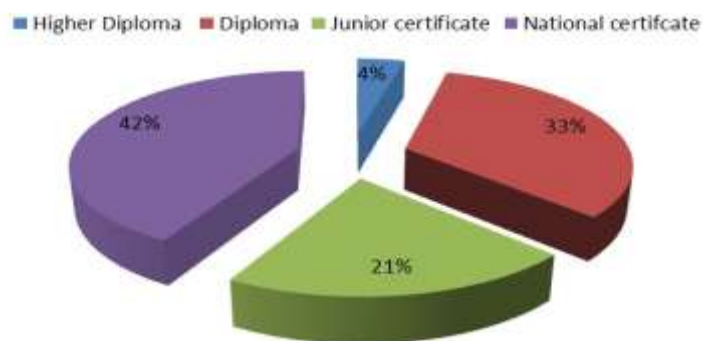


Figure 3. Level of training of the respondents.
Source: Author.

skills expectations also found that individuals with disabilities face persistent challenges in gaining meaningful employment. As such, inclusiveness policy should be strengthened to capture the disadvantaged in the employment opportunities.

Determinants of skills level among the graduates level

The estimated model explains over 75% variation in skill level of graduates (MacFadden's Pseudo $R^2 =$

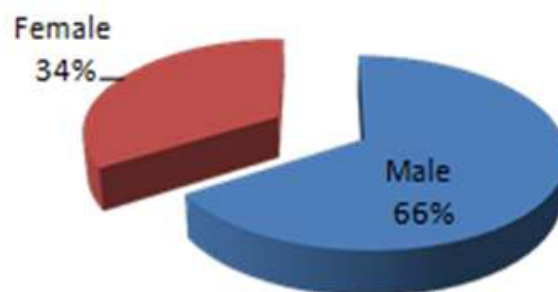


Figure 4. Respondents by gender.

Table 3. The sample characteristics.

Characteristic	Mean
Age of graduates (years)	24.2 (10.4)
Years in of formal schooling	15.4 (3.2)
Skills level (1- Lowest, 5 - Highest)	3.3 (2.1)
Frequency of interacting with the world of work	7.8 (4.5)

Figures in parentheses are the standard deviation.

Source: Field Survey Data (2018).

Table 4. Assessment methods applied on the graduate.

Characteristic	Frequency	Percentage of the respondents	Rank
Class-based written examination	143	95.3	1 st
Class - based practical examination	117	78.0	3 rd
World of work practical	78	52.0	5 th
Real - life projects	138	92.0	2 nd
Industrial training / apprenticeship	104	69.3	4 th

Rank 1 is of the greatest importance.

Source: Field Survey Data (2018).

19.6%) and the penalty is low for the variables included therein (Log likelihood ratio: -193.031). According to the model estimates, four factors which had significant influence on the graduates' skills level were: the class size, training period, age and gender (Table 6). While graduates' prior experience and their perceived satisfaction of the training they underwent never had a significant influence at 5% significance, the variables had positive coefficients as expected.

Class size is associated with a negative coefficient, therefore, when class size increase, the skill level attained decreases. The marginal effect of -0.2909 suggests a 29.1% increase in the likelihood of being skilled if class size declined by one student. Such result is consistent with previous findings such as Thomas and Martin (2011). Also, to revitalize

the African TVET, the African Union (2007) recommended a maximum class size of thirty trainees.

The training period which the graduate underwent significantly determined their skill given a positive coefficient and associated p-value. Results indicate that the likelihood of being skilled would increase by 6.5% for an additional year of training a TVET graduate underwent ($\beta = 0.6651$, $\delta y/\delta x = 0.0254$). Moses (2007) inquiry into issues and trends in African TVET noted the need to increase TVET content in general programs and proposed adequate training period. Age had a significant positive influence on employability. The likelihood of being skilled would be quadrupled for a unit increase in the log of square of age (Table 6). Mature graduates would therefore be more skilled. Agreeably, Kahyarara and Teal F (2008), in their study

Table 5. Logistic regression model estimating the employability of the TVET graduates

Variable	Estimated coefficient	z-value	Resulting coefficient
Skills level	1.325***	12.378	3.762
In Age ²	1.009*	8.456	3.941
Possession of a national award	1.229**	5.182	3.418
Gender	0.098*	3.222	1.103
Training quality	2.734	3.334	15.394
Prior working experience	0.908	2.783	2.479
Disability status	-2.881**	-1.247	0.056

***, **, * Significant at 1, 5 and 10%. MacFadden's Pseudo R² = 0.167.
Source: Author

Table 6. Model estimates on the graduates' skills level

Variable	Coefficient (β)	t-value	Marginal effect ($\delta y/\delta x$)	p-value
Constant	-2.3674	-1.88	- 0.1204	0.063
Class size x1	- 0.2901***	3.02	- 0.2909	0.003
Training Period x2	0.6651***	3.25	0.0254	0.001
In Age ² (x3)	0.8091**	2.46	0.0091	0.015
Gender (x4)	1.6298*	1.04	0.6298	0.299
Experience (X5)	0.0813	2.15	1.345	0.206
Traingsatisf (X6)	0.3249	3.245	1.008	0.123
MacFadden Pseudo R ²			19.6%	
Prob> chi ²			0.000	

Log likelihood ratio: -193.031. ***Significant at 1%, **at 5%, *at 1%.
Source: Author.

about returns to vocational training and academic education in Tanzania, also indicated that returns to vocational school or technical college can differ depending on the stage the student enters the college. Skills level among TVET graduates also significantly and positively depended on gender of respondent. In Table 2, results report that males are 62.9% more likely to be skilled than females thus suggesting gender stereotyping initiatives in the TVET. Gender inequalities have persisted in the general TVET programmes (Moses, 2007).

