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Contents

The Quality of TVET Delivery and Associated Factors in Ethiopia

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ABSTRACT

The purpose of this study was to investigate the quality of TVET delivery in Ethiopia and to identify factors that affect the quality of the delivery. The study employed a mixed methods research approach with a concurrent design. The quantitative data were collected via a questionnaire developed, piloted, and refined by the research team members. Qualitative data was collected by conducting semi-structured interviews with participants from TVET leaders, experts, trainers, employers, and TVET graduates. A total of 174 institutions, 348 deans, vice deans and heads (two deans from each institution), 392 officials and professionals, 40,441 trainees, and 2011 trainers participated in the study. A total of 599 interviews were conducted in nine regions and two city administrations of the country. The instruments for data collection were validated by conducting a pilot study and checking the reliability of the questionnaire using Cronbach's alpha method. *The validity of the instruments was checked by expert review. The findings showed that a number of variables affected the quality of TVET delivery including the TVET policy per se, societal image towards TVET, the governance and structure of the TVET system, the economic situation of the country, the number of industries in the country, the financial and procurement system of the country, and the education system of the country. Moreover; the quality of trainers, the entry behaviour of the trainees, the institutional environment, the availability of resources and facilities affected the training quality. The quality of the occupational standards, curriculum and teaching-learning materials, the way cooperative training is implemented, the assessment strategy, the monitoring and evaluation system, the quality assurance system, and the graduates' employability also affected quality of TVET delivery. The study provided suggestions for improving the quality of TVET delivery.*

Keywords: Quality; TVET Delivery; Occupational Standard; Cooperative Training; Competency Assessment; Employability.

1. Introduction

1.1 Background of the Study

Technical and Vocational Education and Training (TVET) as one education system plays a significant role in fostering the socio-economic development of a country. Indeed, TVET is a major avenue for industrial development as well as for economic and social progress of any country. It is TVET that produces the critical mass of the requisite skilled, technical and professional human power needed for national development. Without the skilled technical manpower produced by TVET institutions, technical development would virtually grind to standstill (Kemevor & Kassah, 2013).

Over the years, three different forms of TVET have evolved in Ethiopia. These comprise the formal, non-formal, and the informal systems. Thus, TVET is seen as an overarching term to describe all modes of formal, non-formal, and informal training and learning provided by all government and non-government-private providers to equip individuals with marketable competences (Edukans Foundation, 2009). The TVET sector aims to provide more opportunities for a wide range of different groups including school leavers, dropouts, people without formal education including illiterates, entrepreneurs and employees, farmers and their families, people from marginalized ethnic groups and other groups (MoE, 2008).

Realizing the need for skilled human power, the TVET Strategy (MoE, 2008) envisaged that TVET in Ethiopia seeks to create competent and self-reliant citizens to contribute to the economic and social development of the country, thus improving the livelihoods of all Ethiopians for sustainable reduction of poverty. It was with this vision that measures were taken to expand the formal and non-formal TVET programs across regions and *Woredas*. Formal TVET program has been provided mainly to secondary school leavers. In addition, working people have also been benefiting from this program through evening classes and distance learning. The formal system is primarily time-bound, institution-based, graded, and certified training offered by institutions such as the polytechnics, technical colleges, and institutes. On the other hand, non-formal TVET has been offering training to a wide range of groups (MoE, 2008). Informal TVET sector is also recognized and described as those operations which are unregistered and operating on a very small scale and with a low level of organization. The informal sector operates without fixed locations, in small shops, outlets, or through home-based activities. The government has little or no direct involvement in informal TVET. It is not supported, or regulated by the government (MoE, 2008).

After the introduction of the Education and Training policy (ETP) in 1994, the number of formal and non-formal TVET provision centers has mushroomed. The Ethiopian government has recognized the importance and the need for establishing a large number of TVET institutions in the effort to promote economic and technological development in the country. Within a short period, the number of formal TVET institutions (excluding those centers which are engaged in short-term and non-formal trainings) has reached 868 in 2017 (Result from preliminary assessment). Realizing the importance of linking education and the world of work, *woreda*s are requesting for further expansion of TVET institutions. There is an attempt to have at least one TVET institution at each *woreda* (MoE, 2015). However, TVET in Ethiopia faces a lot of challenge, among which quality is the major one.

1.2 Statement of the Problem

As was mentioned in the background of the study, the general objective of the National TVET Strategy is set to create a competent, motivated, adaptable, and innovative workforce in Ethiopia that contributes to poverty alleviation and socio- economic development focusing on demand-driven, quality TVET to all sectors of the economy, at all levels (MoE, 2006:10). Moreover, it is noted in ESDP-V that TVET is a priority program to the nation with a goal to produce a lower- and middle-level, competent, motivated, adaptable and innovative workforce, which can contribute to poverty reduction and social and economic development through facilitating demand-driven, quality TVET training and transfer of demanded technology.

It is a widely accepted idea that TVET contributes a lot to address societal need for middle level skilled human power and to ensure employability of the youth. However, this can only be achieved through quality. A study conducted by Lemma (2014) in Oromia region indicated that significant number of TVET trainees lacked the competence to pass COC assessment and also to be competent in the world of work because of the problems in the quality of TVET delivery. In his study, Lemma found out that weak preparation of teaching learning materials, poor implementation of competency based training, poor quality of TVET teachers, poor learning environment of the TVET institutions, and poor linkage with the industries contributes to poor quality of TVET delivery, which is measured through trainees' performance in assessment and their competence in the world of work.

On the other hand, a study conducted at Gurage zone by Desalegn (2014) shows that poor quality and lack of experience, stakeholders' lack of adequate awareness about TVET, weak involvement of companies in cooperative training; lack of collaboration between stakeholders, lack of capable supervisor, lack of appropriate machines and training materials, shortage of budget, lack of promotion activities, lack of professional development trainings for trainers, and lack of subject matter and pedagogical knowledge of trainers were the major factors that affected proper implementation of cooperative training, which is the major component of TVET delivery. A study conducted at Addis Ababa by Alemayehu Kebede (2010) also contends that some of the TVET graduates could not secure employment even in highly demanded jobs because of the fact that the training delivered is devoid of practical application and has not enabled graduates to initiate self-employment as an alternative to wage-employment.

Berhe (2011) also conducted his study in Southern Zone of Tigray Region. His study showed that the assignment of trainers in jobs beyond their qualifications, shortage of different inputs of training (facilities, materials, and services), lack of experience of TVET trainers, low qualification of trainers, the inefficiency of the TVET leadership to properly conduct supervisory activities and provide supportive and timely feedback, and also problems in the training were the challenges that affected the quality of TVET delivery in the selected zone.

These and other similar studies suggest that inadequate instructor training, obsolete training equipment, lack of instructional materials, uncoordinated, unregulated and fragmented delivery system, inadequate financing, poor management, ill-adapted organizational structure, and poor linkage between the training institutions and the labour market are factors that affect the quality of the training in the TVET institutions.

However, the studies which have been conducted so far in the TVET sector in Ethiopia, though helpful, were either scanty or unable to show the national reality. That is, no comprehensive national study has been conducted so far with emphasis on quality of TVET delivery. This knowledge gap has initiated the researchers to conduct a comprehensive national study that has attempted to identify the major challenges to the quality of TVET delivery in the country and to suggest possible strategies believed to tackle the challenges hindering the quality of TVET delivery. With this in mind, the current study attempted to empirically investigate the challenges that might have contributed to the low quality of TVET delivery and to indicate the way forward to tackle the challenges. Thus, this study tried to answer the following **overarching questions**

- What is the quality of TVET delivery in Ethiopia and what are contributing factors?

  Inherent to this question are the following sub-questions:

  - How is the performance of TVET graduates in competency assessment and the world of work?
  - What context-related factors challenge the quality of TVET?
  - What are the input-related factors that challenge the quality of TVET?
  - What process-related factors pose challenges to the quality of TVET?
  - What can be suggested to improve the quality of TVET in Ethiopia?

1.3 Significance of the study

The findings of the study could help different beneficiaries in the following ways:

- TVET institutions could realize their gaps and improve the quality of TVET delivery.

- Policy makers would be informed about the status of the sector and make appropriate reforms on the policy and strategy of TVET.
- Employers could identify their roles in the quality delivery of TVET and thereby make a significant contribution that can improve the competence of TVET graduates who can meet their demands.
- Graduates could see their competence gaps and take additional trainings that make them ready for the world of work.
- Trainers could see gaps in the teaching and training and adjust their method of delivery to ensure quality. It also helps them to see their competence gaps and improve their performance through continuous professional development activities.
- Trainees could see their gaps in terms of their attitude towards TVET and make themselves ready to their expected roles so that they become competent to the labor market demand.
- The larger society could see gaps in their roles and build positive image towards TVET and thereby encourage them to send high caliber students and make positive contribution to the sector.
- Researchers could use it as a reference and spring board for further study in the area.

1.4 Operational Definition of key terms

TVET Delivery- the provision of TVET programs in the formal TVET Institutions of Ethiopia which includes the context, input, process and output that may have direct or indirect bearing on its quality.

Quality -the attainment of knowledge, attitude and skills by the trainees as stipulated in the occupational standard.

Occupational Standard –Sets of standards of competencies as required by the world of work, which are assumed to be developed mainly by industry experts.

Ethiopian Occupational Standard – Set of standards of competencies as required by industries in Ethiopia.

Trainee-a student who is admitted to TVET institutions to attain certain level of competencies in the formal program.

Trainer-an instructor, facilitator, or supervisor who is qualified in a given discipline to deliver education and training in the formal programs of TVET institutions.

Trainee Level – the ladder of training which describes the status of achievements of trainees as stipulated in the Ethiopian TVET Qualification Framework, which is categorized from level I to level V.

Trainer Level – Qualification of trainers which ranges from level A to Level C as stipulated in the Ethiopian TVET Qualification Framework, where level A trainers correspond to MA/MSc degree holders; level B trainers correspond to BA/BSc degree holders (level V TVET certified trainers); and level C trainers correspond to level III and/or IV certified trainers.

Certification of Competence (CoC)-Office where: assessment packages are prepared, assessors are identified, and the national assessment is administered.

2. Literature review

2.1 Overview of TVET in Ethiopia

Technical and Vocational Education and Training (TVET) has a long history in Ethiopia. The first formal TVET institutions were established in the 1940s and1950s during the regime of Emperor Haile-Selassie (Wanna, 1998: 57). According to Biadgilegn Ademe (2018), the objective for establishing these institutions was to produce administrative and managerial elites who can

address the shortage of educated workforce in government offices. Later, the concept of comprehensive program was introduced in Ethiopian secondary school system in the 1960s with the main objectives of preparing students for work, the appreciation of the dignity of all labour, and the promotion of skills of efficiency and workmanship (Girma, Meharie, and Nigatu; 1994: 10-11).
However, the comprehensive school system was found to be inadequate to address the country's need for well-trained and skilled workforce and, thus, a study was made by MoE to review the quality of training in comprehensive secondary schools (Wanna, 1996: 299). According to Wanna (1998), the then existing comprehensive schools were strengthened and new training schools were established to enhance the quality of the training so as to produce well-trained and skilled technical workforce by accepting well performing technical-oriented students after completing grade 10. After the demise of the Emperor Haile Selassie regime in 1974, the military government of Ethiopia introduced polytechnic education with the objective of providing students with the basic skills of TVET together with some academic subjects so that they could work in the industry as technicians and technical managers after graduation (Ademe, 2018). Gumble, et.al, (1983) cited in Ademe (2018) indicated that technical and vocational education was also offered at Addis Ababa and Asmara universities, and also in some higher education colleges.
The TVET sector was given due attention after the introduction of the ETP (1994), which stipulated that the general development of the country would be impossible without well-qualified middle level skilled personnel in various fields of studies (TGE, 1994). Following the policy direction, TVET has expanded throughout the country and a number of TVET institutions have been constructed in all regions of the country. Some years after the formulation of the ETP, students who completed Grade 10 and who failed to join

universities were assigned into 10+1, 10+2, and 10+3 TVET hierarchies (MOE, 2002: 2).

Restructuring of the TVET system occurred in 2006 to increase the relevance of the skills developed through TVET, focusing more closely on those demanded in the labour market, and thus, responding to criticisms that skills acquired in TVET were not useful at work (Fukunishi and Machikita 2017; MoE 2008). The National TVET Strategy was developed in August 2006 (MoE, 2006b). In September 2006, the Federal Ministry of Education developed a National TVET Qualifications Framework (NTQF) to improve the quality and relevance of the TVET system (MoE, 2006c). The ten-level ENQF covers general education, TVET and higher education. The National TVET Qualifications Framework (NTQF) has five levels, from National TVET Certificates I to V, increasing in duration of training from one to three years and level of skill on completion, with level five being the highest (MoE, 2015). Based on this, TVET institutions offer programs from level 1 to 5, where level 1 and 2 courses provide laborer-oriented skills, through to level 5, which is managerial-oriented (NTQF, 2006c). A TVET Leaders' and Trainers' Qualifications Framework (TLTQF) was also introduced in 2010 (MoE, 2010b).

The national TVET strategy is a guiding document for all TVET programs in the country, including Agricultural Technical and Vocational Education and Training (ATVET). This strategy advocates for a comprehensive and integrated TVET system, which is decentralized and outcome based in its approach. It advocates an outcome-based approach, replacing the traditional curriculum-based approach. It utilizes the needs of the labor market and occupational requirements from the world of work as the benchmark and standard for TVET delivery and assessment. (Fukunishi and Machikita 2017;

MoE 2008). Based on this, the government has formulated a national occupational standard in collaboration with the industry. The occupational standard serves as a reference for training and assessment. In the new TVET system, trainees are certified based on their performance during the competence-based assessment.

2.2 Quality of TVET Delivery

Quality is viewed from various perspectives. The British Standards Institution (BSI) has defined quality as "the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs" (1991, p. 1). From the stakeholders' perspective, Vroeijenstijn (2006) noted that quality is in the eye of the beholder and any definition of quality must take into account the views of various stakeholders. Cheng and Tam (1997) described quality as a system that constitutes the input, process, and output of the educational system and that provides services that completely satisfy both internal and external stakeholders by meeting their explicit and implicit expectations.

As educational goals vary widely across TVET institutions, Tan (1986) suggests that what constitutes quality in some institutions may not be as applicable to others. Despite the potentially vague notion of educational quality, there are several people who define a high quality institution as one that fosters a desired level of learning and development. For some, quality is measured by the impact it has on its learners (Nordvall & Braxton, 1996). While some have linked measures of quality with an institution's output. Others still suggest that quality can be measured by focusing on the processes of an institution or, in other words, what the institution itself does to promote the learning and development of its learners (Braxton, 1993).

A fairly common approach in evaluation research to assess the quality of a program is linked to an input-process-output model by examining the relation between the processes and the outcomes when the inputs are held constant (Scheirer, 1994). Schierer points out that if the processes have any influence on the outcomes (as intended), then these two factors should be associated. In other words, high levels of output should be preceded by high levels of the corresponding processes.

2.3 Challenges to the quality of TVET delivery

It is unarguable that the TVET in most of the Developing Countries plays two crucial roles: the first role is to providing training opportunities and the second role is creating career advancement avenues for the increased number of high school completers. The quality of TVET is, therefore, measured from these two points of view. Creating career opportunity for school leavers and providing competent middle level technicians for the labour market is unthinkable without quality education and training.

In the specific context of TVET, high quality is often taken to mean that the education and training received by trainees is relevant to the needs of industry and self-employment needs in the labour market, authentic and rigorous, resulting in graduates who are ready for employment. Hence, quality can be measured by the graduates' employability and-ultimately- employers' satisfaction or the satisfaction of those who are self-employed. Studies show that there are different enabling factors as well as inhibitors that affect the quality of TVET delivery.

For a TVET System to be able to play its role effectively, it is important to ensure that there exits an enabling and TVET friendly environment nationwide. Such an enabling environment can be achieved by putting in place harmonized national TVET policies, provision of adequate funds, developing positive social attitudes towards training and enhanced management.

Different studies show that good quality of institutional as well as workplace training in the TVET system results in company productivity. Konings and Vanormelingen (2010) find that training has a positive and significant effect on value added in Belgium. Harel and Tzafrir (1999) also estimate positive and significant effects of 'systematic and formal' training on perceived organizational and market performance of firms in the public and private sector in Israel. Murray and Raffaele (1997) conclude that classroom-based quality training had positive and significant impact on the quality of China products.

According to MacDonald, Nink, and Duggan (2010), one of the challenges in TVET systems of developing countries is that many TVET programs are established in urban areas owing to the centrality of industry linkages in vocational education and training and the overall advantages of a larger population. Rural and remote areas are often left out of the TVET mix, and as a result of this, rural TVET colleges become under-resourced and lose relevance. Frequently, those TVET graduates from rural TVET colleges move to urban areas seeking further education and employment. Not having the required skill base, such youth face protracted unemployment or under-employment.

Furthermore, the Inter-Agency Group on TVET (IAG-TVET, 2012) noted that teachers' training, teachers' qualification, opportunity for teachers to upgrade themselves, and trainees' access to teachers affect the quality of TVET delivery. According to this group, the better the teachers are prepared to teach and train, the better one would expect the teaching and training to be. The group also added that the teachers' possibility of being re-trained and getting opportunities to upgrade their skills contributes to quality of TVET. They also contended that trainees' access to a teacher (trainee-trainer ratio) is seen as a proxy measure of quality of TVET. In a similar vein, the group contended that good facilities (foremost buildings, equipment and learning material) are expected to lead to better results, partly because having access to good facilities can motivate and empower trainees, and partly because being able to use the equipment enhances the internal learning process of the trainees.

A study conducted at Myanmar by Milio, Garnizova and Shkrel I (2014) identified the following as factors that put challenge on the quality of TVET delivery: lack of coordination and cooperation among different actors in the system, the scarce resource allocated to the TVET institutions, insufficient teaching materials, teaching aids, training laboratories and workshops, poor linkage between the training standards and the labor market, poorly prepared curricula, theory-focused teaching methods, shortage of experienced and qualified trainers, low effort to motivate trainers combined with low salary of trainers and reluctance to retain experienced and qualified trainers in the sector, poor mentoring and coaching mechanisms to support the practical aspect of vocational education and training in companies, and diversity of regional needs combined with inability of the government to address these diverse needs.

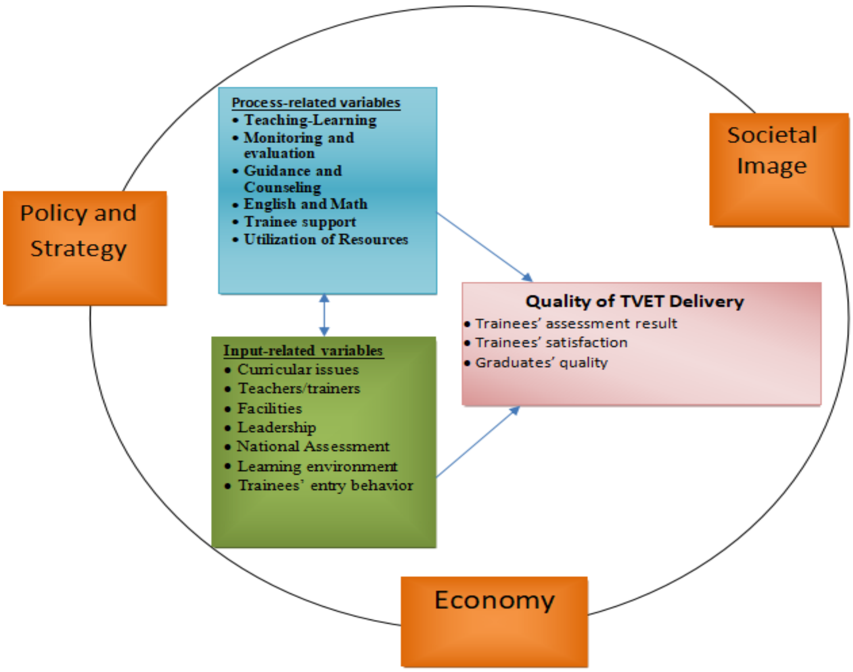
According to Nurul Islam (2008), core problems of TVET in Bangladesh include the following: There is no comprehensive need assessment survey to assess the detailed training requirement; TVET system is not adequately responding to market demand; small industrial base and slow growth to accommodate the skilled workforce comfortably; TVET providers are far behind the international standards, certification and quality assurance; low connection to international labor employment market; weak governance of

TVET; participation of private sector and employers with TVET providers is inadequate; poor monitoring and no performance evaluation of TVET; inadequate orientation to labor market regarding TVET; TVET institutions, particularly private ones, lack workshop, lab equipment and physical facilities; majority of the teachers of private TVET institutions are not properly qualified and trained; lack of sufficient teacher training facility to face the challenges of the TVET system and identify the basic concepts of improving the quality of TVET delivery.

According to Hrmo, Mistina, and Kristofiakova (2016), the main challenge for the quality of vocational education and training in Slovakia is meeting the changing skills needs of individuals and the world of work in accordance with the principle of lifelong learning. These authors noted that the competences that are focused only on one specific situation are rapidly becoming obsolete, they become useless. They suggest that trainings should focus on key competences which enable individuals to occupy a range of job positions and functions to perform various jobs, and which are appropriate to address a wide range of mostly unforeseen problems that allow an individual to successfully cope with rapid changes in work, personal and social life. They are intended to address the multiple problems in different contexts, for achieving multiple objectives; they are to be applied not only in different professions, but also in various areas of human activity, in school, at work, in social and personal life. They further suggested that TVET graduates should achieve the knowledge base in mathematics, physics, chemistry and in professionally oriented subjects. They also added that courses in humanities and social sciences, including foreign languages, contribute to the general basis for their intellectual momentum and professional development. According to these authors, to increase the chances of professional practice, it is necessary for TVET graduates to acquire not only language but also professional communication competence. They emphasized that professional communication language skills along with other key competences play an important role in professional career of TVET graduates (Ibid).

2.4 Conceptual framework

It can be learnt from the above studies that the major challenges hindering the quality of TVET delivery can be organized as context-related, input-related and process-related factors which, in turn, affect TVET graduates' performance in assessment as well as their performance in the world of work. Based on the findings from literature review and using the CIPP (Context-Input-Process-Product) model for program evaluation, the following conceptual model was developed to graphically represent factors that may challenge the quality of TVET Delivery.



This model is a modified form of the CIPP (Context-Input-Process-Product) model. According to the model, quality of TVET delivery is measured by Trainees' assessment result, Trainees' satisfaction, and Graduates' quality.

Input related variables include curricular issues, teachers/trainers, Facilities, Leadership, National Assessment, Learning environment, and Trainees' entry behavior. The process-related variables include Teaching-Learning, Monitoring and Evaluation, Guidance and Counselling Service, the way English and Math are integrated in the curriculum, Trainee Support System, and Utilization of Resources. The variables on the circle (Education and training policy of the country, economic condition of the country, and societal image towards TVET) are context-related variables. The arrows pointing towards the box containing quality of TVET delivery anticipate that quality of TVET delivery is challenged by the input and process variables. Moreover, it is anticipated in the model that the context-variables circling all the other variables have influence on the other variables. Generally, it is anticipated that the quality of TVET delivery, which is measured by trainees' assessment result, their satisfaction and the competencies they have after graduation, is challenged by the input, process and context-related variables.

3. Research Methodology

The research approach employed in this study was a mixed methods approach with concurrent design. The study was descriptive in that it attempted to describe the current status of the phenomenon under investigation. In this study, all TVET institutions, TVET bureaus, *woredas* with TVET institutions, employers and TVET graduates were included. All regions and the two city administrations were parts of the study. Simple random sampling technique was used to select some zones of regions and sub-cities of the two city administrations. The same sampling strategy was used to select TVET institutions and *woredas* from the zones and the sub-cities. Respondents for the quantitative data were also selected by using simple random sampling.

Participants in the focus group discussion and key informant interview were selected purposively based on their relevance to the issues raised.
In this study, 20% of the government institutions and 20% of the private institutions were selected from each region using simple random sampling technique. Accordingly, two institutions from Dire Dawa (1 government and 1 private), three institutions from Ethio-Somali region (2 government and 1 private), two institutions from Harari region (1 government and 1 private), 15 institutions from Tigrai region (8 government and 7 private), 29 institutions from Amhara region (20 government and 9 private), 90 institutions from Oromia region (70 government, 20 private), 16 institutions from SNNPR (10 government, 6 private) and 17 institutions from Addis Ababa (8 government, 9 private) were included in the study.

Then, 10% of the trainees and 10% of the trainers were selected from the selected institutions. Trainees of the selected institutions were also selected based on their level (Level1, 2, 3, 4, and 5) using stratified sampling technique. Trainers were also selected based on stratified sampling technique, using the level positioned to deliver training (A, B and C) as criteria. Two leaders were selected purposively from these institutions for focus group discussion. A purposive sampling strategy was also employed to select a total of 392 officials and professionals from regional TVET agencies and *woreda* or sub-city TVET offices. As a result,174 institutions, 348 deans, vice deans and heads (one dean and one vice dean from each institution), 392 officials and professionals, 40,441trainees and 2011 trainers were included in the study. However, due to respondent attrition and other related reasons, only a working sample of 12, 326 trainees (M=5976 & F=6353) and 997 trainers (M=802 & F=197) successfully completed the questionnaire.

In the quantitative strand, questionnaire was used as a means of data gathering from the selected sample units. In the qualitative strand, focus group discussions and key informant interviews were held at the selected centers and institutes/colleges. In addition, secondary data from policy documents and other curriculum related documents were included. A preliminary study was conducted (2017) in selected five regions and two city administrations: Somali, SNNPRS, Tigrai, Amhara, Oromia, Dire Dawa, and Addis Ababa. The purpose of the preliminary study was to get authentic data about the population of the study. This was followed by development of data collection instruments. Then the instruments were piloted; the reliability and validity of the instruments were checked. Finally, the quantitative data collected was analyzed using SPSS (Statistical Package for the Social Sciences), quantitatively using descriptive statistics such as frequency count, graphs, percentages, correlations and inferential statistics (t-tests, ANOVA, and regression analysis). Regression analysis was conducted to measure the degree of association between the variables. All factors affecting the quality of TVET (student, institute, government, general education, and other factors) were taken to be the independent variables while quality of TVET was taken as dependent variable. All the inferential statistics were tested at 0.05 level of statistical significance. For the qualitative phase, data was analysed using Guba and Lincoln's constant comparative method of analysis (in Leech & Onwuegbuzie, 2007:565). Content and document analyses were employed.

4. Results and Discussions

4.1 Analysis of the Demographic Data

Table 1 illustrates the trainee respondents' biographical information. The total number of respondents was 12,329.

Table 1: Frequency distribution of the biographical data of the trainees

Variable	F	%
Gender: Male	5976	48.5
Female	6353	51.5
Age: Below 20 years	7565	61.4
20-30 years	4556	37.0
31-40 years	159	1.3
Above 40 years	49	0.4
Year of training: 1st year	4295	34.8
2nd year	4124	33.4
3rd year	2766	22.4
4th year	1030	8.4
5th year	114	.9
Trainees' level: Level 1	3594	29.2
Level 2	3413	27.7
Level 3	2765	22.4
Level 4	2394	19.4
Level 5	163	1.3
Ownership: Government	10111	82.0
Private	2218	18.0
Nature of the institution: Polytechnic	6040	49.0
College	5771	46.8
Institute	67	.5
University College	426	3.5
Other	25	.2

In the study, it was found that the majority (51.5%) of the trainees who participated in the study were females. This implies that the participation of females in TVET is unexpectedly increasing. This is contrary the participation of females in TVET in other countries. For example, a study conducted in Kenya in 2015 showed that women lag behind with regard to enrolment in TVET. According to this study, in 2012, 60.5% of total enrolments in TVET were male while 39.5% were female; in 2013, 59.49% were male while 40.51% were female and in 2014, 60.59% were male and 39.41% were female (Ngugi & Muthima, 2015). The high enrolment of females in TVET in Ethiopia could be attributed to the fact that relatively few females join universities and the percentage of females left to compete for TVET is large. The other possible explanation could be the fact that some occupations which are associated with females, such as garment and ICT, are available in almost all colleges. The study also revealed that the majority (61.4%) of the trainees who participated in the study are below 20 years old, which shows that trainees join TVET at a younger age. This implies that relatively younger students are joining the TVET sector. This could be attributed to the fact that the majority of the trainees who are joining TVET are the students who complete grade 10 at early age. With regard to level, it was found that the majority (56.9%) of the trainees who participated in the study are level 1 and level 2 trainees, and only a few of them (1.3%) are level 5 trainees. This means that most of the TVET trainees are level one trainees and only a few of them continue their training up to level 5.

Table 2: Frequency distribution of the biographical data of the trainers

Variable		F	%
Gender:	Male	802	80.4
	Female	195	19.6
Age:	Below 20 years	20	2.0
	20-30 years	743	74.3
	31-40 years	172	17.2
	Above 40 years	62	6.2
Year of training experience:	<=5 years	544	54.4
	6-10 years	320	32.0
	11-15 years	57	0.57
	16-20 years	24	0.24
	>=21 years	52	0.52
Trainers' level:	C- Level	475	47.5
	B-Level	416	41.6
	A-Level	91	0.91
	Other	15	0.15
Ownership of the institution:	Government	901	90.1
	Private	96	0.96
Nature of the institution:	Polytechnic	459	46.0
	College	504	50.6
	Institute	21	2.1
	University college	11	1.1
	Other	2	0.2

This could be attributed to the fact that the majority of the trainees have access to level 1 training and only few of them have access to level 5 training. Table 2 above illustrates the trainer respondents' biographical information. The study also revealed that the majority (80.4%) of the trainers who participated in the study are males. This means that only few females have the opportunity to get hired as TVET trainers.

This disparity could be attributed to the fact that females may not have the interest to serve as trainers which, in turn, may be due to absence of female role models as TVET trainers, or the TVET institutions may not be friendly to females to serve as trainers, or the recruitment criteria may not be permissive to females. The study revealed that the majority (74.3%) of the trainers who participated in the study are between the ages 20-30 years, only 2% of them are below 20 years, and only 6.2% of the trainers are above 40 years old. This shows that the TVET training staff is populated with early adult group. It was found in the study that the majority (54.56%) of the trainers who participated in the study have training experience of 5 or below that whereas 32.1% of them have 6-10 years of experience. Overall, 86.7% of the trainers have teaching experience of 0-10 years of experience. Those who have above 10 years of experience in the sector are only 13.3%. This shows that the TVET institutions have shortage of highly experienced trainers which could be attributed to the fact that the expansion of the TVET sector is a recent phenomenon. Another possible explanation to this could be that the TVET system might have failed to retain experienced trainers.

4.2 Results of the quantitative strand

1) What context-related factors affect the quality of TVET delivery?

The context related factors that have been identified as affecting the quality of TVET delivery were attitude, economic, and policy and strategy related factors.

a) Trainees' response for the attitude, economic, and policy and strategy related issues

Sample trainees all over the country gave their responses to items of the context related factors affecting the quality of TVET delivery. Their response is displayed in Table-3 below. To determine the trainees' levels of agreement and disagreement on issues of context related factors, their scores on the five sub-scales were grouped into three sub-scales as 'agree, undecided, and disagree' for simplicity.

Table-3: Trainees' response on context-related factors

	Statements	Agree (%)	Undecided f (%)	Disagree f (%)
1	Societal attitude towards the TVET sectors positively influences individuals to be drawn to the TVET system	5818 **(47.2%)**	2811(22.8%)	3700 **(30%)**
2	The society has enough awareness of the decisive importance of TVET sector for the economic and social development.	6006 **(48.7%)**	2377 (19.30)	3946 **(32%)**
3	The society understand what TVET is, including how it is different and similar to other learning options	5792 **(47%)**	2706 (22)	3831 **(31.1%)**
	Average of attitude related items	5872 (47.63%)	2631 21.36%)	3826 (31.03%)
4	The local context enables TVET graduates to join the world of work easily.	5548 **(45%)**	2685 (21.8)	4096 **(33.2)**
5	The TVET trainings given are related to the demand of the local labour market	7243 **(48.7%)**	2465 (20.)	2621 **(21.3%)**
6	The trainings provided in the TVET institutions are in line with the real condition of the country.	7887 **(64%)**	2310 (18.7)	2132 **(17.3%)**
	Average of economic issue items	6893 (52.56)	2486 (20.16)	2950(23.93)
7	The assessment strategy (competent or not yet competent) motivates TVET trainees to work hard.	7614 **(61.8%)**	1669 (13.5)	3046 **(24.7%)**
8	The COC certification policy encourages trainees' hard working habits during training.	8328 **(67.5)**	1534 (12.4)	2467 **(20%)**
9	The TVET education policy attracts high calibre individuals/trainees to the TVET system.	6623 **(53.7)**	2367 (19.2)	3339 **(27.1)**
10	The TVET policy and strategy enables to produce competent graduates and professionals.	8752 **(71)**	1624 (13.2)	1953 **(15.8)**

As shown in Table-3 above, a significant number of trainees showed their disagreement that the context-related variables (attitude, economic, and policy and strategy related aspects) contribute to quality of TVET delivery. As can be seen from table 3, more than 50% of the respondents either remained undecided or disagreed on the positive contribution of societal attitude, economic condition, and the policies and strategies to the quality of TVET delivery.

b) Trainers' response for the attitude, economic, and policy and strategy related aspects

According to Table 4, for the same context related factors mentioned above, the sampled trainers' response for these context factors are displayed in Table 4 below. Respondents' agreement or disagreement of the items for the context related factors are indicated in this table.

Table 4: Trainers' response on context-related issues

	Statements	N	AG(%)	UD (%)	DA (%)
1	The TVET assessment strategy motivates TVET trainees to work hard.	997	53.46	11.03	35.50
2	The COC certification policy encourages trainees' hard working habits during training.	997	54.06	13.34	32.59
3	Societal attitude towards the TVET sectors positively influences individuals to be drawn to the TVET system.	997	39.61	15.24	45.13
4	There is clear view that TVET supports the strengths, aspirations and goals of trainees.	997	31.99	14.14	53.86
5	The TVET system attracts qualified and competent teachers/trainers	997	40.42	14.84	44.73
6	Teacher/trainer attrition in this institution is high.	997	33.09	19.75	47.14
7	There are clearly stated selection criteria to attract individuals into the teaching profession in the TVET system	997	23.97	17.75	58.27
8	Strategies are in place to engage with employers to support TVET.	997	42.12	21.46	36.40
9	The TVET education policy attracts high calibre individuals/trainees to the TVET system.	997	48.74	15.14	36.10
10	Strategies are in place to attract and retain the best qualified individuals in TVET teaching/training	997	52.25	19.15	28.58
	Average		45.77	16.18	38.03

As can be observed from Table 4 above, significant number of trainers (more than 50% of them) showed their reservation or disagreement in accepting that context-related variables (societal attitude, the economic situation, and policy and strategy related aspects) contribute to quality of TVET delivery.

2) What are the input-related factors that affect the quality of TVET delivery?
The input related factors, with regard to the TVET trainees, which have been identified as affecting the quality delivery of the TVET training systems are: Curricular related issues; Factors related to teachers'/trainers; Facilities;

Leadership issues; The competency assessment; Safety and conduciveness of learning environment; and Trainees entry behaviour. Analysis of each of the seven factors is given as follows.