RECOMMENDATIONS

Since graduates with disabilities were associated with a lower likelihood of employability, the paper argues that administrators of training institutions originate a special training and assessment methodology for the disabled to enhance their skills and self-employability. Employers are also urged to consider the disabled in the recruitment. The study found that class sizes negatively and significantly influence skill level, therefore small and

manageable class rooms should be ensured during training such that learner's skills increase. The paper further proposes that the training period be longer and learners attend for the entire period to acquaint themselves with work-world demanded capabilities. It is also crucial that TVET training considers recruitment of female learners to address the gender gap in enrollment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

An Exploratory Study on Product Development Processes and Models Adopted by Ghanaian Fashion Designers

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The study focused on exploring qualitatively the product development processes, Ghanaian fashion designers adopt in their design creation line. A sample of twenty-one (21) small and medium scale fashion designers was sampled using the purposive sampling technique. An interview and observation guides were the primary data collection instruments. The findings indicate that fashion designers adopt varying strategies and stages in developing products for clients without necessarily following standardized models; hence, a model was proposed by the researcher for adoption.

Key words: designers, fashion, garment production, model, product development.

INTRODUCTION

Every manufacturing business must adhere to a production schedule. In the fashion industry, production programmes are embodied a collective plan. The plan involves a wide range of actions that manufacturers engage in, thus, leading to effective product development. Several definitions for Product Development (PD) exist in the literature, and therefore, there is no generally accepted definition among researchers. Moretti (2017) defined it as “a business process that aims to transform data and technical possibilities into market opportunities and information, enabling and assisting product design development”. Slijepčević and Perčić (2019) also perceived the concept as “the transformation of a market

opportunity into a set of assumptions about the technology of the product for sale, in addition to being the main source of product and process quality”.

The Product Development Process (PDP) encompasses the entire process of bringing a new fashion product onto the market. The process aims to provide customer satisfaction whilst minimizing returns. Product development has become one of the most critical yet risky activities manufacturing companies perform (Papahristou and Bilalis, 2017).

Researchers in this domain have established and emphasized the need to employ a systematic Product Development Process and Model to achieve a higher

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success rate in product development (Silva and Rupasinghe, 2016). Although Product Development research is thought to have begun in the 1960s, it was not until the 1990s that effective Product Development procedures and models received substantial attention (Powell and Cassill, 2005). Designers employ several complex activities to deliver new products to the market. Some fashion houses have different stages for products to be developed. Papahristou and Bilalis (2017), for instance, identified five phases as against three macro phases presented by Capaldo and Henrique (2007). From the literature concerning the development of fashion products, basic steps such as research for the drafting of ideas, conceptual lines and preparation for production and the market can be identified in the process. Within each step are countless design and development activities carried out sequentially. Moretti (2017) and Burns et al. (2011) attributed this long-standing challenge to the complex nature of PDP technologies and procedures. However, the quality of Product Development Process (PDP) management which is closely linked to standardization process (Moretti, 2017), is of concern. Sujova et al. (2016) indicated that once the process becomes standardized, several designers can use it, and it is documented as a model. The formalization of the PDP management model integrates the activities of all major stakeholders in the entire production process. It appears that fashion manufacturing companies are becoming more open to product development approaches that define products based on what people need and create experiences for the consumer rather than simply designing products. Hence, practitioners and researchers have struggled over the years in terms to identify the best strategy that can be adopted to achieve, sustain and improve business performance (Antonelli and Fassio, 2016). Most fashion manufacturing industries are 'forced' to revise their product development practices to address this and trigger more competition. Thus, blending concepts, breaking concepts into sub-units and synthesizing this into new concepts. Hence, a review of how fashion designers in Ghana develop their products is deemed necessary to find answers to the following research questions:

- i) What activities constitute the Product Development Processes of the Ghanaian fashion designer?
- ii) Which model guides the production of fashion products among designers in Ghana?

LITERATURE REVIEW

The sections below review some generic product development models and discuss how they relate to the fashion industry. This eventually narrows into the next sub-section that reviews models specific to the fashion industry.

Generic product development models and their applicability in the fashion industry

Stage-gate system model

Many top manufacturing firms have developed their own product development processes with inspiration from the Stage-Gate System which was propounded by Robert Cooper. The Stage-Gate System Model offers conceptual and operational modes for taking a new product through from concept to launch (Cooper, 1990). Recent stage-gate systems facilitate parallel concurrent processing, improving flexibility and reducing unnecessary time lapses between the process stages (Fred, 2011). In the Stage-Gate System, the whole project is broken down into distinct stages, and evaluation criteria are set at the end of each part of the project (Silva and Rupasinghe, 2016). The evaluation criteria serve as the gate for the project's next stage. Systematic stage-gate processes act as a roadmap for defining and supporting each distinct stage of the entire process, beginning with launch (Högman and Johannesson, 2013; Cooper, 1994). Each stage features a "Go/Kill decision point or gate" intended for the projects to be quantitatively and qualitatively evaluated before moving on to the next stage.