The trainees' response to input-related factors

Table 6 shows percentages for agreement, undecided, and disagreement.

Table 6: The trainees' response on input-related factors

	Factors	AG (%)	UD(%)	DA(%)
1	The curricula approved for use at the institutions contributed positively to the quality of TVET delivery	6665 (54)	2918 (23.7)	2746 (22.3)
2	Teachers'/trainers' competence allows them to contribute to the quality of TVET delivery	9451 **(76.7)**	4519 (36.7)	4523 (36.7)
3	The facilities in institutions allow them to deliver quality training	**4949 (40.6)**	2520 (20.9)	**4862 (39.6)**
4	The leadership contributes to quality TVET delivery	5670 (46)	2950 (24)	3710 (30)
5	The competency assessment contributes to producing competent TVET graduates to the labour market	6583 (53.39)	3199 (25.94)	2546 (20.65)
6	Institutions are safe and conducive to deliver quality TVET training	5242.8 (42.52)	2644 (21.45)	4442.2 (36.03)
7	Competent and motivated trainees are attracted to the TVET system	6588 (53.4)	2517 (20.4)	3223 (26.1)

Table 6 shows that a significant number of the trainee respondents (close to 50%) show their reservation or disagreement on the positive contribution of input variables (Curriculum, trainers, facilities, institutional environment, leadership, the competency assessment, and trainees' entry behaviour) to quality of education. The input related factors associated with that of trainers affecting the quality delivery of TVET systems has been expressed in the following table (Table 7). Table 7 depicts trainers' agreement or disagreement to the 10 factors of the input related issues of the TVET systems.

Table 7: Trainers' agreement/disagreement of the input-related factors

No	Factors	AG f (%)	UD f (%)	DA f (%)
1	The curricula approved for use at the institutions contributed positively to quality of TVET delivery	437 (43.81)	165 (16.59)	395 (39.59)
2	Teachers'/trainers' competence allows them to contribute to quality of TVET delivery	263 (26.37)	216 (21.66)	518 (51.95)
3	There is sufficient support provided to trainees	369(37.01)	161(16.14)	467(46.84)
4	The facilities in institutions allow them to deliver quality training	562 (56.31)	151 (15.17)	284 (28.51)
5	The leadership contribute to quality TVET delivery	345 (34.60)	226 (22.66)	426 (42.72)
6	The competency assessment contributes to produce competent TVET graduates to the labour market	356 (35.70)	179 (17.95)	462 (46.33)
7	Institutions are safe and conducive to deliver quality TVET training	491 (49.28)	161 (16.18)	344 (34.53)
8	Competent and motivated trainees are attracted to the TVET system	569 (57.10)	186 (18.63)	242 (24.25)
9	There is shortage of staff	313(31.42)	149(14.94)	535(53.62)
10	Budget allocated to TVET is	398(39.91)	297(29.83)	302(30.24)

It can be seen from Table 7 that a significant number of the trainer respondents (more than 50%) showed their reservation or disagreement on the positive contribution of the curricula, the trainers' competency, the institutional safety and conduciveness, the facilities in the institutions, the entry behaviour of the trainees, support provided to the trainees, the leadership, and the competency assessment contribute to quality of TVE delivery. A significant number of the respondents also showed that there is shortage of trainers and budget in the TVET that affected the quality of the training delivery.

3) What process-related factors affect the competence of TVET delivery?

The process related factors (considering the trainee respondents) are: Teaching-learning related issues; Monitoring and evaluation issues; Counselling related issues; English and Mathematics; Issues related to trainees support; and Utilization of resource. Analysis of each of the six factors is presented as follows.

Trainees' response for the process related factors

Table 8 shows the trainees' agreement ratings in percentage on the six 'process' related factors".

Table 8: Trainees' response on process related factors

	Factors	AG f (%)	UD (f %)	DA f (%)
1	The teaching-learning process contributes to quality of TVET delivery	6123 **(49.7)**	2965 (24.1)	3239 (26.3)
2	Monitoring and evaluation system is contributing to quality TVET delivery	5875 **(47.7)**	3379 (27.4)	3074 (24.9)
3	Trainees receive counselling service that contributes to quality of TVET delivery	5804 **(47.1)**	2917 (23.7)	3607 (29.3)
4	English and Mathematics are well integrated in the TVET curricula to contribute to quality of TVET delivery	5515 **(44.7)**	2661 (21.6)	4152 (33.7)
5	There is sufficient trainees support	4857 (39.4)	3028 (24.6)	4443 (36.0)
6	There is proper utilization of resource to deliver quality TVET	5156 (41.8)	2935 (23.8)	4236 (34.4)

Table 8 shows that more than 50% of the trainees either remain neutral or disagree that the process-related factors indicated in table 7 contributed to quality of TVET delivery.

Trainers' response for the process related factors

The process related factors (considering the trainee respondents) are: Teaching-learning related issues; Monitoring and evaluation issues; Assessment issues (Institutional and COC); Issues of supporting Trainers; and Counselling related issues

Table 9: The trainers' response on process-related factors

	Factors	DA f (%)	UD f (%)	AG f (%)
1	The teaching-learning process is contributing to quality of TVET delivery	222 (22.24)	140 (14.11)	635 (63.64)
2	The monitoring and evaluation system is contributing to quality of TVET delivery	282 (28.22)	182 (18.33)	533 (53.44)
3	The competency assessment contributes to producing competent TVET graduates to the market	285 (28.58)	172 (17.25)	540 (54.16)
4	There is proper support to trainers to contribute to quality of TVET delivery	529 (53.02)	157 (15.78)	311 (31.19)
5	There is appropriate counselling service	380 (38.04)	194 (19.45)	424 (42.49)
6	English and Mathematics are well integrated in the curriculum to contribute to quality of TVET	685 (68.70)	136 (13.64)	176 (17.65)
7	There is sufficient student support	460(46.11)	182(18.25)	355(35.63)
8	There is proper linkage with industries to enhance cooperative training	367(36.76)	251(25.26)	379(37.97)
9	There is proper utilization of resource	379(38.03)	133(13.34)	485(48.62)

Moreover, issues related to English and Mathematics; trainees' support; Linkage issues, and Utilization of resource. Trainers' responses related to these factors are presented in Table- 9 above. As can be observed from this Table, a significant number of the trainer respondents (more than 50% of them) either remained neutral or showed that the process-related factors indicated are not properly implemented to contribute to quality of TVET delivery (except for the teaching-learning process, which they agreed that it positively contributed to quality of TVET delivery).

4) What product-related factors affect the competence of TVET delivery?

The product related factors (considering the trainee respondents) affecting the quality delivery of the TVET systems are: Graduate related issues and Trainees' satisfaction issues. Analysis of each of the two factors is presented as follows.

The trainees' response on product related factors

The sampled trainees reflected their agreement or disagreement on the major product related factors as can be seen in Table 10 below. Accordingly, a significant number of the trainee respondents perceive that the graduates have not received the required competency to fit to the world of work. A significant number of them also perceive that the status of the TVET graduates after graduation is not positively contributing to quality of TVET delivery. In fact, the majority perceived that they received training in the area of their choices; they also perceived that the majority felt that the training helped them to develop technical skills and, contrary to the qualitative data, 60.4% of the trainee respondents perceived that they have developed positive work culture. As shall be seen in the qualitative analysis part, employers mentioned that TVET graduates from government institutions lack work culture.

Table 10: The trainees' response on product-related factors

	Statements	AG f (%)	UD f (%)	DA f (%)
1	The graduates from the TVET institution work in the occupations/ qualifications they have learned.	4485 (36.4)	3763 (30.5)	4081 (33.1)
2	The graduates from the TVET institution pass COC exam with one seat.	6048 **(49.1)**	3525 (28.6)	2756 (22.4)
3	Employers are satisfied with the TVET graduates	5179 (42)	4765 (38.6)	2385 (19.3)
4	The TVET graduates are getting employed in different companies or creating their own jobs.	4842 (39.3)	4424 (35.9)	3063 (24.8)
5	TVET graduates are contributing to economic development of the country	5420 (43.9)	4183 (33.9)	2726 (22.1)
6	In this institute, I take training with my first choice.	7930 **(64.3)**	1925 (15.6)	2474 (20.0)
7	Trainees are satisfied with the quality of training they receive in the TVET institutions.	5969 (48.4)	2749 (22.3)	3611 (29.3)
8	Trainees are capable of copying and transferring technologies.	5391 (43.7)	3130 (25.4)	3808 (30.9)
9	The TVET training enabled me to identify the different areas of work occupations.	7140 **(57.9)**	2493 (20.2)	2696 (21.8)
10	This institute helped me to develop technical skills.	7541 **(61.2)**	2374 (19.3)	2414 (19.6)
11	This institute helped me to develop good work culture.	7445 **(60.4)**	2493 (20.2)	2373 (19.4)

The trainers' response on product related factors

The product related factors (considering the trainer respondents) affecting the quality delivery of the TVET system is that of graduate related issues. The sampled trainers reflected their agreement or disagreement on the major product related factor as can be seen in Table-11. Consequently, this Table shows that significant number of the trainer respondents (more than 50% of them) perceive that the status of the TVET graduates after graduation is not positively contributing to quality of TVET delivery. However, the majority of the trainer respondents (more than 60% of them) perceived that the TVET graduates are contributing to economic development of the country.

Table 11: The trainers' response on product-related factors

	Statements	DA f (%)	UD f(%)	AG f (%)
1	The graduates from the TVET institution work in the occupations/ qualifications they have learned.	309 (30.99)	253 (25.37)	435 (43.63)
2	The graduates from the TVET institution pass COC exam with one seat.	374 (37.51)	279 (27.98)	344 (34.50)
3	Employers are satisfied with the TVET graduates	259 (25.97)	389 (39.02)	349 (35.00)
4	The TVET graduates are getting employed in different companies or creating their own jobs.	201 (20.16)	264 (26.47)	532 (53.36)
5	Trainees are capable of copying and transferring technologies.	523 (52.45)	241 (24.17)	233 (23.37)
6	TVET graduates are contributing to economic development of the country	179 (17.95)	217 (21.76)	601 (60.28)

4) The relationship between Quality Delivery and the CIP Variables

Dependent: Graduates Quality (Result from multiple regression)

As it is well known, multiple regression will help us the most predictor variables to the quality of TVET delivery, which is explained in terms of graduate quality (employability) and trainees' level of satisfaction. The following table shows the strength of the different variables in predicting the quality of TVET delivery.

Accordingly, the factor loading displayed in Table-12 below shows that the way resource is utilized in institutions is the strongest predictor variable to graduates' quality, followed by the teaching-learning process. This implies that emphasis has to be given to the way resources are utilized and the teaching-learning processes are carried out to enhance graduates' quality. The following table depicts the order of the influence of the variables on quality of TVET delivery as measured with respect to graduates' quality.

Table-12: Relationship between TVET delivery and CIP variables

Variables	Parameters		Standardized Parameters	$t_{Cal.}$	p-value
	B	SE	Beta		
(Constant)	.408	.039		10.600	.000
Cxt-Attitude	.036	.006	.041	5.704	.000
Cxt-Economic	.081	.007	.090	12.171	.000
Cxt-Policy	.022	.007	.024	2.963	.003
Input-Curricula	.070	.009	.068	7.693	.000
Input-Teachers	.039	.009	.039	4.488	.000
Input-Facility	.021	.007	.025	2.919	.004
Input Leadership	**.008**	**.009**	**.009**	**.887**	**.375**
Input-COC	.080	.007	.086	11.014	.000
Input-LearnEnvt	-.045	.008	-.050	-5.356	.000
Input-TraineeBehav	.070	.008	.073	9.358	.000
Process-TeachLearn	.112	.011	.106	10.349	.000
Process-MnE	.054	.009	.057	6.196	.000
Process-Counsel	.042	.008	.050	5.545	.000
Process-EngMath	.062	.007	.071	8.311	.000
Process-StudSupport	.032	.008	.038	3.997	.000
Process-ResourceUtil	.147	.007	.167	19.689	.000

In addition to a regression analysis of specific CIP variables, the same technique was carried out to analyse the variance accounted for the independent variables. Consequently, process-related factors, followed by input-related variables accounted for the largest variances for quality delivery as measured by graduate employability. But, context-related variables had the least prediction power. This implies that more has to be done on process variables to bring about quality TVET delivery followed by input factors. Table-13 below shows which of the three independent variables is the strongest predictor variable to quality of TVET delivery measured with respect to graduates' quality (employability).

Table-13: Summary of a regression analysis of CIP-related factors

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.618	.027		23.062	.000
	Context	.167	.009	.148	19.206	.000
	Input	.204	.014	.168	14.802	.000
	Process	.431	.012	.385	37.048	.000

4.3 Results of the Qualitative strand

5) What context-related factors affect the quality of TVET delivery?

i) The TVET policy and strategy

The results from the qualitative data revealed that the existing TVET policy and strategy needs revision in such a way that it gives direction to the system taking the national context into account. Participants of the study showed their concern by stating that the existing TVET policy and strategy was copied from other countries without considering the context of our country.

ii) Socio-economic factors

The qualitative data revealed that the country's socio-economic situation is one of the factors that affect the quality of TVET delivery. One of these factors was found to be societal image towards TVET. The qualitative data generally revealed that though there is improvement with regards to societal image, there is still a negative societal bias which is preventing high calibre students from enrolling on TVET. Still many parents and students associate TVET with low academic performance. Still TVET is regarded as "second choice" for the majority of students completing grade ten.

The other factor mentioned by participants of the study as having effect on quality of TVET delivery is the economic situation of the country. As was depicted on a conference paper presented at the 2017 TVET International Conference held at Addis Ababa, it is the Ethiopian government that is investing on hard trade trainings in the TVET sector; private TVET providers are investing on soft trade trainings. The policy objective of the country is to foster and support industry ownership of the system. However, the industries in the country are at infant stage and have insignificant contribution in sharing the government's financial burden in the delivery of TVET. The burden is on the government in investing on expensive machineries which are needed for quality of TVET delivery. Due to low economic condition of the country, the TVET sector, which requires large investment, is underfunded by the government which, in turn has affected the quality of TVET delivery.

iii) TVET structure and governance

One factor that was raised as one constraint to have negative effect on the quality of TVET delivery is the TVET structure. As it is indicated in the education policy, students in the formal education will have access to TVET if they drop out of the general education at some level or after completing grade 10. Those students who join the formal TVET with no prior exposure to TVET join the system with no know-how about their vocational preference.

As it is stipulated in the TVET strategy, the TVET system aims at progressive decentralization, i.e. the responsibility for all functions will be gradually devolved to lower levels in the system in order to increase efficiency of services and responsiveness to the needs of the actual target groups. In this decentralized TVET system, the main responsibility for implementation of the new TVET system rests with the state authorities; and to ensure the demand-orientation of the actual TVET delivery and its linkage with the local labor market, the TVET system delegates major responsibilities directly to the TVET institutions.

The TVET strategy also acknowledges the granting of more financial autonomy to the institutions and capacity utilization in TVET institutions through flexible recruitment rules. The strategy also informs that once granted financial autonomy in the course of decentralization, TVET institutions will be free to award salary supplements and bonuses to well-performing staff in line with transparent criteria. However, in practice, it was found out that the TVET institutions are not exercising their autonomy due to the interference of authorities from above. Participants of the study revealed that though decentralization assumes autonomy of managing own resources, it is the regional bureau that assigns budget to the institutions.

The National TVET strategy clearly implies that programmes of TVET institutions shall be drawn up based on local skilled human resource needs.

6) What are the input-related factors that affect the quality of TVET delivery?

i) The Occupational Standard

One of the factors that was identified as an input factor that affects the quality of training is the Occupational standard (OS). As stipulated in the TVET policy document, the OS is supposed to be developed by the local industry. This is for the simple reason that if the industry identifies the occupations and the competencies which are required to carry out the activities in the occupations in the form of OS, then the training providers deliver the training in accordance with the OS and the assessment for judging the competency level of the trainees will also be conducted based on the OS which, in turn would help to provide a competent TVET graduate that meets the requirement of the industry. However, it was reported by almost all the participants of this study that the OS was copied from other countries.

Other participants of the study also argued that there are machineries included in the OS which are not available in any of the local industries. It was also revealed from the qualitative data that some units of competencies which have to be included in the OS are missing and some units of competencies (UCs) which are not important are also included in the OS. It was also reported by the study participants that the OS is not revised on time. Even after revision, trainers are required to deliver their training based on the revised OS without getting them acquainted with the new OS.

ii) The TVET curriculum and TTLM

The other factor reported to have effect on the quality of training is the curriculum. According to the TVET strategy, the curriculum is supposed to be prepared by the trainers in the TVET institutions by taking their existing situation into account. An issue that has been repeatedly raised in relation to this is that the trainers, especially in the institutions where there are not A or B level trainers, are not capable of translating the OS in to a curriculum. With regards to the curriculum, the exclusion of some courses like English, Maths, Entrepreneurship, Civic and Ethical Education, and ICT has resulted in devastating effect. It was learned from the data that as the trainees do not come with good English and maths background from the general education, they need to take these courses in the TVET institutions. Employers noted that TVET trainees need to be equipped with language skill so as to deal with customers who may speak only in English. The study participants also argued that mathematical knowledge and skill is important for TVET trainees to flexibly apply their mathematical knowledge in different situations.

The importance of ICT was also raised as trainees can't cope with the digital age unless they are competent in ICT. Civic and Ethical Education was also reported to be important as TVET graduates mainly from public TVET institutions lack work ethics. Entrepreneurship was also said to be important as it helps trainees for self-employment. It was also argued by the interviewees and FGD participants that trainers of major subjects cannot properly teach the aforementioned courses with short-term trainings and hence specialists of the subjects themselves have to teach the courses.

Similarly, it was reported that the Training-Teaching-Learning Materials (TTLM) are supposed to be prepared by the trainers themselves based on the curriculum. One of the issues raised in relation to this is that trainers use internet as their major source for developing content. Lack of access to internet, lack of additional reference materials, and the relevance and quality of information accessed from internet are the major challenges in preparing quality TTLM.

iii) The Trainers

The other input variable that was identified by the qualitative data as a barrier to quality of TVET delivery is related with trainers. One factor is trainers' competence. It was generally revealed from the qualitative data that C-level trainers do not fit to be trainers. The data revealed that they are competent in skill but they lack theoretical knowledge and language skill as well as pedagogical skill and knowledge. A and B level trainers who are directly recruited after graduation from universities were also accused of having difficulties in skill, but they were thought to develop the skills easily with simple training. The other issue raised together with trainers' competence was that the majority of TVET trainers lack industry experience.

The other issue raised in relation to trainers is their preparation. The study participants argued that there should be a TVET teacher training institution like the Federal TVET Institute but the training should balance both the technical and the pedagogical aspects. The other important issue raised in relation to trainers is that TVET trainers are unnecessarily overloaded with lots of work like curriculum and TTLM preparation, delivery of the courses, supervising trainees during cooperative training, supporting SMEs through the four packages, and copying and transferring technology to SMEs. The study participants particularly resented the responsibility of trainers to support SMEs for two reasons: one is that it makes trainers too busy to get prepared and deliver training effectively. The second reason is that SMEs themselves do not usually show interest to get the supports that are predefined by the trainers.

iv) Trainees' prior knowledge and readiness

The other input variable that is thought to have affected the quality of TVET delivery is trainees' prior knowledge and readiness. According to the study participants, as the majority of the trainees get first exposure to technical and vocational education and training after they finish grade 10, they find it difficult to cope with the new training and education system that they are encountering for the first time. It was also reported by the study participants that some trainees also lack motivation mainly because of the wrong societal image towards TVET. It was stressed by the study participants that demotivated trainees are not expected to perform well in the training.

The other input variables that were reported to have influence on quality of TVET delivery is resources and facilities. It was reported by the study participants that as the sector is resource intensive, most of the TVET institutions have shortage of the required facilities and resources.

Study participants also argued that the shortage of resources is aggravated because of uneven distribution of the resources.

v) The leaders

The other input variable identified by the study participants is the quality of leaders. The interviewees and the FGD participants revealed that some of the TVET leaders do not know the TVET system at all and are simply political assignees who lack the competency to be leaders.

vi) Assessment tools and the assessors

The other input variables that were identified to have effect on quality of training are assessment tools and the assessors. The study participants revealed that similar assessment packages appear year after year which paved a way for trainees and the trainers to focus only on those competencies which appear in the assessment exams.

According to the study participants, the assessment tools contain only few units of competencies which may make the assessment tool invalid as it doesn’t cover all the competencies required to perform a certain task. The study participants also witnessed that some of the competencies in the assessment tools are not there in the OS. It was also reported by the participants that the assessors from the industry are not well trained.

7) What process-related factors affect the competence of TVET delivery?

The qualitative data revealed that process related variables such as the implementation of project based cooperative trainings, the monitoring and evaluation system, the communication system, the capacity building activities and the labour market study affect the quality of TVET delivery.

i) Project based training

One of the process factors that affect the quality of TVET delivery as reported by the research participants is the implementation of project-based training. The study participants stated that the training is focusing on the assessment package which does not cover all the identified units of competencies in the OS. It was also reported by the participants that project based training is hampered by the lack of the necessary tools and machineries. Lack of competency to use machineries was also reported as one problem in implementing project-based training.

ii) Cooperative training

One major challenge that is reported to have affected the quality of TVET delivery in Ethiopia is the weak linkage between the industry and the TVET institutions in conducting cooperative training. It was revealed by the interviewees and FGD participants that cooperative training is not properly implemented in almost all areas though the problem is saviour in relatively remote institutions where there are no sufficient industries or even SMEs. It is indicated in the TVET strategy that about 70% of the TVET training is given in the industries and the remaining 30% is given in the TVET institutions. However, most of the study participants suggested to reverse it so that 70% of the training is given in the TVET institutions and the remaining 30% is carried out in the industries.

Even in those areas where cooperative training is relatively implemented well, taking trainees to the industries at the end of each unit of competency has been reported to be impractical. The study participants said that they take their trainees to the industry after covering certain number of units of competencies. This was related with transportation problem and the problem of adjusting the schedules with the industry trainers. The other problem raised in relation with cooperative training is that there are no qualified industry trainers in most of the companies that participate in cooperative training.

The common issue that was mentioned by the research participants in relation to cooperative training is that the industries do not show interest to participate in the training with the fear that the trainees may destroy machines, may hurt themselves, may waste resources during the training, may share production time, or lack prerequisite skill that they need to have to operate the machines. One other problem raised is lack of motivation of the trainees to go to the industries where the industries are not competent to deliver the trainings. One more issue that is raised in relation to cooperative training is trainers' reluctance in supervising their students during cooperative training. Some employers reported that the trainers drop their trainees to the company and then disappear.

iii) Monitoring and Evaluation

The other process related factor that was reported to have influence on quality of TVET delivery is the monitoring and evaluation system. Participants of the study reported that there is no continuous monitoring and evaluation system in the TVET sector. Those at the regional TVET bureau go to the TVET institutions or the local offices vary rarely.

iv) Communication and data management system

The other issue that is considered by the participants of the study as one factor in affecting quality of training is the communication system. It is believed that free flow of information from top to down and from bottom to up will help to make immediate intervention when needed. It also helps decision makers to make informed decision. The study group noticed that there is no proper communication among different sectors in the system. The participants of the study also revealed that there is poor data management system which has contributed to poor communication among different parties in the TVET sector.

The other process factor that is reported to have effect on the quality of TVET delivery is the capacity building activities in the TVET system. Trainers were reported to have lack of competence in some areas; TVET leaders at different levels have been reported to make decisions without consulting others. Even though it is believed that trainings should be provided to the trainers and the TVET leaders, the trainings given so far are not sufficient to bring about the required change.

v) Labor market study (Research undertakings in the area)

The other important process-related variable that has affected the quality of the TVET delivery was found to be the labor market study. As is stipulated in the TVET strategy, TVET institutions are supposed to deliver demand-driven high quality technical and vocational trainings which is based on labor market study. However, participants of this study revealed that there are inconsistencies in the findings of the labor market study conducted in similar areas, which are reported to have emanated from a lack of competency in conducting the study. The other problem related with labor market study as reported by the research participants is that the results of the study are not taken seriously by the concerned bodies.

8) What product-related factors affect the competence of TVET delivery?

Participants of this study revealed that some of the TVET graduates still remained unemployed or joined a different occupation. This was reported to have negative implications to those who want to join the TVET system.

5. Conclusions and Recommendations

5.1 Conclusions

It can be concluded from the study that the quality of TVET delivery is influenced by multi-faceted factors such as the economic and political contexts of the country, the societal image to the sub-sector, trainers' motivation and competency, entry behaviour of the trainees, the support provided for the training, availability of required resources, conduciveness of the institutional environment, the teaching-learning process, the practice of cooperative training, absence of monitoring and evaluation system, absence of reliable data for decision making, weak management of the national competency assessment, limited finance, unsuitable procurement system, poor working culture and work ethics, and lack of entrepreneurial skills. ?? Multi-faceted intervention with the involvement of different actors is therefore important to address the quality of TVET delivery in Ethiopia.

5.2 Recommendations

The following recommendations were forwarded based on the findings of the study:

The TVET policy has to be revised taking the national context into account; awareness creation about the benefits of the TVET sector to national as well as individual development has to be made, a responsive financial and procurement system has to be established; a new structural and governance system of the TVET sector has to be introduced; the education system in general has to be revised; Conducive institutional learning environment has to be created; a new approach to the preparation and capacity building of TVET trainers has to be considered; the assessment system has to be revised; a strong monitoring and evaluation system has to be established; a quality assurance system has to be in place; research centres have to be established at different levels in the TVET system. The dissemination activities will include submitting the first draft of the analyses and the executive summary to the leaders of the institute, discussion with the institute leaders on the findings of the study, organizing a validation workshop with different stakeholders, presenting the findings at international conferences, disseminating summary of the report to different stakeholders through booklets and publishing articles on different journals.

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Integrating Green Skills into VET Curricula

Biadgelign Ademe (PhD)[1]

Abstract

The main objective of this study was to identify green skills which need to be integrated into Vocational Education and Training (VET) curricula and to explain the understanding/ perceptions of A-Level Trainers/ lecturers about the same. I did this due to the fact that neither VET strategy and policy nor VET curricula/ modules give emphasis on the need for green skills. To this end, I administered a self-constructed valid questionnaire to 141 A-Level trainers from 5 of 6 PTCs in Addis Ababa. The result disclosed that 132 respondents understood 25 of 25 green skills (where mean scores range from 0.61 to 1.21 of 2.00 in the continuum of the 5-point rating scale). Moreover, these respondents better understood 6 of 25 green skills (where mean scores range from 1.00 to1.21 of 2.00). Based on this, I concluded that 132 A-Level trainers averagely understood 25 green skills (4=agree=1 point in the continuum of the 5-ponit rating scale) and averagely agreed (4=agree=1 point in the continuum of the 5-ponit rating scale) regarding the integration of these green skills into VET curricula.

Key Terms: Curriculum, Green Skill, Vocational Education and Training, Integration

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1. Introduction

The greening of the economy is a shared goal for advanced and less advanced economies alike, particularly where sustained and inclusive employment is an objective for policy-makers. However, the challenges of such greening, and the implications for employment and skills, vary across regions and countries. In the transition from high-to low-carbon production, labor market impacts are becoming more evident and changes will likely affect all workers. However, while these changes may be minor for the majority, they will be substantial for a small number of industries and professions. Preparation for the adjustments is essential to take full advantage of green growth opportunities (Publications Office of the European Union, 2015). Accordingly, when the future of mankind is at stake, the need for proactive and strategic integration, combining employment with climate and energy policies seems a relatively small but imperative task.

1.1. Background of the Study

Ethiopia, according to the Federal Democratic Republic of Ethiopia (2020), is among the countries that are most vulnerable to climate change in East Africa, and the phenomenon is expected to negatively impact progress in sectors such as agriculture, transportation, energy, and health. Ethiopia's pastoral and agro-pastoral communities, as well as smallholder farmers, are particularly vulnerable to climate change and will require a concerted focus on adaptation to reduce poverty and build resilience. In the 21st century, green technology is advancing rapidly and has gained attention from different governments as well as industrial sectors. In Ethiopia, for instance, green growth is outlined as one of the twelve chapters from its Ten-Years Development Plan (2021-2030); Moreover, according to this development plan, the idea of green skills, directly or indirectly, are raised in other chapters like in Chapters three and five. Countries around the world, according to ILO (2011), are now experiencing the consequences of environmental pollution and facing the challenges of environmental degradation as well as climate change. Environmental pollution, in return, resulted in weather changes, extreme droughts or monsoon season, sea-level rise, global warming and so on (Mousavi, et.al.2011). Accordingly, all countries, especially the underdeveloped ones, have to pay high costs due to environmental problems that eventually badly affected their economic and social activities (Sern, et.al. 2018). Moreover, Climate change, according to the Federal Democratic Republic of Ethiopia (2020), is a global development challenge that is causing widespread impacts on socioeconomic development through the increased intensity of weather extremes such as droughts, heatwaves, shifts in seasons, and intense storms. This crisis requires that countries adapt to its associated phenomena by integrating climate change responses into development planning activities, budgeting and should be taught in schools.

In order to mitigate environmental problems, green economy shall be taken as an alternative way that will be beneficial for nation development without inducing detrimental effects on the environment. This is because there is a shift of the conventional economy to a greener economy which, according to ILO (2011), will trigger the creation of new green technologies; increase investment in the green industry; generate more new green jobs; and hence, green jobs require workers with green skills.

Moreover, as human beings are primarily responsible for creating and intensifying climate change, according to Andreotti (2011) in Mochizuki and Bryan (2015), their capacity to derive their own solutions to the problem should be encouraged and promoted through climate change education. As such, these writers noted that climate change education for sustainable development should support learners to develop and enhance a range of analytical skills that will enable them to consider the multiple causes and dimensions of climate change, and determine possible courses of action and consequences of potential solutions to this complex problem.

Similarly, the need for sustainable system transformation and the associated green skills, according to the Publications Office of the European Union (2015), pushes classical technical and vocational education and training (TVET) to its limits. Specific technical skills can be provided easily within classical TVET structures, when a set of skills is already established and reproducible and scalable. Accordingly, key learning capabilities associated with climate change education for sustainability development, according to Mochizuki and Bryan (2015), include the following: critical thinking, systems thinking and problem solving skills (reasoning, recognizing and questioning patterns); dealing with rapid change and uncertainties; analyzing, synthesizing and evaluating information; planning and management skills; life-long learning skills (learning how to learn, to adapt knowledge to new contexts, and to engage in self-directed learning); and information, media and technology skills

Within the context of the 21st century, the green economy is seen as an economic model that serves as a potential driver for national development. Green economy does not only generate economy growth, but it also puts the focus on sustainable development which, in turn, will improve the quality of life of the people in the aspects of economy, social, and environment (OECD, 2018). Nevertheless, the benefits of green economy will not be visible without supports from the green industry. In this regard, the Federal Democratic Republic of Ethiopia (2020) outlined series of activities for the greening of the environment as follows: Implement and improve basic public health measures such as the provision of clean water and sanitation, Providing training on improved and climate-proofed latrine technology options, Demonstrating improved and climate proofed latrine technology options, Producing and distributing booklet on household water treatment and safe storage, Self-sufficiency in water and energy supply, Prevent and manage waterborne and communicable diseases, Create awareness on water, sanitation, and hygiene, Development of water infrastructure (boreholes, water facilities, etc.), Creating business models for investments in the water sector adaptation,, community awareness raising and mobilization on access to water, Promote watershed management/ community-based water resource management, Capacity building on sustainable water management, Promoting research on climate change adaptation in the water sector, Mobilization of finance and other resources for local implementation of water resource management initiatives, and providing technical support for sustainable water management.

In general, the green industry means the industry that is friendly to the environment. For instance, the waste and recycling industry is considered green industry because the nature of the industry is friendly to the environment. Likewise, the construction industry can also be regarded as a green industry if the industry introduces and implements environment-friendly policies in its operations (Heong, et.al. 2016). The green industry will create green jobs, whereas the conventional work can be 'greened' by integrating green elements into it (Sern, et.al. 2018). For example, the interior designer is considered a green work if the design integrates an environmental friendly concept, such as designing a building that has natural ventilation systems or optimizing the use of natural lighting. Specifically, green jobs are any work either in agriculture, manufacturing, research and development, administration and service activities that contribute to the preservation and conservation of environmental quality (UNEP, 2008). Green jobs require workers with green skills. In a broad sense, green skills are defined as the skills for sustainability in which the skills can include technical skills, knowledge, values and attitudes needed by a worker to develop and sustain the social, economic and environmental aspects (McDonald, et.al. 2012).

1.2. Statement of the Problem

When the idea of green skillis considered in the Ethiopian context, Vocational Education and Training (VET) graduates do not seem have the green skills required by the green industry. One of the reasons for such problems could be lack/less emphasized elements of green skills in the VET strategy and curricula. For instance, 0 of 12 objectives and 1 of 9 guiding principles of VET strategy have indicators for green skills (Ministry of Education, 2008); and according to Federal TVET Agency (2020), 1 of 9 TVET Relevance and Quality components of Core Policy Issues is about green skills. Moreover, the Outcome Based Curricula revealed that, for instance, on 'Power Transmission, Distribution, Inspection and Maintenance' for Level-II, 1 of 25 modules; on 'Building Electrical Installation' for Level-III, 0 of 15 modules; and for 'On-Site Building Electrical Installation' for Level-IV, 0 of 15 modules integrated green skills (General Wingate, 2021). With this in one hand, on the other; the Federal Democratic Republic of Ethiopia (2020) sensed the impact of climate change as follows.

> *Ethiopia emits a very small proportion of global greenhouse gases and yet is highly vulnerable to the impacts of climate change, which have grave implications for the achievement of its development goals. It has been estimated that climate change could reduce the country's GDP by up to 10% by 2045 compared with a 2011 baseline scenario. Climate variability and changes such as the increased intensity of severe weather events (particularly droughts), prolonged intra-sessional dry spells, and flash flooding stemming from rising temperatures and*

increasing rainfall variability, have impeded the country's efforts to realize its vision of inclusion and prosperity. Climate change, poverty reduction, and economic development are inextricably linked; consequently, climate change adaptation must be mainstreamed in development planning, projects, and programs.

In order to respond to the growing threat of climate change, the Federal Democratic Republic of Ethiopia (2020) crafted the Climate-Resilient Green Economy Strategy in 2011 and mainstreamed it into the second Growth and Transformation Plan (GTPII). This strategy consists of climate resilience and Green Economy components, with adaptation and mitigation programs prioritized within the strategy. The Climate Resilience component, focused on climate change adaptation, outlines the strategy for achieving economic development sustainably, highlighting both the country's prospects for growth and its vulnerability to climate risks and changes that require a coordinated and sustained effort by all parts of the Ethiopian society-the government, civil society, academia, and-most importantly-the public (Federal Democratic Republic of Ethiopia, 2020).