The early generations of stage-gate processes, such as the "Phased Review Process", were very engineering-driven and addressed the product strictly on physical design and development (Silva and Rupasinghe, 2016). New generations' stage-gate systems treat each distinct stage as a cross-functional team effort; marketing and manufacturing involvement are considered an integral part of the product development process. The Stage Gate model promotes substantial business and marketing engagement and a thorough manufacturing assessment for a successful new product launch (Silva and Rupasinghe, 2016). Most of the conventional product development process models are sequential. The third-generation stage-gate system improved flexibility by having fuzzy gates that permitted conditional "Go" decisions depending on the situation. Process stages could be overlapped but focused on the resource availability in the organization. Subsequently, several improvements followed the typical stage-gate system. Stage-gate model embarks with open innovation concepts to promote more innovations. Manufacturing companies are becoming more open to product development approaches that define products based on what people need and create experiences for the consumer rather than simply designing products (Figure 1).

New product development model

More sequential New Product Development (NPD) models were published by Urban and Hauser (1980), Gruenwald (1992) and Himmelfarb (1992) in the early

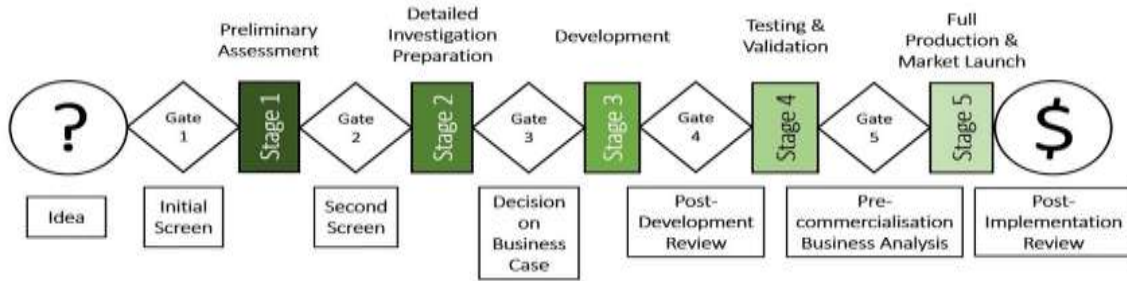


Figure 1. Stage-gate system model.
Source: Silva and Rupasinghe (2016).

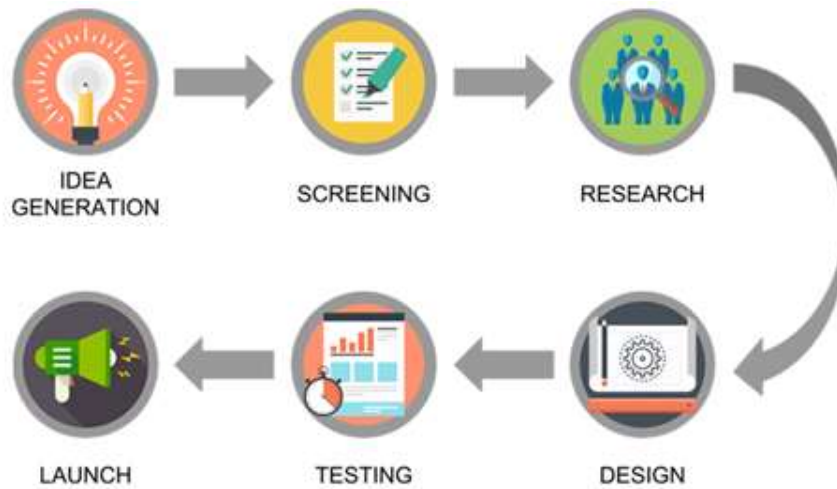


Figure 2. New product development model.
Source: Silva and Rupasinghe (2016).

stages of NPD, even though they were restricted to rationalizing the inter-related process activities of product design and development (Silva and Rupasinghe, 2016). These models helped identify the list of activities involved in the product development process unlike other models that did not feature current complicated product development processes. Early NPD process model development saw the publication of a number of sequential processes but such models were unable to accommodate the interconnected complex process (Gurbuz, 2018; McCarthy et al., 2006). Most of the sequential models consist of series of activities in NPD from the idea of “generation, market/ technical assessment, concept development, prototyping and ultimately finished testing” (Sujovala et al., 2016) (Figure 2).

Parallel or concurrent product development process models

Subsequently, parallel or concurrent product development

process models were introduced to address some of the weaknesses in the earlier sequential processing models. In these concurrent models, the multiple departments involved in the product development execute their tasks simultaneously towards optimizing product development cycle time. A typical example is Erhorn and Stark (1994) integrated approach. Beyond this was the supplier integrated NPD model was propounded by Handfield et al. (1999). In their model, process flow was clearly emphasized and paved way for suppliers to be integrated into the series of stages (Silva and Rupasinghe, 2016). Thus making it possible for key suppliers’ capabilities and design expertise, performing of technology risk assessments and risk evaluations that enhance the success rate induced by supplier support (Figure 3).