Accordingly, among its short-term priorities (2020-2022), according to the Federal Democratic Republic of Ethiopia (2020), capacity-development trainings; strengthening of monitoring and evaluation system; conducting study and/or research programs in collaboration with relevant universities and research institutions so as to measure the effectiveness of past, present, and future adaptation interventions and to inform the business plans and financial models developed in the agriculture and water sectors; and publishing and disseminating the experience generated from the study and research program are noted. In general, those green skills related to problem-solving skills related to environmental pollution; interpretative skills on environmental phenomena; research skills on environmental issues; data collection skills; analytical skills; exploitation skills on green technology; management skills on natural resources; design skills; controlling skills on environment pollution; raw material management skill; energy-saving skill; recycling skill; and reuse skill are needed. The curricula that contain the element of green skills will be able to produce those who are able to meet the industrial needs and contribute to economic, social and environmental sustainability. Therefore, based on the aforementioned arguments, this study aims to answer the following research questions.

1. What is the understanding/perception of A-Level trainers on green skills in Polytechnic Colleges (PTCs)?
2. What types of green skills should be integrated into TVET Curricula?

1.3. Objectives of the study

The ultimate purpose of this study is to explain the understanding of A-Level TVET trainers in PTCs in Addis Ababa. Moreover, the study aims to list down the types of green skills which should be incorporated into VET curricula offered in PTCs in Addis Ababa.

1.4. Significance of the Study

The study is important to influence policy and practice; for instance, it helps curriculum experts and trainers to enhance their understanding on green skills; to integrate green skill components into the curriculum, and hence, to assist students to acquire knowledge, skill, and proper attitude towards the greening of the environment and work in green industries. The study will also help those concerned decision makers on the need to integrate green skills to the education system of Ethiopia in the fight against drought, variability of rainfall, flashing flood, and so forth.

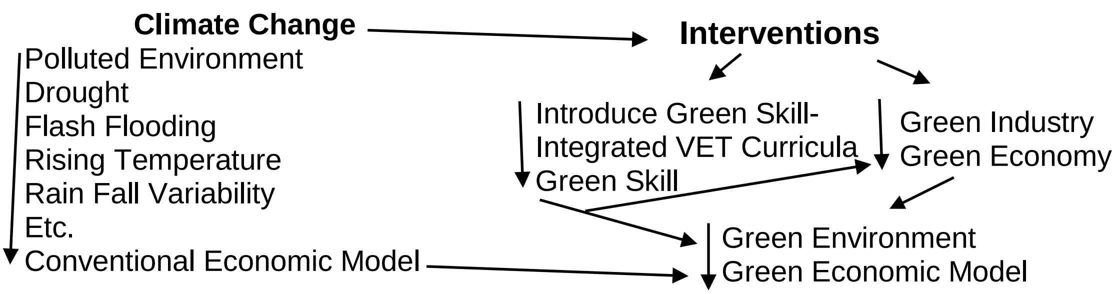
The result of the study could also become an important impetus to Ministry of Agriculture of Ethiopia to further enhance the capacity building and institutional coordination through training and use of networks to coordinate resilience responses between communities and delivery agencies. This is for the fact that institutions and governance structures staffed by adequate human resources at national and sub-national levels are key components for the effective implementation of its adaptation options. Moreover, the study will help as a base-line information provider to researchers to do research on green skills in more depth and breadth.

1.5. Scope of the Study

The magnitude of this study is delimited only in terms of the explanations of the understandings of A-Level trainers in PTCs on green skills in Addis Ababa. Moreover, the content is specified only in terms of the identification of green skills which need to be integrated into VET curricula in PTCS in Addis Ababa.

1.6. Conceptual Framework

Conceptual Framework is the researcher's research guide and ground useful where to locate green skills and their integration in TVET curricula. It is a visual/diagrammatic representation of an expected relationship between variables (in this case, curriculum and green skills). This framework was adapted based on the researcher's insights into the environment and his comprehension from readings of the paragraphs herein above. Hence, the conceptual framework was summarized as in the figure below.



1.7. Ethical Consideration

This is an issue where the researcher associated his confidentiality that respondents will feel at risk. Therefore, in the questionnaire, the researcher clearly explained and informed participants not to write their names and/or any other that may identify him/her. Moreover, the researcher did the data analysis only based on the nature of research questions and objectives. In short, the researcher tried to be ethical, trustful, careful, and demonstrated integrity/honesty, effort and rigor/strictness in the inquiry process.

2. Methodology of the Study

In this research, the researcher employed descriptive survey method with a quantitative design for the very reason that descriptive survey method provides brief explanation of phenomena which serves to put each one in proper perspective. This method of research concerns itself with the present phenomena in terms of conditions, practices, beliefs, processes, and relationships. Moreover, survey method gathers data from a relatively large number of cases at a particular time. However, it is not concerned with characteristic of individuals as individuals. The same logic holds true for this study. Hence, among six PTCs in Addis Ababa, the researcher took 5 of 6 though the plan was to take all the six PTCs just to raise the reliability and validity of the result. However, 1 PTC was involuntary and hence, it was excluded as a source of information. From these five PTCs; the researcher took all, 141, A-Level (trainers with M.Sc. degree) trainers/lecturers based on availability sampling technique. The researcher selected A-Level trainers for the fact that, according to Ministry of Education (2018), TVET trainers' level of education will be at least A-Level.

2.1. Data Collection Instrument

The researcher measured the perceptions/understandings of trainers/lecturers on green skills using a self-constructed questionnaire which comprised of 25 green skills. Because, from the researcher's own experience, questionnaire is economical; it has wide coverage; it is useful to present repetitive items for cross-checking purpose; it is an easier tool to use, even, for beginning researchers; it puts less pressure on the respondents since they are going to use it on their own time, pace, and with own confidentiality; and it discloses uniform inquiry items for all respondents. The researcher used a 5-point measurement scale questionnaire which consisted of 1 (strongly disagree = -2 points), 2 (disagree = -1 point), 3 (uncertain = 0 point), 4 (agree = +1point) and 5 (strongly agree = +2 points). The researcher determined the validity of the instrument through expert validity process where he selected three experts in curriculum Design and Development to assess the sufficiency of the questionnaire items. Then the researcher corrected and refined items of the questionnaire based on the comments and suggestions from the experts. Accordingly, at the start, there were 22 green skills but after the expert comments, the researcher raised green skills to 25 on top of the wording of the statements of these green skills. Besides, the questionnaire has obtained a sufficient level of reliability (α = 0.91) computed as in table 1 herein below.

Table 1: Reliability Statistics

Cronbach's Alpha	N of Items
.911	25

3. Results and Discussions

3.1 Results

The researcher administered a total of 141 questionnaires for lecturers, of which 6 questionnaires were unreturned and 3 were discarded due to incomplete responses. Hence, the researcher considered 132 (93.62%) A-Level trainers' responses as sources of information where 38 (28.79%) of them were female trainers and the remaining 94 (71.21%) were male ones. The researcher summarized this source of data as in Table 2 below just to present insights into the qualities/characteristics of respondents to readers.

Table 2: Biodata of Respondents

Department	Gender		Teaching Experience		Total
	F	M	10≤ yrs	>10 yrs	
Automotive Technology	4	10	3	11	14
Construction	10	21	8	23	31
Electrical-Electronics Technology	3	10	4	9	13
Garment Technology	6	9	8	7	15
ICT	3	5	2	6	8
Manufacturing Technology	4	20	11	13	24
Textile Technology	5	7	6	6	12
Others*	3	12	8	7	15
Total	38	94	50	82	**132**

*** *Included Hotel Management, Agro-Processing, and Business***

The researcher analysed the data using descriptive statistics so as to get mean scores and standard deviations for each of the green skills. In this regard, Statistical Package for Social Sciences, SPSS version 20 was used. Table-3 herein below shows the mean score and the standard deviation of the green skill items.

Table 3: Descriptive Statistics

The following green skills should be integrated into VET curricula	**N**	**Mean**	**SD**
Q1. Problem-solving skill related to environment pollution	132	0.79	1.08
Q2. Critical thinking skill	132	0.87	0.99
Q3. Interpretative skill on environmental phenomena	132	1.08	1.02
Q4. Research skill on environmental issues	132	0.75	1.14
Q5. Data collection skill	132	0.67	1.14

Q6. Analytical skills	132	0.98	0.94
Q7. Analyzing, synthesizing and evaluating information skill	132	0.81	1.13
Q8. Dealing with rapid change and uncertainties skill	132	0.71	1.17
Q9. Exploitation skill on green technology	132	0.61	1.16
Q10. Management skill on natural resources	132	0.92	1.02
Q11. Science skill	132	1.17	0.96
Q12. Design skill	132	0.78	1.14
Q13. Adapt knowledge to new contexts skill	132	0.82	1.05
Q14. Controlling skill on environment pollution	132	1.14	1.05
Q15. Raw material management skill	132	0.89	1.11
Q16. Information, media and technology skills.	132	0.81	1.17
Q17. Planning skill	132	1.05	0.92
Q18. Technological and technical skills	132	0.86	1.14
Q19. Learning how to learn skills	132	0.71	1.27
Q20. Engage in self-directed learning skill	132	0.73	1.20
Q21. Energy saving skill	132	0.94	1.02
Q22. Recycling skill	132	1.21	1.00
Q23. Operations management skill	132	1.04	0.92
Q24. Reasoning, recognizing and questioning skills	132	0.91	1.10
Q25. Reuse skill	132	0.76	1.24
Valid N (list-wise)	132		

Mean scores, according to Table 3 herein above, range from 0.67 to 1.21. This reveals that all items/green skills considered in the study gained positive understandings/perceptions from PTCs lecturers. In specific terms, the green skill on 'Recycling skill' received the highest mean score (M = 1.21 of 2.00) and the green skill on 'Exploitation skill on green technology' received the lowest mean score (M = 0.61 of 2.00). Moreover, Standard Deviations range from 0.92 to 1.27, which implies that variability is minimal.

3.2 Discussion

The findings, according to the understandings of PTCs' lecturers in PTCs in Addis Ababa, revealed that all the green skills listed in Table 2 herein above should be integrated into VET curricula. This is for the very reason that all the green skills the researcher listed in the form of questionnaire items are positively understood. More specifically; 6 of 25 green skills on: recycling skill (M=1.21); science skill (M=1.17); controlling skill on environment pollution (M=1.14); interpretative skill on environmental phenomena (M=1.08); planning skill (M=1.05); and operations management skill (M=1.04) are better understood than the other green skills (19 of 25) for the respective mean scores are greater than or equal to 1 in the continuum of the rating scale (4=agree=1 point). Such green skills can be taken as important inputs for the implementation strategies of the National Adaptation Plan of Ethiopia. Some of such strategies, according to the Federal Democratic Republic of Ethiopia (2020), include the following.

> *Improving agricultural productivity in a climate-smart manner; improving access to potable water; strengthening sustainable natural resource management through safeguarding landscapes and watersheds; improving soil and water harvesting and water retention mechanisms; conserving biodiversity; enhancing sustainable forest management; improving human health systems through the implementation of changes based on an integrated health and environmental surveillance protocol; improving early warning systems; developing and using adaptation technologies; reinforcing adaptation research and development; enhancing alternative and renewable power generation and management; and developing adaptive industry systems*

All these strategy options for the implementation of the national adaptation plan, clearly reveal the necessity of green jobs which in return require green skills. That is, those strategies which involve improving, strengthening, enhancing, conserving, developing, using and so forth require different green skills. For instance, data collection skills and analytical skills are needed; tasks related to data collection, analysis of data, and make an accurate interpretation of data related to the environmental phenomena are needed. In short, research skill on environmental issues is needed; which, indirectly these skills are complemented with other skills such as communication skills, organizational skills, time management skills and so on.

Furthermore, the application of Green Technology is in line with the concept of sustainable development; natural resource management skills should also be needed, that is; skill on managing natural resources that can reduce wastage, wastes, pollution and misuse of natural resources are needed; and a skill on the utilization of natural resources by present and future generations for the well-being of mankind is needed. On top of this, if there is no proper planning and coordination in the use of raw materials like steel in automobile production, or rubber in hand glove manufacturing, wastage in manufacturing will occur and also produce more manufacturing wastes; if those manufacturing wastes are not recycled or reused and are not appropriately disposed of, then they will certainly pose a threat to the environment.

In general, environmental pollution has brought about devastating effects to many countries; hence, everyone should be knowledgeable concerning the consequences of various types of environmental pollution and skilful in environmental protection. Since most of the pollutions are caused by industrial activities like emission of greenhouse gases; workers with environmental problem-solving skill are very much needed to assist industry to move to a greener working environment. In light of this reason, environmental problem-solving skills should be integrated into the VET curricula, so that the VET graduates are able to apply this skill to solve the environmental problems in the industry.

Moreover, the exploitation of such green skills is so vital; and hence, to be included in VET curricula so that VET graduates will have an adequate level of skill in applying green technology and/or whatever skill when working in the green industry. This is for the very reason that curricula that contain the element of green skills will be able to produce those who are able to meet the industrial needs and contribute to economic, social and environmental sustainability. Individuals/workers who are going to use these green skills, hence should acquire them from Polytechnic Colleges. Therefore, PTCs' curricula should integrate green skills.

4. Conclusions and Recommendations

Lectures/A-Level trainers in PTCs in Addis Ababa have the perception/understanding about green skills. They rated their agreement about the need to integrate such green skills into VET curricula. Specifically, those 6 of 25 green skills; like on recycling skill (M=1.21); science skill (M=1.17); controlling skill on environment pollution (M=1.14); interpretative skill on environmental phenomena (M=1.08); planning skill (M=1.05); and operations management skill (M=1.04) are better understood than the other green skills (19 of 25) for the respective mean scores are greater than or equal to 1 in the continuum of the rating scale (4=agree=1 point) should be integrated into VET curricula.

In addressing the problems related to environmental pollution and global warming, the existing conventional economic model needs to be shifted to a more environmental-friendly economic model so as to sustain social, economic and environmental development. This economic transformation requires cooperation and supports from the industry. For instance, industrial organizations can make the changes by integrating green elements into their administrative and production operations. These changes will create green jobs and require workers with green skills. Training institutions, such as PTCs, play significant roles in producing workers who are able to meet the needs of the green industry.

Therefore, the existing VET curricula in PTCs need to be revised in order to embed and emphasize the element of green skills into VET programs of study offered in PTCs. Moreover, based on the findings of this study, several green skills (at least, 25 green skills) should be integrated into VET curricula in PTCs in Addis Ababa.

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Optimization of Sand-Casting Process Parameters to Produce Quality Astm-A48 Class 35 Grey Cast Iron Pulleys: Simulation Results

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Abstract

Green sand-casting process for ASTM-A48 Class 35 gray cast iron (GCI) was simulated in order to identify and validate appropriate process parameters to assure least possible casting defects, optimum microstructure, good machinability and mechanical properties for sound productions of medium–size pulleys. Chvorinov's rule and Wlodawer methods were used to calculate the values of parameters associated to the gating system and related components. Three–dimensional model of the pulley was constructed using SolidWorks software. ESI ProCAST 2018.0 software was used as a numerical simulation tool to predict the evolution of the filling state and temperature fields during solidification, the solidification at different positions of the casting, the temperature changes and the formation of gas porosity and shrinkage defects in the cast metal based on Niyama criterion. During simulations, the effects of dimensional parameters of mould and gating system on predicted outcomes were analyzed and correspondingly adjusted and customized in order to prevent occurrence of anomalies. Results of simulation trials showed a high level of confidence between the mould design criteria and process parameters. Correspondingly, optimum parameters leading to a cast metal with appropriate cooling time and free of porosity and shrinkage were identified and selected for appropriate mould design, what lead to an optimized mould cavity design and solidification process of the cast parts. The least possible casting defects, the optimum microstructure, good machinability and mechanical properties are expected in upcoming experimental validation tests.

Keywords: *Niyama criterion, cast iron, pulley, foundry defect, porosity, shrinkage.*

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1. Introduction

Due to its economical characteristics, sand casting is nowadays widely used to produce approximately 70 % of all metal casting (Prabhakara et al. 2011; Banchhor & Ganguly 2014 and Hawaldar & Zhang 2018). This is due to the fact that availability and low cost of sands, the flexibility to produce castings of any material, providing great freedom of design in terms of size, shape and product quality and the weight of castings can range from tens of grams to hundreds of tons makes sand casting processes economical. Additionally, advanced high technology sand casting process (improved sand quality and mould rigidity) enables this method to produce higher precision cast products with better as-cast surface finishing that reduces the cost of after–cast touch–up. This will enhance the capability of sand casting to produce “near–net–shape” products and improve its competitiveness (Prabhakara et al. 2011).
With the extensive use of computer simulations, mould filling and solidification analysis has become easier for foundry engineers, as well as optimization of gating system design and identification of potential casting defects before production of casting starts. Computer–aided casting simulations essentially helps to visualize mould filling, casting solidification and solid–liquid fraction development, thermal changes and internal distortion caused by heat transfer, as well as to predict hotspot locations and possible problem areas and defects such as air blow holes, shrinkage porosities, hard zone and microstructure properties that might occur during the casting process as main outputs.

Great saving of materials, energy and time can be achieved if casting design can be corrected prior to moulding on the basis of defects predictions, being solidification a phenomenon of great interest to physicists, metallurgists, casting engineers and software developers (Choudhari et al. 2013). That’s why during the solidification of a cast metal in a mould, a good understanding of the fluid flow, heat transfer, thermal history, time– temperature profile and solidification rates is essential to evaluate how their combinations with the metal composition and the process variables influence the solid cast component and its quality. A wrong combination of the involved factors may result in poor quality or casting defects. Advanced analysis tools to assist sand casting technologies have made it a more efficient and reliable process. In particular, representational tools such as models and simulations –as mediators between theory and practice– have been at the forefront of sand-casting technologies progress in predicting casting defects (Ravi 2008; Hebsur & Mangshetty 2014; Khan & Sheikh 2018).

In the last years, the numerical simulation of the casting solidification process has been developed and in the 1980's, research on numerical simulation of casting solidification process reached a climax (Niyama et al. 1990). It is found that numerical simulations of solidification have received considerable attention from researchers (Prabhakara et al. 2011; Ravi 2008; Choudhari et al. 2013; Hebsur & Mangshetty 2014; Hebsur & Mangshetty 2014; Paul & Rathish 2014; Shrikant et al. 2014; Khan & Sheikh 2018; Kaikui 2020). On the basis of such simulation raise, Niyama criterion (Niyama 1982; Niyama 1990; Niyama & Anzai 1995; Ignaszak 2017) have been playing a decisive role due to the accuracy that it provides when the probability of presence of shrinkage porosity in castings. Niyama as a prediction criterion for shrinkage defects, involves the expression $Ny = G/\sqrt{R}$, where G and R denote the temperature gradient and cooling rate, respectively. If the Niyama value of a node in a simulation is below a critical value, then that node can have micro–shrinkage. Critical Niyama values for a selected group of alloys are: Steels: 1; Cast Irons: 0.75; Aluminum: 0.25–0.3 and Copper Base: 1.3. Thus, the lower the value of Ny, the higher the probability of shrinkage formation (Niyama 1982).

Regardless of their capabilities and accuracies, a number of commercial programs are available today to conduct casting simulations and, among others, ANSYS (Ravi 2008; Choudhari et al. 2013; Shrikant et al. 2014), ESI ProCAST (Trębacz et al. 2014; Abdullin 2017), AutoCAST (Choudhari et al. 2014), NovaFlow&Solid (Dojka, 2018) and SolidCAST (Nurjaman, 2018) are between the most preferable by researchers. Most of them use Finite Element Method to discretize the domain and solve the heat transfer and/or fluid flow equations (Khan & Sheikh 2018). The main inputs include the geometry of the mould cavity (including the part cavity, feeders, and gating channels), thermos-physical properties (density, specific heat, and thermal conductivity of the cast metal as well as the mould material, as a function of temperature), boundary conditions (such as the metal-mould heat transfer coefficient, for normal mould as well as feed-aids including chills, insulation and exothermic materials), and process parameters (such as pouring rate, time and temperature).

However, casting models and associated elements (feeders, gates, and/or runners) must be created using a solid modelling Computer Aided Design system (CAD) and imported into a Computer Aided Engineering (CAE) program for casting simulation. Besides, parts of casting material, mould properties, and process parameters (filling and pouring temperature, casting to mould heat transfer coefficient) have to be provided by the designer.

The research problem associated to this paper is the need to investigate the causes of defects and how to solve the numerous surface quality problems and other defects in medium−size pulleys manufactured using sand casting process, that lead to poor properties such as high hardness that confers low machinability that result in a huge number of pulleys with poor quality that are rejected, an increased energy consumption, high unit costs and lower morale of foundry personnel.

The present paper aims on the simulation of green sand–casting process in order to optimize the design parameters of medium-sized pulley using GCI to guarantee the least possible casting defects such as porosities and shrinkages, and ensuring the optimum microstructure, good machinability and mechanical properties.

The scope of the research is the design and simulation of heat flow, mould filling and shrinkage formation of medium-sized pulley for power transmission using ASTM–A48–03 Class 35 Grey Cast Iron material.

2. Methods and Materials

The pulleys under analysis have maximum diameter Ø = 270 mm, 25 mm thickness and a total weight of Wg = 22.5 kg. Two pouring temperatures: 1485 °C and 1500 °C are considered for simulations and the casting material to be considered is ASTM–A48–03 Class 35 GCI with composition shown in Table 1. The mould material is taken as green silica sand.

Table 1. **Composition (wt%) for GCI considered in this research, with standard values given by ASTM A48/A48M–03.**

Composition	C	Si	Mn	P	S	CE
Standard	3.20–3.50	1.7–2.2	0.8–1.2	≤0.15	≤0.12	3.20–3.90
Used for simulations	3.2	1.95	0.8	0.04	0.04	3.86

Owing to the carbon (C) and silicon (Si) high contents, the pulley is considered to have a hypoeutectic composition with a carbon equivalent 3.2<CE<3.9 (CE = %C + ⅓ (%Si +%P), according to US Patent 5577545 (1996). The thermos-physical parameters of the material tested and mould material used for simulations are summarized in Table 2.

Table 2. Thermo-physical parameters of Grey Cast Iron and mould material required in the simulations (Viswanathan et al. 2008).

Material's properties	Materials	Values
Liquidus point, K (°C)	GCI	1736 (1463)
Solidus point, K (°C)	GCI	1626 (1353)
Specific heat (kJ/kg·K)	GCI	• 0.49 at 298 K (25 °C) • 0.95 at 1736 K (1463 °C)
	Green Sand	• 0.68–0.88
Conductivity (W/m·K)	GCI	• 51.7 from 0 till 373 K (0-100 °C) • 44 at 773 K (500 °C) • 40 at 1273 (1000 °C)
	Green Sand	• 14–0.5 from 0 till 373 K (0-100 °C) • 0.7 at 773 K (500 °C) • 0.9 at 1273 K (1000 °C)
Density (kg/m^3)	GCI	• 7200 at 298 K (25 °C) • 6964 at 1736 K (1463 °C)
	Green Sand	1550
Viscosity (Pa·s)	GCI	14.3×10^{-3}

Factors such as weight of casting (*Wg*) and pouring time (*tp*) and the dimensions of conventional gating system namely total ingate area required (*Ai*), area of runner (*Arun*), volume of riser (*Vrb*), pouring speed of melt (*vp*) and Fluid flow condition (*Re*) and associated parameters were computed previous to the design, according to (Chalekar 2015 and Sama et al. 2018). Once selected the shape and computed the dimensions of runners (width, height and length), the sprue (height, h; top diameter, d_{top}; exit diameter, d_{exit} and volume, *Vsp*) and riser (height, top diameter, exit diameter and volume), the relative freezing time of riser and casting (freezing ratio) and riser feed (feed metal volume) were computed. The sprue and riser geometry were set to be a typical frustum–shaped cone and, in order to prevent defects such as shrinkage, cavities or porosity, the minimum size of riser was designed using Chvorinov's rule and Wlodawer (modulus) method, as described by Brown (2000) and Nurjaman et al. (2018). To ensure that the casting will solidify before the riser, the total solidification time for the riser was set to be 50 % greater than the total solidification time for the casting. The height of the riser was set to be 1.5 times the top diameter. Similarly, the bottom (exit) diameter was considered as 1.15 times the top diameter.

Total head, velocity of molten metal and total solidification time of a riser (*tr*) and casting (*tc*) were calculated using expressions given by Brown (2000), Harshil et al. (2014) and Dojka et al. (2018). Calculations of metal flow rate and flow velocities were based upon laws of fluid dynamics (law of continuity and Bernoulli's equation respectively) under assumptions of steady state, incompressible and in viscous flow. SolidWorks software was used to produce the three–dimensional (3D) model of the pulley, while simulations of mould filling, temperature fields during solidification at different locations, the solidification time at different positions of the casting and shrinkage were conducted aided by ESI ProCAST 2018.0 software. Planar meshes were generated and used to solve the equations. In order to improve accuracy, the meshes considered the finest refinement in zones where the steeper gradients in the variables could be affected by the higher cooling rates. Two pouring temperatures for the melt were considered: 1485 ^{o}C and 1500 ^{o}C.

The simulations were conducted following the three main parts of ProCAST software: 1) pre-processing, consisting on project description, define job, gravity/symmetry, volume manager, interface heat transfer coefficient (HTC) manager, reading the CAD geometry and mesh generation; 2) main processing (adding boundary conditions, thermal and materials data, and simulation parameters taken from Table 3, filling and calculations) and 3) post processing (presentation and evaluation). To minimize the errors, the effects of conduction and convection heat transfer conditions in the metal–mould–air interface and the mould material (green sand in this case) on the transient–thermal analysis were taken into account. Simulation tools to predict the formation of gas porosity and shrinkage defects analysis in the cast metal were based on Niyama criterion (Niyama 1982; Niyama 1990; Niyama & Anzai 1995) computed by ProCAST software. The effects of dimensional parameters of mould and gating system on predicted outcomes were analyzed during simulations and correspondingly corrected and customized in order to prevent occurrence of abnormalities.

3 Results and Discussions

Analytical calculations, mould design and assembly

Criteria used and values obtained for parameters considered in mould design and simulations are given in Table 3.

Table 3: Summary of design and technological parameters used.

Location of parting line	At the center of the rim thickness
Gross weight of cast metal (including the pulley and ingate system, kg)	Wg = 26
Mould thickness (mm)	150
Pouring temperature (^oC)	1485 and 1500
Pouring time (s)	tp = 24
Total ingate area required (m^2)	$A_i = 3 \times 10^{-6}$
Amount, shape and dimensions of the Runner	Total runners to be placed: 2 Cross–section: Square $A_{run} = 1089\ mm^2$ Width x height = 33 mm x 33 mm Length = 30 mm $V_{run} = 32670\ mm^3$
Type, shape and dimensions of the Sprue	Vertical Frustum cone-like shape $V_{sp} = 1.7 \times 10^{-4}\ m^3$ $d_{top} = 50$ mm $d_{exit} = 43$ mm h = 100 mm
Gate	Parting line side
Ingates (connecting runners)	2 ingates at 180 ^{o}
Pouring speed of melt (m/s) at sprue exit	$v_p = 4.12$
Type, shape and dimensions of the Riser	Vertical type Frustum cone-like shape $Vrb = 2.63\ 10^{-4}\ m^3$ $dr_{top} = 63.37$ mm $dr_{exit} = 55.1$ mm hr = 100 mm Latent height = 103 mm
Cast freezing time to riser freezing time ratio (s)	$R_F = 1.533$
Calculated total solidification time of riser (s)	$t_r = 67.41$
Calculated total solidification time of casting (s)	$t_c = 44.88$

The 3D models for split pulley pattern, sprue, riser and the assembly prepared for simulations are presented in Figure 2a, 2b and 2c. The mould cavity patterns consisting in the sprue and the riser pattern models (Figure 2a, 2b), the runner, sprue base and the solid pulley pattern model were combined together using SolidWorks software to provide the whole model for simulation presented in Figure 2c. Frustum cone-like shape, as per the design criteria and calculations for both the runner and the raiser are visible in Figure 2a-b.

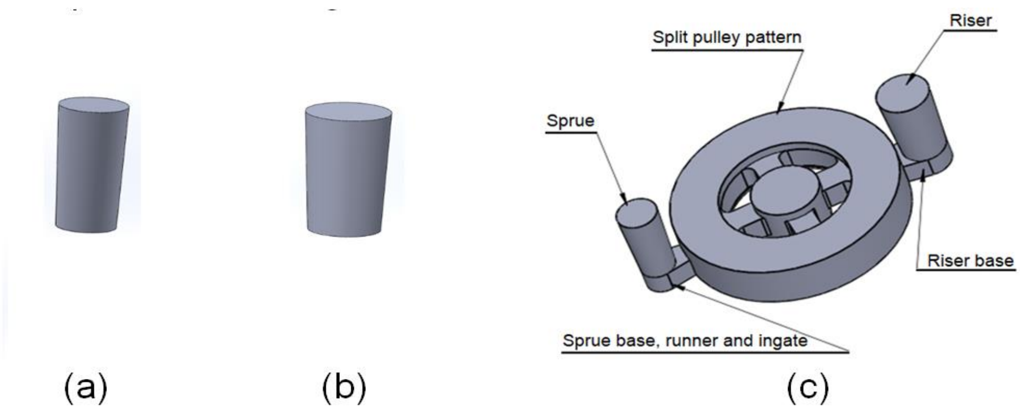

Figure 2. 3D models used in the simulation, a) sprue, b) riser and b) assembly.

Pre-processing

Figure 3 represents the meshed surface of the mould imported from SolidWorks Software and used for simulations. According to the calculation box provided by ProCAST and shown in the left side of the capture, a total of 21208 2D meshed elements were generated as pre-condition to create the 3D meshing. Planar meshes for 161965 3D tetra elements and 20614 new nodes were created and used to solve the equations for thermal and fluid flow process conditions.

Finally, the two existing models (cast cavity and mould) were updated and validated and the 2CAD volumes were transferred to the FE model, ready for pouring and filling simulations and further analysis. Selection of pouring and filling directions, the appropriate gravity vector value and unit were assigned before the trials.

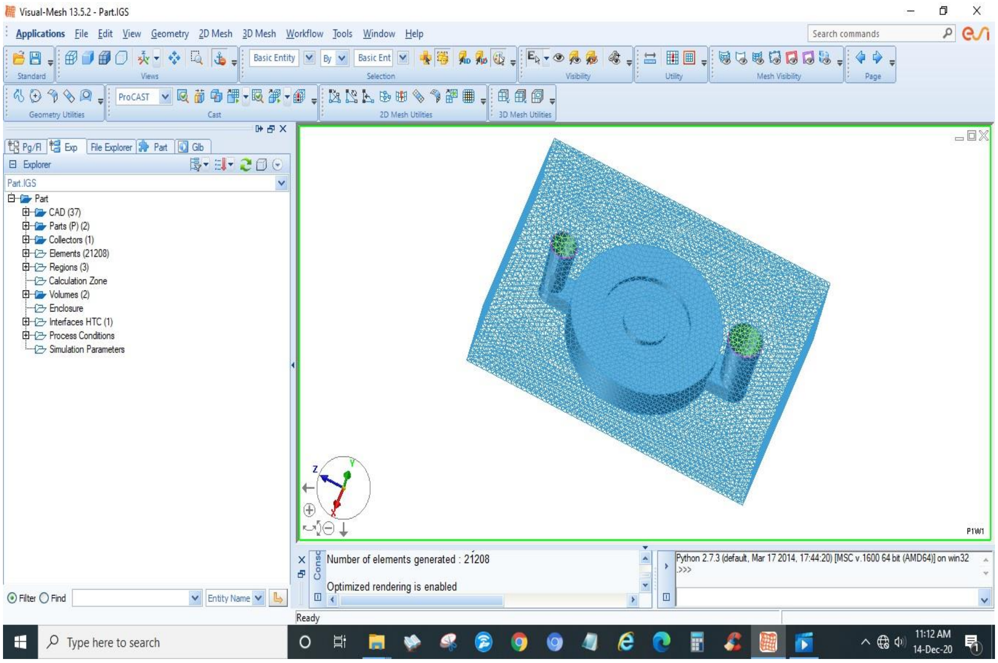

Figure 3. Meshed surface of the mould used for simulations.

Main processing

Figure 4 shows a captured window for temperature distribution, percent filled and solid fraction of solid outputs. A uniform mould filling, as the melt was raised regularly through the cavities of the mould was predicted until it was completely filled up, what ensured a uniform temperature distribution in the mould and, consequently, a solidification rate considered fairly consistent throughout the casting. Cooling rates forecasted were in the range of around 10–20 °C/s. Such rate of solidification ensures a uniform temperature distribution, mould filling of 100 % and 100 % of solid fraction. Also, this solidification rate promotes minimum thermal gradients leading to minimization of probabilities of cracking, shrinkage and cavities due to non–uniform cooling rates. Appropriate size, shape, distribution and amount of the graphite flakes and, consequently, acceptable hardness of the matrix determined by gray iron, which will also result in a good strength and machinability of the final product, are expected as well. After pouring, the predicted temperature profile showed highest temperature values located at the top of the raiser and ranged from 1500 °C to 1400 °C. At the same time, the temperature values in the sprue were predicted to be below 1250 °C.

The highest temperature values at the riser were simulated to be kept for around 24.38 s, what foresees a later cooling of riser compared to the sprue. Given the calculated total solidification time of riser (t_r = 67.41 s) and the cast metal (t_c = 44.88 s) in Table 3, the time difference is 22.53 s, 7.58 % different from 24.38 s.

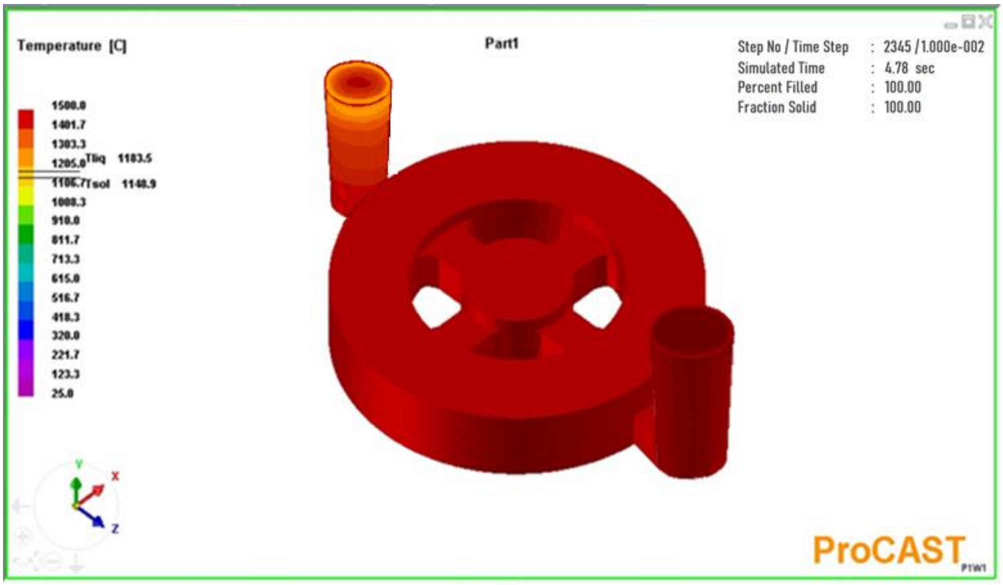

Figure 4. Temperature profile, percent filled and solid fraction after solidification stage.