New Product Design and Development Model (NPDD)

In 1999, Peters, A.J. and the research team came out with a generic model for New Product Design and Development (NPDD) for small-medium industries (Silva

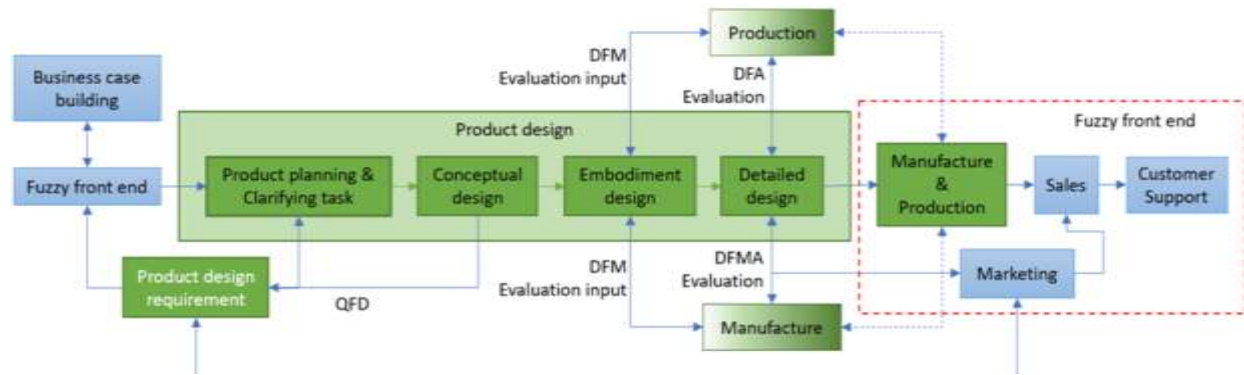


Figure 3. Concurrent product development process models. Source: Adopted from Duhovnik et al. (2009).

and Rupasinghe, 2016). This model is a detailed identification of activity of an NPDD process from design to delivery (Peters et al., 1999). The approach also encourages process iterations and flow of information, as captioned under "Facilitation Issues" (Silva and Rupasinghe, 2016). However, the model fails to clarify and describe how to process iterations are operated as well as stakeholders involvement in the information flow.

Quality Function Deployment (QFD) Methods

These methods offer visible connective approaches that seeks to consider the needs of the consumer throughout the processes (Bouchereau and Rowlands, 2000). Numerous NPD process models were designed using Quality Function Deployment (QFD) techniques in a variety of industries, including fashion industries (Silva and Rupasinghe, 2016). QFD is a method implemented to facilitate the development of marketable products with product attributes desired by the customer aimed at improving quality (Syreishchikova, 2021).

Open innovation model

Open Innovation principles emerged as an extended version of external collaborations, which have led to accelerated and enriched the New Product Design, Development and launch. The model assumes innovative approaches by integrating both internal and external ideas to solve problems within a firm (Parveen and Arslan, 2015). From a broader perspective, Open Innovation is defined as leveraging external sources of knowledge to drive internal growth. In this approach, active customer engagement is coordinated in new product development than conventional product development (Silva and Rupasinghe, 2016). The open innovation practices provide a normative guide for organizational growth by inspiring best practices from

external sources. Especially lead users may generate innovative ideas, and probably they have the potential to suggest feasible plans to end up with commercial products. However, there is a high risk when exposing new product strategies to external teams.

The electronic new product development model

The Electronic New Product Development (E-NPD) emerged from knowledge management concepts, and this model is intended to create core knowledge repositories and the information interdependency between all components of the value chain. In addition, the authors highlighted that successful product development projects need the participation of many experts from cross-functional departments with various knowledge domains. However, NPD is often described as a continuous learning process, and the knowledge management view emphasizes acquiring knowledge through learning processes. Further, Knowledge Innovation is explained as a core activity of NPD and knowledge acquisition, protection, integration, and dissemination are also explained as key directions of the model development. There were some directions for applications of electronic tools presented under the E-NPD model.

Virtual customer integration was initiated in the manufacturing of high-tech industries and transferred some techniques into the manufacturing of consumer goods. This technology has become popular among apparel designers and customers. Virtual customer integration is beyond web-based market approaches, and those models will absorb customers' knowledge and experience on products explicitly. Such customers' responses to virtual products will reduce NPD failures by early detecting the customers' acceptance of the final product. In combination with virtual reality (VR) and augmented reality (AR) technologies, the Web is the enabler for virtual customer integration. VR based

simulator involvement is proven advantageous and beneficial in many fields. The virtual New Product Development Team concept is also an emerging concept that will enhance the New Product Development by optimizing the human skill deployment. More of the functions are decentralized, no matter their physical placement, collaborated with their work with the support of novel electronic communication technologies in cost-effective ways.

Review of models in the area of fashion

In this part of the study, NPD models, which were inherently designed for the fashion industry, have been discussed. Although the apparel development process differs significantly from the other product development processes, some manufacturing firms have used generic models and concepts such as QFD in apparel product development (Mahmood and Kess, 2016). There are inherent qualities of apparel development that need to be considered when designing normative process models. In addition, during this reviewing process, other applications of NPD models are evaluated.