The calculated total solidification time of riser (t_r) and the cast metal (t_c) from Table 3 are fully consistent with the predicted ones. This way, being the riser foreseen to solidify 24.38 s later than the cast metal, ensures an effective feeding of liquid metal from the riser to the mould, as anticipated in the calculations. This behavior was similar for simulations using both temperatures: 1485 ℃ and 1500 ℃. A captured window presenting predictions of shrinkage and porosity formation during the solidification using Niyama Criterion is given in Figure 5. As observed in the Niyama values distribution profile, even when they are very small, the maximum forecasted Niyama values are located in the top of both the riser and the sprue, which values are around 33.0779 x 10^{-2} lesser than 0.75, the threshold value limit for cast irons as per Niyama (1982 and 1990) and Ignaszak (2017).

As deducted from the discussion above, the predictions for critical shrinkage and porosities values are localized at the top of the sprue and the riser, as expected. In the body of the pulley, shrinkage and porosities are foreseen to be practically nulls (maximum 4.3333 x 10^{-2}). Based on these considerations, the design aspects of the gating system in terms of geometry, section and locations relative to the pattern, give the impression that good gating–mould interfacial heat transfer properties were obtained. As projected, the pattern is predicted to solidify slowly and the sprue will solidify before the riser that is: the riser will be the part to solidify last outside the mould and ensures the presence of enough liquid metal available to compensate any loss into the mould due to shrinkage as the casting cools and contracts on solidification.

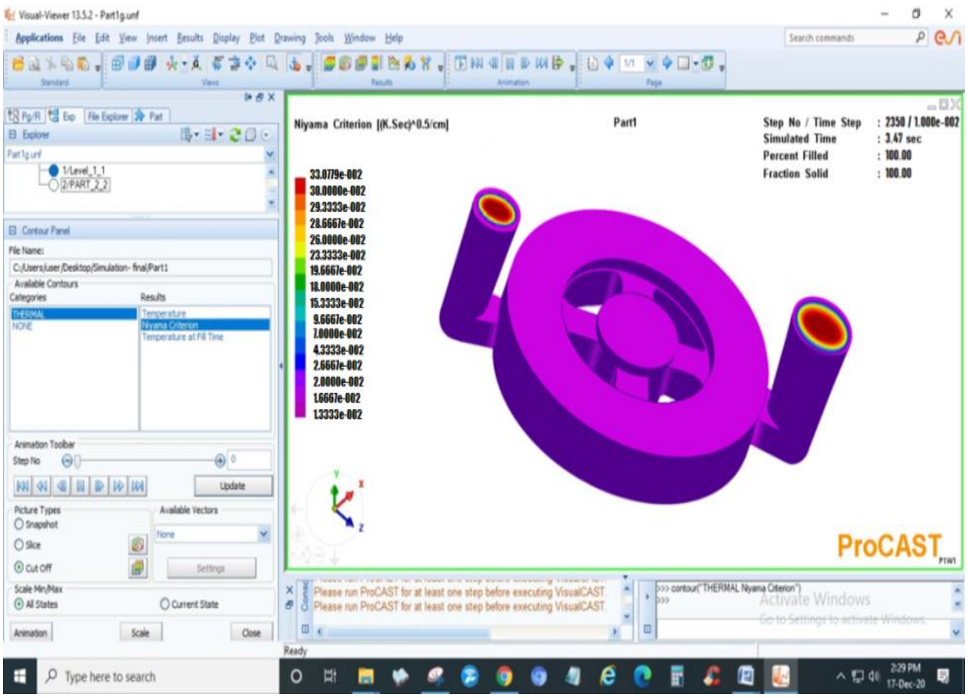

Figure 5. Simulation results of shrinkage and porosity during the solidification stage using Niyama Criterion.

The prediction results for the temperature profiles, mould filling, cooling and solidification and the practically null shrinkage and porosity probabilities also support the criteria that the technological and design factors initially established –or later corrected and optimized during runs and trials– for mould design and the physical and technological properties established for molten metal and sand considered in Table 3 are appropriate. These results confirm, as well, high probabilities of improvements in quality of GCI medium–size pulleys under the specific conditions simulated in this paper.

This way, the sand-casting process parameters calculated and used in this research are considered as optimized and validated throughout the simulation tests. These parameters are recommended to be used to assure the production of ASTM-A48 Class 35 gray cast iron medium-sized pulleys free from casting defects such as porosities and shrinkages, assuring least possible casting defects, optimum microstructure, good mechanical properties and machinability. This casting simulation, undoubtedly, helps to shorten shop–floor trials casting stages and minimize the lead time to achieve the desired geometry of components at the highest quality.

4. Conclusions and implications

Simulations predicted uniform mould filling as the melt was raised regularly through the cavities of the mould until the riser was completely filled up. Thermal analysis predicted fairly consistent solidification rates throughout the mould of around 10–20 °C/s along with uniform distribution of temperature profile inside the mould with lowest values of temperature for the sprue (from 1200 °C in the top to 1400 °C in the core), the highest temperature values in the raiser (around 1500 °C) and a consistent mould filling and solid fraction of 100 %, both.

Solidification rates of around 10–20 °C/s and uniform cooling of the casting predicted during simulations also will lead to the minimum presence of thermal gradients and the minimization of defects such as cracking, shrinkage and cavities due to non–uniform cooling and make possible the characteristic microstructure of grey iron consisting in flake–like graphite and the corresponding low hardness values, good strength and machinability.

Simulated Niyama values much less than to 0.75 indicate a very low probabilities of shrinkages, cavities or porosity formations in the mould, what also suggests the possibility to produce good quality ASTM-A48 Class 35 GCI medium–sized pulley manufactured under the specified conditions and parameters simulated in this paper.

Simulations to predict the evolution of the filling state, temperature fields, solidification at different locations and shrinkage aided by ProCAST software evaluated for two different pouring temperatures: 1485 ℃ and 1500 ℃ showed a good correlation between the analytical calculations of casting process parameters and ProCAST Software and helped to identify optimum parameters for appropriate mould design to produce sound ASTM-A48 Class 35 GCI medium–sized pulleys.

The parameters used are considered as optimized and are recommended to be used to assure the production of ASTM-A48 Class 35 gray cast iron medium-sized pulleys free from casting defects such as porosities and shrinkages, assuring least possible casting defects, optimum microstructure, good mechanical properties and machinability.

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Development of Functional Nonwoven Materials from Knitted Garment Waste Recycled fibers through Recycled Opener Machine for Thermal Insulation Application

[Bahiru Melese, Eshetu Solomon, Daniel Asfaw, Seblework Mekonnen][4]

Abstract

The knitted fabric wastes recycled from cotton and polyester fibers have a possible input of raw materials that can be used for thermal insulation function. The nonwovens for this research were developed by chemical bonding method with a spray bonding technique using poly vinyl acetate latex binder (PVA). All the six samples have been a proportion of 100% recycled cotton, 100% recycled polyester, 50/50, 70/30, 30/70 and 60/40 recycled cotton and polyester. The samples were confirmed for thermal insulation function. Their physical and thermal behaviours were tested with respect to ASTM and ISO standard. The results revealed that the nonwovens were prepared from recycled cotton and polyester knitted fabric wastes, which are suitable for the thermal insulation application. The recycled waste cotton and polyester knitted fabric waste nonwovens have the ability to insulate without disturbing the thermal insulation properties. The results exposed that the nonwovens produced from 30% recycled cotton and 70% recycled polyester (S5) sample have the highest value and 50% recycled cotton and 50% recycled polyester (S3) sample with chemical bonded nonwovens have the next higher value with a thermal insulation value of 0.0606 and 0.0518 thermal resistance value respectively, sample S5 has better thermal insulation performance as compared to the all other samples. It's concluded that the insulation property of the nonwoven fabrics increases with increasing the layer/ thickness of nonwovens and fabric weight. Finally, from this research, fabric thickness, fabric weight, air permeability and nonwovens thermal conductivity have an important effect on thermal insulation ability of the developed chemical bonded nonwovens.

Keywords: Thermal Insulation, Recycled Knitted fabric wastes, Nonwovens, Chemical Bonding.

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1. Introduction

Thermal and acoustics insulation plays an important role in contributing to the automotive by heat gains and losses through the envelope. And a study reported that effective sound insulation in the automotive interior parts. Knitted fabric wastes can be changed into short fibers by the application of mechanical processes. A series of operations have been undertaken in the course of the research aimed at more or less complete reuse of fibers from end-of-life textiles. First of all, knitted fabric waste is crushed with a shredder.Danihelová.et.al (2019).

The use of recycled cotton and polyester nonwovens has many advantages compared to conventional thermal insulators, including reduced product cost, good handling, and environmental protection. The industrial materials are manufactured from reused fibers to offer the sound and thermal insulation application. And also introduced into a detailed manufacturing process for nonwoven materials and acoustics insulation materials and internal of automotive application, so it gives intelligence to find out the ability of the materials made from recycled knitted fabric wastes to acoustics and thermal insulation. Abdel-Rehim.et.al. (2006)

There are many compelling reasons for the recycling of waste from textile products, processes and garment industry. The resources on this planet are ultimately finite. The two key fibers in the textile industry are cotton and polyester which represent over 85% of global fiber production. Cotton relies on a finite land mass for agriculture and competes with food production. Polyester relies on finite sources of oil (petroleum based) and its extraction is damaging to the environment. Therefore, effective resources management in the industry is now becoming high- priority. Environmental issues are also associated with sector – include high energy and water usage and use of toxic chemicals. Synthetic fibers products will not decompose in the landfills. Taking 100"s of years to decompose such waste discarded in landfill has no resale value and it pollute the atmosphere, if not degraded they get accumulated and spread infectious diseases and foul smell.

The fabric wastes the company sends to the landfill result in environmental pollutions such as soil contamination and water pollution. This research aims to produce non-woven fabric from recycled fabric waste that is generated during garment production and study various properties of the new product. Series of trials have been undertaken in the course of a research project aimed at a more or less complete reuse of fibers from end-of-life textiles. First of all, knitted waste is crushed with a shredder. The design of those fiber shredders requires sharp cutting edges and a tight gap between the cutting blades and the feeding bed to avoid wrapping.

In this research the main objective was to develop functional chemical bonded nonwoven materials produced from knitted garment waste recycled fibers through recycled opener machine for thermal insulation. Several other possibilities for the recycling of waste in the textile and garments industry include the conversion of waste by several methods into other alternative renewable energy resources and new products, Aimee Chan, (2019/20). The research also focused on characterizing of various recycled waste knitted Fabric non-woven samples. Comparison of all the developed chemical bonded non-woven samples for the indented use. The research is significant because it concerns a recycling, reducing and reusing of knitted waste from garment industry and nonhazardous solid textile waste is a viable alternative. The research also addressed the society to make alternate materials for non-woven and technical textiles. While recycling is new to the textile industry, it is now a necessity brought on by increased fees at landfills and decreased availability of landfill space. Recycling is more than simply a trend or a new marketing campaign designed to make a profit as an economic necessity of the garment industry. The main objective of the research is to address the issues of waste recycling process in Ethiopian textile and Garment industry to reduce, recycle and reusing the waste materials as sustainability processes.

2. Materials and Methods

The raw materials used in the study are cotton and polyester, of colored and white materials of knitted fabric wastes, which have collected in Desta Garment PLC and Jay Jay PLC Bole lemi industry zone. These wastes are then fed into the re-used fabric opener machine which is opened in Debrebrhan blanket factory Debrebrhan, to obtain recycled fibers, and their characteristics have been studied as per the ASTM standards. Mini carding machine has used to form a web preparation. Short fibers of recycled cotton, polyester, cotton polyester blends with color and white can be processed easily, allowing textile waste materials to be used in non-woven. In alternative means of producing fleeces is offered by machines by using aerodynamic feed of fibers. In this case those fibers form carding cylinder are carried in air currents and deposited onto a condenser cage, from which they are drawn of in sheet form. Random laid webs are made as a single layer and are claimed to have equal properties in all directions. Cotton and polyester fibers parameters were preferred for this experiment.

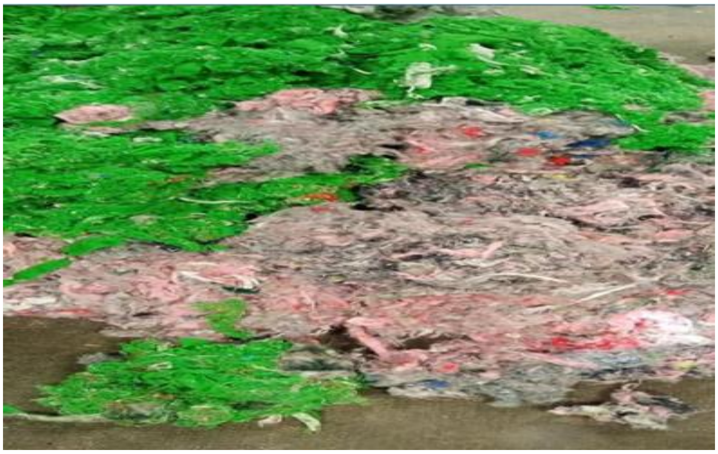

Figure 1. Collection of Fabric waste

Machines and Equipment's

Table 1: Equipment and materials

Name of equipment's	Type of the test and function	Location it is found
Grinding machine	for grinding selvedge wastes	D.B.F PLC
Carding machines	for dry laid web formation	FTI Textile Lab
Digital thickness tester	Thickness test	FTI Textile Lab
Non fabric weight tester	GSM /areal density	FTI Textile Lab
Air permeability tester	Air permeability	Gumruk in Addis Ababa
Thermal conductivity	Thermal conductivity	Angel textile institute ,India
Thermal insulation	Thermal insulation	Angel textile institute ,India
Poly vinyl acetate (PVA)	For bonding application	From the market

2.1.Methods of Development in Chemical Non-woven

The nonwoven samples were developed by using chemical bonded method and the sample development flow chart is shown in figure below.

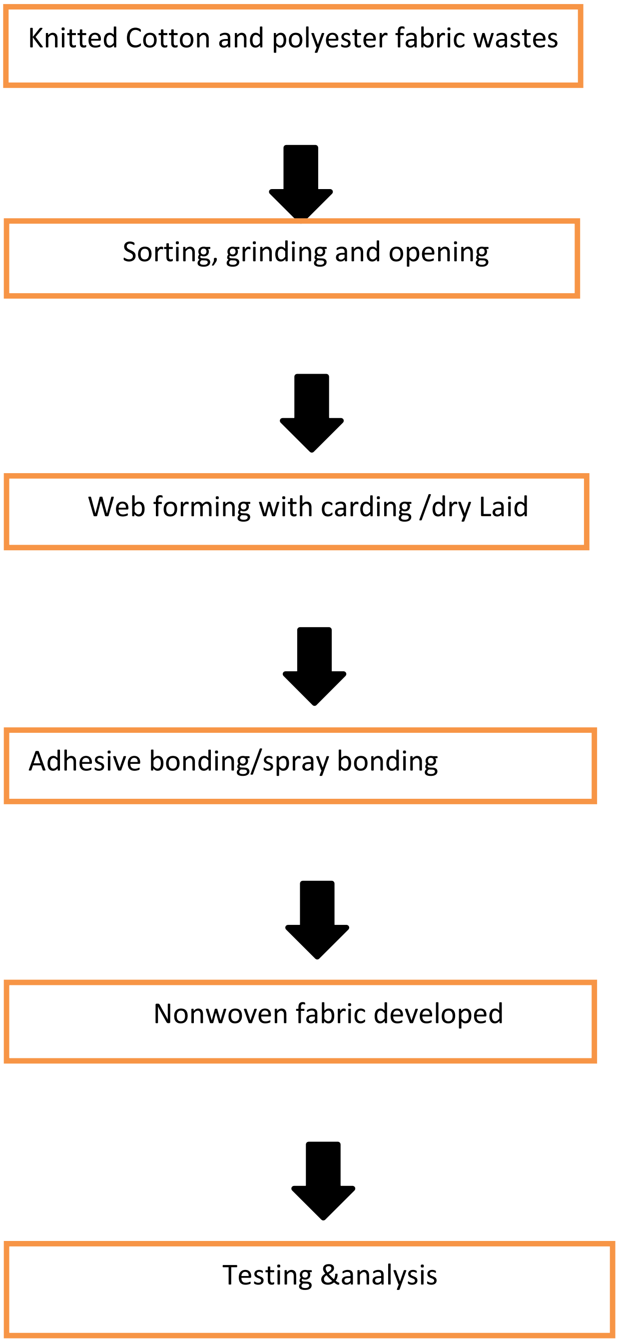

Figure 2: Methods of Development in Chemical Non-woven

2.2.Blending of Recycled Fibers

Cotton and polyester fibers have been blended with different proportions using a mini laboratory carding machine. The different blending proportions of cotton and polyester fibers used for the manufacturing of nonwoven fabrics are given in Table below.

Table 2: Blending of Recycled Fibers

S.No	Fiber blending composition/proportion	C/P	Coding
1	100% recycled cotton fibers	100:00	S1
2	100% recycled polyester fibers	0:100	S2
3	50% recycled cotton fiber and 50% recycled polyester fiber	50:50	S3
4	70% recycled cotton fiber and 30% recycled polyester fiber	70:30	S4
5	30% recycled cotton fiber and 70% recycled polyester fiber	30:70	S5
6	60% recycled cotton fiber and 40% recycled polyester fiber	60:40	S6

2.3. Processes of non-woven fabric manufacturing

2.3.1. Web formation

100% recycled cotton, 100% polyester fibers and the blended cotton/polyester fibers were fed into a mini laboratory carding machine to obtain carded webs. For the period of carding process, the fiber blending was extra open and individual fibers were combed to make parallel. The fiber blending was carded four times to improve web uniformity. With different webs, layers are superimposed one above the other to obtain the required thickness in the final nonwoven fabrics, and the parallel or random laying techniques allows nonwovens with range of mass per unit area to be manufactured, in which fiber orientation can be made much more random than in the case of the traditional web layering. The nonwovens manufactured by this technique. Six different types of web were manufactured, such as 100% cotton, 100% polyester, 50/50 Cotton/Polyester, 70/30 Cotton/Polyester, 30/70 Cotton/Polyester and 60/40 Cotton/Polyester blended materials.