First, apparel products are designed as seasonal lines or groups of products rather than individual products. Second, several product lines produce within a year; hence, stages of the development process may overlap. Third, the strategy for developing any one product in the apparel line may differ from another product.

No-interval coherently phased product development model

Considering the above limitations, a conceptual model named, No-Interval Coherently Phased Product Development Model for apparel (NICPPD) was developed by delegating the responsibility of apparel product development among four functional divisions; Marketing, Merchandising, Design and Development, Production (Silva and Rupasinghe, 2016). The main model of NICPPD illustrates an overview of the six phases of the apparel product development process, and this is followed by the other six models, which elaborate an in-depth examination of each phase of the development process. This descriptive model did not show the customer integration, and that gap was filled by the development of the Proactive Product Development Integrating Consumer Requirements (PPDICR) Model by the same couple of researchers in 2005.

Proactive Product Development Integrating Consumer Requirements (PPDICR) model

The PPDICR model contributes to the theoretical

understanding of apparel product development and which avenues can be adopted to capture consumers' requirements. Effective use of this model will facilitate the development of a commercial product with an adaptation of a systematic method to capture consumers' needs. Apparently, eventual product success is determined by the level of acceptance by the end consumer. Customers' knowledge has become a valuable input in the innovation process as they have the expert knowledge in using it for a particular purpose over the years (Silva and Rupasinghe, 2016).

Functional, expressive, aesthetic (FEA) model

The functional, Expressive, Aesthetic (FEA) model can be used to identify end consumers' needs with respect to unique apparel design. Functional, expressive and aesthetic aspects are considered when assessing users' needs and wants.

The degree of influence of those factors will depend on the product category. The target consumer is at the core of the model. Culture determines the connectivity between the customer and the above factors, which need to be analyzed by the designer when designing customized apparel solutions. In a rapidly changing fashion environment (Chavan, 2018), culture will not be the factor to evaluate when acquiring their desires for apparel design. The three-stage design process consists of three main phases in product design and development (a) problem definition and research, (b) creative exploration, and (c) implementation (Silva and Rupasinghe, 2016). Labat and Sokolowski (1999) applied this model for a textile product design project. This model encourages creative exploration of new products and lends a measure of quality assurance of the novel products (Silva and Rupasinghe, 2016) (Figure 4).

The new product development process in the fashion industry

In the fashion industry, NPD is a dynamic process characterized by a high seasonal demand, which depends on the seasonal nature of fashion products (Mahmood and Kess, 2016). The entire NPD process runs at least two times per year, one time for each season and with short Time-To-Market (that is, 15 months in the apparel industry, 12 months in the leather industry). Several product revisions occur, with continuous interactions among designers, stylists and marketing functions (Paper et al., 2013).

Often during a single season, revisions and modifications are still happening when the final product is already on the shelves; this occurs to make some re-arrangements and re-alignments in accordance with customers' demand (e.g., change of colours for a model

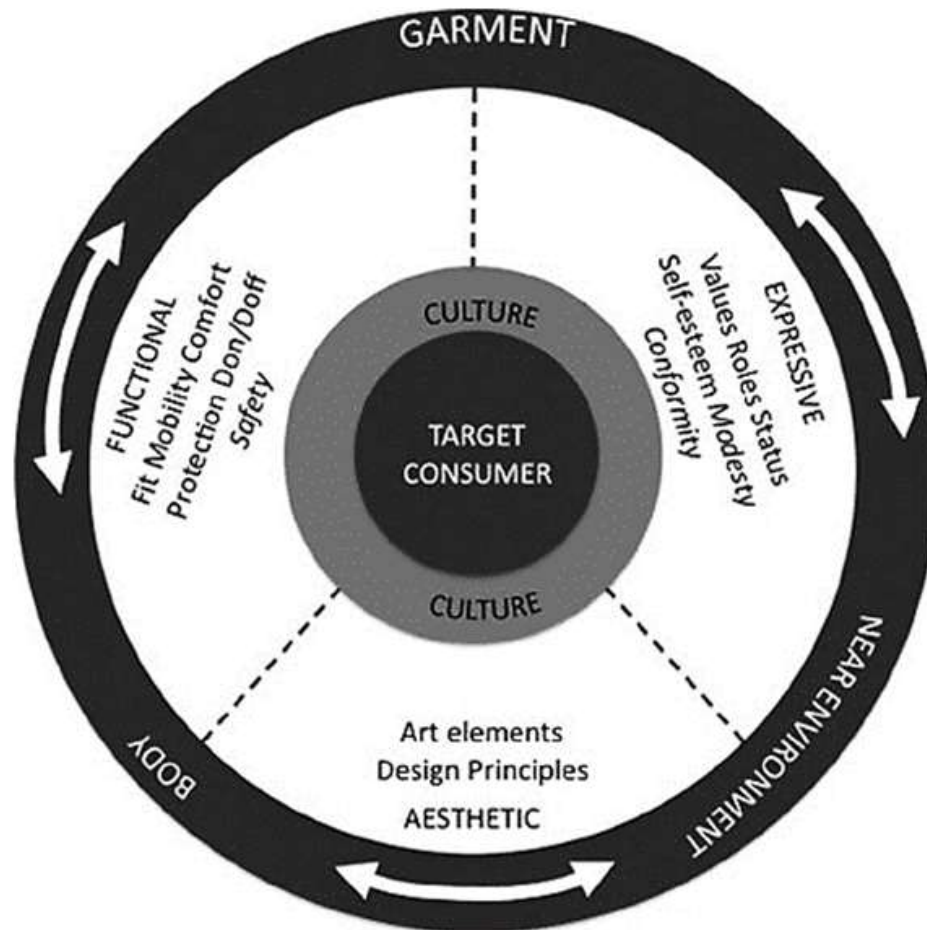


Figure 4. Functional expressive aesthetic model.
Source: Lamb and Kallal (1992).

in the apparel sector). In this context, as is described in the literature, NPD is a comprehensive process, which starts from (i) design, (ii) modelling/prototyping (to realize the demonstration products to be shown at the fashion fairs), (iii) detailed engineering, (iv) material sourcing and then ends with (v) production and distribution (Powell and Cassill, 2005).

The production phase usually lasts 3-4 months and starts when material sourcing is completed. The sourcing phase is very particular: its duration can change from 2 weeks up to two and a half months, depending on the duration of the commercial launch, which generally takes place at the same time, in conjunction with the fashion shows and fairs (e.g., the Pitti Florence fair, Milan and Paris fashion weeks, etc.). At the beginning of the sourcing phase, a provisional and generic order of raw material is submitted to the suppliers, while confirmation of the raw material quantity is given at the end of this phase, with a maximum gap of 20-30% from the provisional phase (Silva and Rupasinghe, 2016). During this very short period, as soon as the number of sold units is known for the current season, the company board

has to decide which products will be produced and which not; accordingly, the raw material to order needs to be defined (Paper et al., 2013).

During this period, most companies also had to finish the engineering phase: for example, in most cases, the generation of the final Bill of Material (BOM) took place when orders had already been launched. Once the company's decision is made, the creations of the BOM and the raw material purchase order have to be submitted quickly. Moreover, the decision of what has to be produced can change very rapidly during the period when fashion shows take place. In some companies, the engineering phase was completed for all the products before the beginning of the fashion fairs, permitting quick management of the sourcing activities (Paper et al., 2013).

METHODS

This survey adopted the qualitative research approach to gather and analyze data. Qualitative research focuses on fewer samples to gather more detailed and richer data (Cohen et al., 2007). The

Table 1. Fashion house categories and mode of operation.

Fashion house type (FHT)	Firm label	Number of workers	Mode of operation	
Small	FHT 2	1	Self-managed with 3 apprentices	
	FHT 3	1	Self-managed with 7 apprentices	
	FHT 5	1	Self-managed with 3 apprentices	
	FHT 6	1	Self-managed with 2 apprentices	
	FHT 7	1	Self-managed with 5 apprentice	
	FHT 8	1	Self-managed with 3 apprentices	
	FHT 9	1	Self-managed with 2 apprentices	
	FHT 10	1	Self-managed with 6 apprentices	
	FHT 12	1	Self-managed with 1 apprentice	
	FHT 13	1	Self-managed with 3 apprentices	
	FHT 14	1	Self-managed with 4 apprentices	
	FHT 15	1	Self-managed with 4 apprentices	
	FHT 16	1	Self-managed with 2 apprentices	
	FHT 17	1	Self-managed with 7 apprentices	
	FHT 18	1	Self-managed with 3 apprentices	
	FHT 19	1	Self-managed with 8 apprentices	
	FHT 20	1	Self-managed with 3 apprentices	
	FHT 21	1	Self-managed with 5 apprentices	
	FHT 22	1	Self-managed with 4 apprentices	
	Medium	FHT 1	2	Institutionally managed with casual workers
		FHT 4	5	Self-managed with 4 workers
		FHT 11	3	Self-managed with 2 workers
Total	21	29		

Source: Authors Fieldwork, 2022.

Table 2. Participants' responses on type of production.

Main findings

All participants produce on custom-based

Mass production is done at a specific time and on demand

Source: Authors Fieldwork, 2022.

population comprised Fashion Designers in Ghana. The purposive sampling technique was used to reach out to twenty-one (21) Fashion/Garment producers in the Central, Greater Accra, Ashanti and Ahafo Regions in Ghana. Interview and observation guides were the main instruments used to gather data. Data obtained were analyzed and discussed based on themes that emerged from the study.

RESULTS

Participants comprised eighteen (18) females and three (3) males whose ages ranged from 26-55 years. Their working experience ranges from 2 to 18 years. Participants' industries were categorized as Small and Medium production scales based on the number of employees and mode of operation. Details are presented

in Table 1.

Mode of production

Participants were also asked to indicate their production line. The results are summarized in Table 2. Participants generally indicated that they produce on custom-based. However, there were times when some designers produce in masses for specific groups on request.

Sampled responses:

"I mostly sew on custom-based, but once a while, I do produce for the masses on request which is usually for schools". (Participant 2)

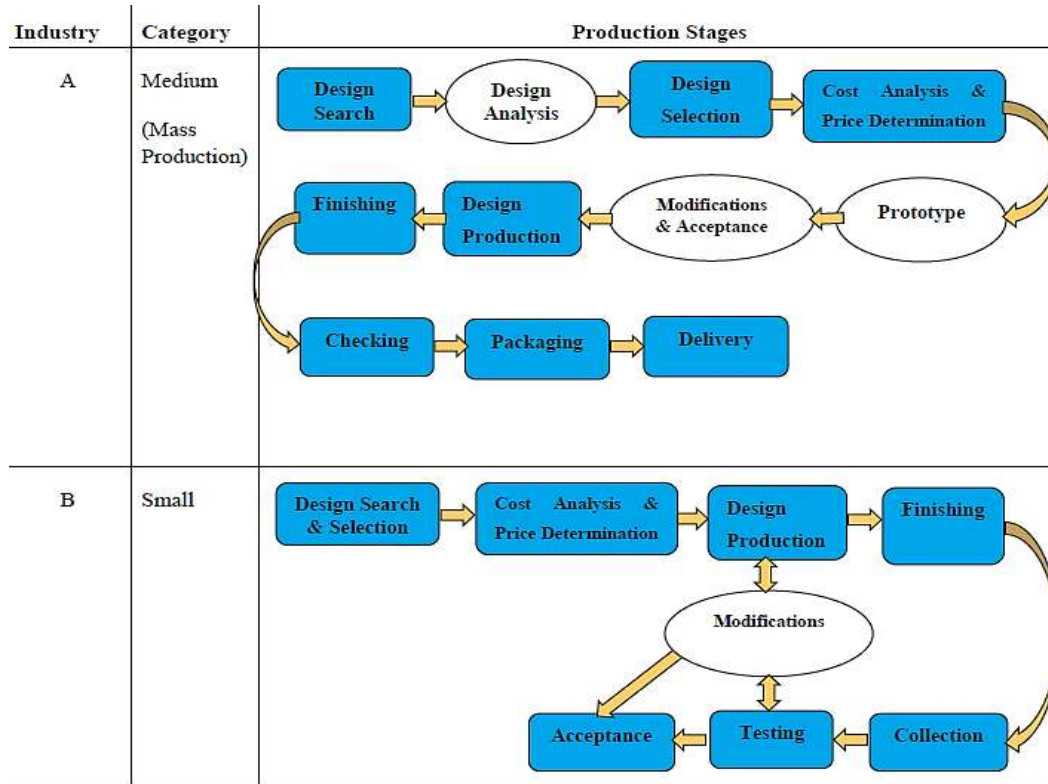


Figure 5. Product development stages designers adopt.
Source: Authors Fieldwork, 2022.

“I do custom-based sewing” (Participant 7)
 “We sew on both custom-based and mass production.
 But most of the time is the custom-based that we produce more” (Participant 4).

Participant 1, however, had a different production line:

“The production centre does more of the mass production than the custom-based since the focus is to produce items in masses upon request”

Research question one: Which model guides the production of fashion products among designers in Ghana?

Participants were asked to indicate the kind of model they follow in designing products for their clients. The findings revealed that designers do not have a specific standardized guide they follow in designing. The researchers further observed their production process is to cross-check which of the internationally recognized models designers follows. The study observed that designers apply indicators from different models in their design creation and delivery. Sampled views from the participants are shared below:

Participant 5:

“I do not have any standard I follow. I create my designs based on the standard practices
 When the customer selects her style of preference, then I check if the fabric will require special treatment. I do memory costing and charge the person. After full or partial payment, I measure the person and begin production. When the product is ready, I call or inform the owner to come for it”.

The result indicates that the participants have no exposure to standardized product development models but instead rely on processes that suit them best in their production line. This is evident as participants 2, 5, 6, 7, 9, 13, 16, 18 and 21 have similar views.

Research question two: What activities constitute Product Development Process of the Ghanaian fashion designer?

Product development processes of designers

The designers were asked to describe the stages they go through to develop the design from consumer requisition to delivery to validate what is observed. The participants’ views were summarized into general processes, and this is presented in Figure 5.

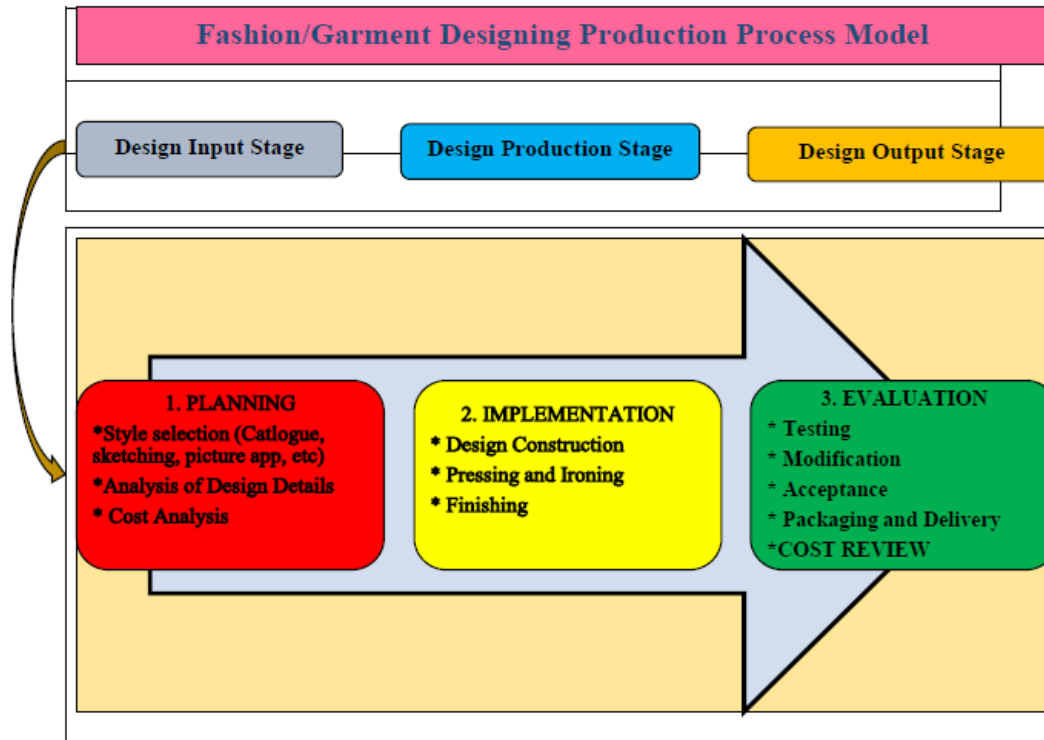


Figure 6. The red-gold-green fashion/garment production process model.
Source: Authors own construct (Fieldwork, 2022).

Figure 5 shows the indicators of the Product Development Processes small and medium scale designers in Ghana practice. Participants within the small-scale production shared similar processes. However, the participants who engage in mass production in the Medium Scale Production follow procedures that slightly differ from the custom-based production process. Sampled view from Participant 1 is shared below:

“What the Production Unit does after product requisition, the client is shown a sketch of the product, and then the design is analyzed. Upon initial acceptance, a budget is prepared for approval by the finance unit. The client is then given a copy of the sketch for acceptance and depositing of production cost into an account follows. After, the invoices are sought for the purchasing of the raw materials. Upon purchasing, a prototype is made for review and acceptance then, production begins. The sample(s) made are assessed at each stage to check for faults and corrections. At the end of the production, the final finish is given and the products are packaged for delivery to the client.”

Proposed product development model

After cursory review and analysis, the researchers

realized a gap in the standardized Models of the Product Development Process. Since the standardized model seems not applicable in the Ghanaian context, the researchers proposed a model captioned “Red-Gold-Green Fashion/Garment Production Process Model” for adoption and review. The model is presented in Figure 6.

DISCUSSION

This study explored and reviewed some Product Development models and processes fashion/garment designers in Ghana adopt. The results indicated that designers do not have standardized models that they follow; however, there were indications that some activities within standardized models are practiced by the Ghanaian Fashion Designers. The standardized models seem to have undergone several evolutions resulting in the refinement of Product Development Models over time. Models reviewed in this study have their own unique structures, which the Ghanaian designers adopt and adapt some stages for successful design creation. Successful businesses must be able to broaden their knowledge base and acquire new skills in an increasingly competitive global economy (Cooney, 2012).

The study revealed that fashion designers in Ghana rely mostly on clients’ description to come up with a new product. Additionally, most models reviewed have

focused on the product but not necessarily customer inputs. There also seems to be lack of clarity on innovation and flexibility on the adoption of the standardized models; the processes designers generally go through to complete projects for customers remain unchanged. This places such products and their introduction into the market at disadvantage since the acceptance level may be affected.

The Ghanaian Fashion Designers seem unaware of design models available. Instead, the designers follow their own pattern for creating new design which lacks documentation. The inability of the designers to create their own models has been attributed to lack of financial resources, structured product development and innovation processes (Fueglistaller, 2004), lack of understanding on design concepts (Moultrie et al., 2007) and lack of management of new knowledge and resource use (Acklin, 2013). The proposed model for the Ghanaian fashion designers has the potential to develop designers' creativity and minimize waste associated with the introduction of prototypes. However, the proposed model seeks to favour only the consumers who request for designs to be created. This generally implies that while standardized models aim at marketing specific products, the proposed model by the researchers aims at satisfying individual consumers' specifications.

Conclusion

Product design models are structures that serve as guide for production among several production units of which the fashion/garment production industries are not exempted. Although several models have been proposed for use in the fashion industries none of these standardized models truly reflect the Ghanaian fashion industries' production process.

The study concludes designers in Ghana may not have been exposed to such models and they rely mostly on the mode in which they are trained as designers. The adoption of standardized models in design creation by the Ghanaian Fashion Designers may be challenging since there seems to be gap with the target clients. Hence, this study recommends the proposed model for adoption and implementation by Fashion Designers in Ghana since its use reflects their creation line and it is manageable and flexible.

Recommendations

1. Further research is required to introduce and practice the proposed model from this study for an extended period to validate the effectiveness of the proposed interventions for the Ghanaian fashion designers.
2. A comprehensive review of Product Development Process in Ghana is required since recommended

models seem not to be applicable in the Ghanaian context.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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