2.3.2. Method of Chemical bonding

The fibrous layer from the web former is sprayed with polyvinyl acetate at a constant pressure and flow as shown in the figure below. Precaution is taken to avoid excessive or lesser flow of adhesive through the sprayer. By the calendar roller pressure, the fibrous layer is converted into nonwoven fabric.

2.3.3. Method of Drying

The bonded sheets are dried through the drying chamber at 120^0C; 160^0C. The pre heated fabrics are calendared and heated again to bind the fabric according to the required thickness.

Figure 3: dried non-woven sample

2.4.Testing of Physical Properties of Developed Nonwovens

2.4.1. Thickness Testing Measurement

The thickness tester was used to measure the thickness of nonwovens. The sample size which was taken for thickness measurement was 15-cm width and 30-cm length. The mean value of all the five random readings of thickness has been taken. It was used to determine the nearest value in mm, and the calculated result is the average values of thickness of the samples under the test. The nonwovens thickness was determined in accordance with the digital thickness tester with ISO 9073 test methods.

2.4.2. Fabric Weight Measurement

GSM is the weight of nonwovens in one gram per square meter. The nonwoven fabrics sample was cut with GSM cutter in (g/cm2), then after, weight the nonwoven fabric with an electronic balance, the cut sample is 100cm2, the weight of the samples is multiplied by 100 or divided by 0.01 to change the centimeter in to meter. It was performed five random readings, and takes the average values from five reading. Then the result is the GSM of the particular non-woven fabric.

The nonwovens fabric weight was determined in accordance with the GSM tester with ASTM D- 3776 test methods.

2.4.3. Nonwoven Air Permeability Measurement

The measurements of air permeability were carried out by using 20 cm^2 circular nonwoven fabrics with 100 Pascal of pressure difference. The results were expressed in $cm^3/s/cm^2$ by taking the average of five random readings of different measurements. The test was performed according to ISO 9237:1995 test method.

Figure 4: Air permeability tester

2.4.4. Nonwovens Thermal Conductivity Measurement

The specimen with 4 cm in diameter was placed between the discs (A) and (B). The heat is supplied between the discs. Temperature of (A) and (B) discs were measured using two thermometers. Two thermometers T1 and T2 were inserted into two holes in a metallic disc and a steam chamber, respectively. The temperature of the samples of the ambient was also measured until it reached at the saturation. The rates of supply energy were noticed and then place the nonwoven insulating material on the lower circular metal disc. Start recording the temperature at half-minute intervals. Continue till the temperature falls by 10^0c from T1. The measurements thermal conductivity was determined by ASTM D 6343 test methods.

Figure 5: Thermal Conductivity Tester

2.4.5. Nonwovens Thermal Insulation Measurement

The guarded hot plate device Lambda-Meter EP500 was used for determining the thermal conductivity as per the EN 12667 standard. It measures the sample thickness t [m] of the produced nonwoven samples, the temperature difference T [K] over the samples and the heat flux Q [W/m2]. The thermal conductivity λ [W/ (m.K)] is determined based on the defined measurement area S [m^2] and the one-dimensional thermal conduction as follows in equation below (Wazna et al., 2019). The sample size used for measurement was 200 mm X 200 mm. In this study, the measuring temperatures were 15, 30 and 45^{O}C. Where t [m] is the thickness of the sample, λ is the thermal conductivity [W/ (m.K)].

Figure 6: Thermal Insulation Test

3. Results and Discussion

Six different types of chemical bonded nonwoven samples were developed from cotton, polyester and cotton/polyester blended in different blending ratios. The physical properties of the chemical bonded knitted fabric waste nonwovens of recycled from cotton and polyester fibers were measured and mean values with standard deviation of samples were given in Table 3. The physical properties of developed samples of 100% recycled cotton knitted fabric waste (S1), 100% recycled polyester (S2), 50/50 recycled cotton/polyester (S3), 70/30 recycled cotton/polyester (S4), 30/70 recycled cotton/polyester (S5) and 60/40 recycled cotton/polyester (S6) knitted fabric wastes chemical bonded nonwovens were tested according to the ASTM and ISO standards to determine the properties of the nonwovens in accordance with their thermal insulation applications.

Table 3; Mean ± STD of physical properties of chemical bonded nonwovens

Samples Codes	Thickness (mm)	Fabric Weight (g/m2)	Air permeability (cm3/s/cm2)
S1	2.094 ± 0.31238[c]	223.314 ± 6.52498[d]	38.222 ± 0.55751[a]
S2	2.990 ± 0.10368[b]	259.334 ± 7.09120[b]	31.144 ± 1.88323[c]
S3	3.498± 0.10232[a]	287.716 ± 2.68012[a]	28.338 ± 0.58692[d]
S4	2.160 ± 0.28311[c]	235.866 ± 3.07800[cd]	36.652 ± 0.49456[ab]
S5	3.692 ± 0.09808[a]	300.790 ± 2.56492[a]	25.974 ± 1.83839[d]
S6	2.352 ± 0.35717[c]	240.392 ± 2.66299[c]	34.688 ± 0.49118[b]

STD= standard deviation

The average values are arranged such that the letter „a" shows the higher average value and the letters „b" shows the medium value and the letter „c,d,e" shows lowest average value. Any other average values not sharing a letter in common mean that they are significantly different from each other at 95% confidence level. Means with the similar letter from the result are not significantly different.

Table 4: Mean ± STD of thermal properties of chemical bonded nonwovens

Samples code	Thermal conductivity (W/m.K)	Thermal insulation m2.K/W
S1	0.0422 ± 0.00130[a]	0.0306 ± 0.00207[d]
S2	0.0306 ± 0.00207[c]	0.0444 ± 0.00241[c]
S3	0.0288 ± 0.00228[cd]	0.0518 ± 0.00421[b]
S4	0.0404 ± 0.00134[ab]	0.0318 ± 0.00259[d]
S5	0.0272 ± 0.00303[d]	0.0606 ± 0.00297[a]
S6	0.0378 ± 0.00239[b]	0.0332 ± 0.00192[d]

Form above Table the results showed that, all the measured values of physical and thermal properties of all the six nonwoven samples. From these results it can be observed that sample S5 which was 30% recycled cotton and 70% recycled polyester samples has the highest value of thicknesses and fabric weight and S3 which is 50% recycled cotton and 50% recycled polyester sample has the second higher thickness value and fabric weight when compared from S1, S2, S4 and S6 samples respectively. S5 has highest thermal insulation with a value of 0.0606 m2. K/W. And S3 nonwoven sample has the next higher thermal insulation with a value of 0.0518 m2. K/W. besides this, sample S1, which was developed from 100% cotton recycled fiber shows lower thermal insulation value with lower thickness values (2.094) than all other chemical bonded nonwoven samples. The results of all physical properties were measured for ten times at random reading for each sample and the average value were taken to reduce the error.

3.1.Thermal Insulation Performance of Developed Nonwovens

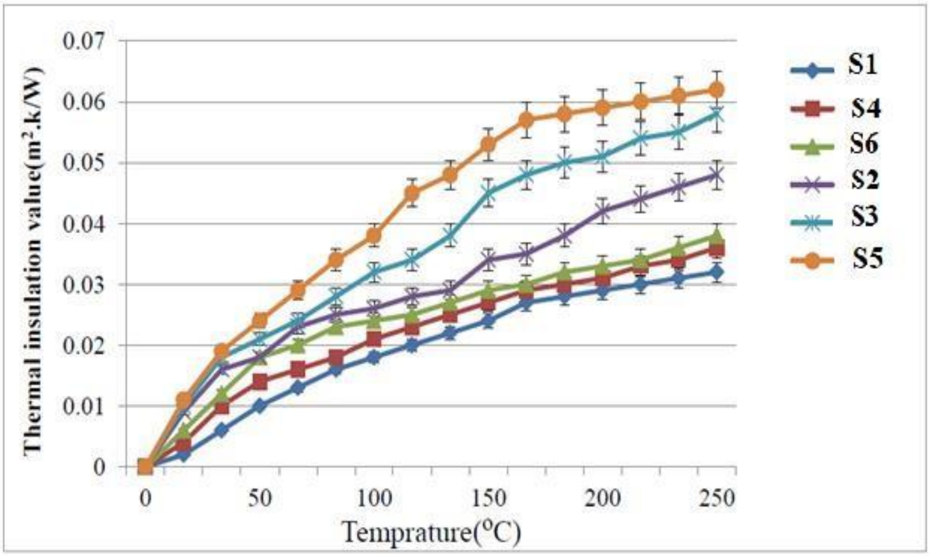

Figure 7: Chemical bonded nonwovens thermal insulation performances

Thermal insulation values of all the developed samples in different blending ratios and pure 100% cotton and 100% polyester were shown in Figure 7. From figure 7, it can be showed that nonwoven sample S5 which was developed from 30% recycled cotton and 70% polyester knitted fabric waste fibers nonwoven sample indicates better thermal insulation performance as compared to all other samples when temperatures raised from 50 to 250°C. And the higher thermal insulation value was achieved at higher temperature value. The thermal insulation depended upon the thickness and fabric weight of the nonwovens related to their temperature values. On the other hand, recycled cotton and polyester based nonwoven samples can be shown that while polyester composition increases, the thermal insulation value of the samples S5 becomes increased with a maximum value of 0.0606 m^2. K /W. At the same time, the temperature increases up to 250°C, the thermal insulation performance of the nonwovens increased simultaneously. Since from the figure 7 it is observed that sample S5 has the best thermal insulation performance as compared to the other samples. On the other hand, sample S1; it was developed from 100 % recycled cotton knitted fabric waste fiber nonwoven, which has lower thermal insulation value of 0.0306 m^2. k/W compared from the all other developed nonwoven samples.

3.1.1. Influence of Thickness on Thermal Insulation

There is a linear correlation between nonwoven fabrics thickness and its ability to thermal insulation performance. This is predominantly due to increasing the thickness of the chemical bonded nonwoven fabric, which means increasing the number of fibers in the unit area, thus increasing the compactness of the nonwoven fabrics, which reduces the amount of heat lost during aerobic blanks, so that the thermal insulation performance of the developed nonwoven samples was increased.

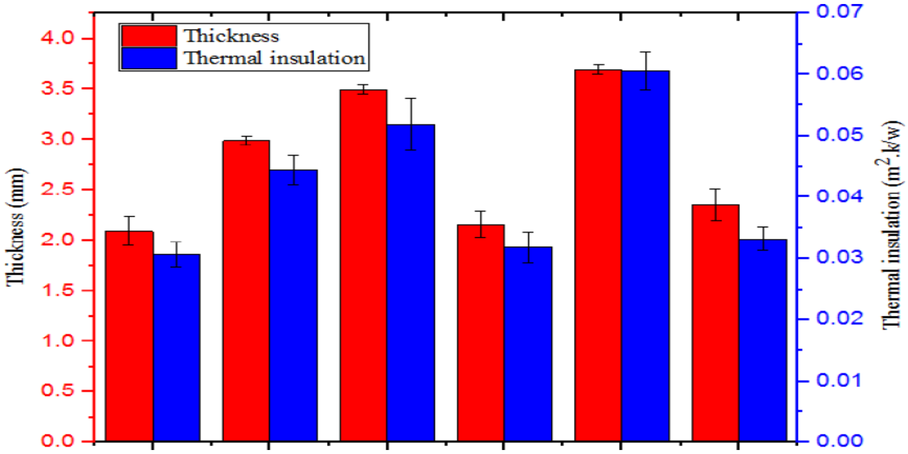

Figure 8: Influence of thickness on thermal insulation

From figure 8 and table (4&5) it was observed that the nonwovens, S5 which was developed from 30% recycled cotton and 70% recycled polyester chemical bonded samples shows highest thickness and thermal insulation value of 3.692-mm thickness and thermal insulation value of 0.0606 m^2. k/W. Besides this sample S1, with a proportion of 100 % recycled cotton knitted fabric waste fibers developed nonwoven sample, which has lower thermal insulation value of 0.0306 m^2. k/W was achieved with a minimum thickness value of 2.094 mm as compared from all other developed nonwoven samples. From this analysis, it can be observed that with the increase of the nonwovens thickness and layers, its thermal insulation value also increases. So that, from this, it can be understood that thermal insulation is mostly dependent on the thicknesses of the manufactured knitted fabric waste, recycled chemical bonded nonwovens. Thermal insulation performance has direct relationship with developed nonwoven thickness. Therefore, this study shows a high increase of thermal insulation value as the material gets thicker; the thermal insulation property also increases. A similar research finding was obtained in the literature by (El Wazna, et.al, 2017).

3.1.2. Influence of Fabric Weight on Thermal Insulation

From figure 4.3, it was observed that with the increase of the weight of the nonwovens, its thermal insulation value also increases as shown in the figure. So that thermal insulation of nonwovens was extremely dependent on the weight of nonwovens. And from this figure it was observed that nonwovens developed from 30% recycled cotton knitted fabric waste fibers and 70% recycled polyester knitted fabric waste fiber, which indicates highest fabric weight and highest thermal insulation performance as compared to all other developed chemical bonded nonwoven samples.

At the same time, nonwovens developed from 50% recycled cotton knitted fabric waste and 50% recycled polyester knitted fabric waste have the next higher nonwoven fabric weight and thermal insulation value as compared to all other nonwoven samples.

It is obvious from table (3) and figure (9) that there is a direct relationship between nonwoven fabrics weight and their ability to thermal insulation performance of the developed nonwovens. Nonwoven sample S5 which was developed from 30% recycled cotton and 70% recycled polyester, it has value of 300.790g/m^2 fabric weight, scored the highest values of thermal insulation with a value of 0.0606 m^2. K /W as comparing from all other developed samples. On the other side, sample S3 which was developed from 50% recycled cotton and 50% recycled polyester, which has a value of 287.7160 g/m^2 fabric weight, has scored the next higher thermal insulation performance with a value of 0.0518 m2. K/W. Sample S1, which was developed from 100 % recycled cotton knitted fabric waste fiber nonwoven, which has lower fabric weight and thermal insulation value of 223.314 g/m2 and 0.0306 m2. k/w, respectively, as compared from all other developed nonwoven samples.

This is due to the increase in nonwoven fabric weight which increases in the number of fibers per unit area. So that, higher the compactness of nonwoven fabrics, this decreases the aerobic spaces between these fibers, which is leads to decreasing the heat lost during those spaces. Based on this reason, thermal insulation performance of the developed nonwoven fabrics increased. From table 3 and figure 9, it is clearly observed that the fabric weight of sample S1 is lower than all other samples, whereas sample S5 has the highest nonwoven fabric weight.

3.1.3. Influence of Air Permeability on Thermal Insulation

While increasing thickness of the produced nonwoven fabrics from recycled cotton and polyester knitted fabric waste, and recycled cotton and polyester blended, the air permeability decreases as shown in figure 9. Air permeability was a very essential parameter for thermal insulation performance of the developed recycled chemical bonded nonwovens. Lower air permeability leads higher air flow resistance through the nonwoven fabrics, which resulting in higher thermal insulation performance.

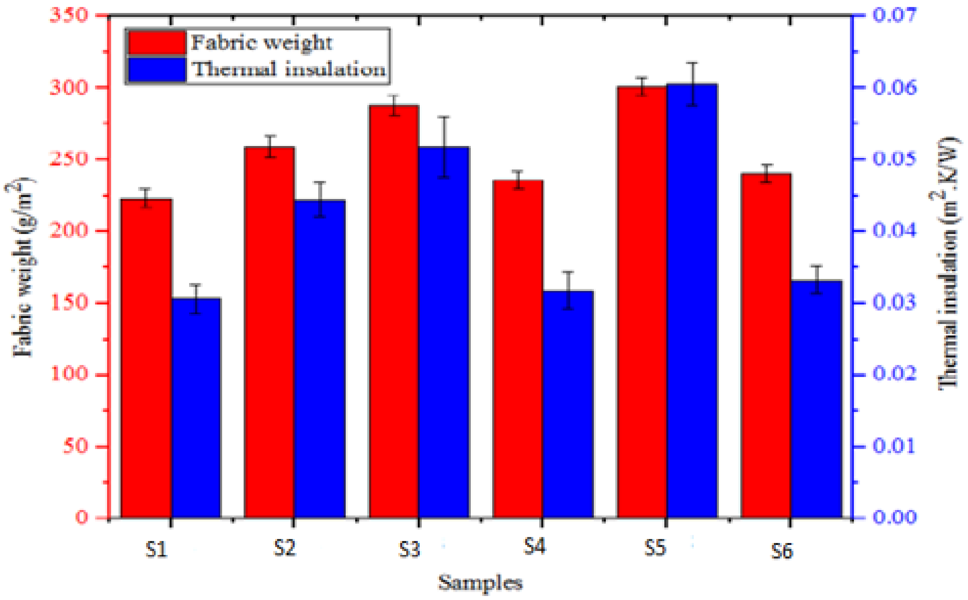

Figure 9: Influence of fabric weight on thermal insulation

As shown in Figure 10, the air permeability was lower for developed nonwoven samples with higher nonwoven fabric thickness and nonwoven fabric weight. Lower air permeability makes it suitable for thermal insulation application. The lower air permeability result was obtained in sample S5 with a minimum value of 25.974 $cm^3/s/cm^2$, which was developed from 30% recycled cotton knitted fabric waste fibers and 70% recycled polyester knitted fabric waste fibers. And sample S1, which was developed from 100% recycled cotton shown the maximum air permeability value of 38.222 cm^3/s/cm2. This is due to lowest nonwoven fabric thickness and nonwoven fabric weight. The air permeability of recycled cotton and recycled polyester blended nonwovens as shown in table 3 and figure 10 differs with thickness; it is not affected by the variation in the proportion of the cotton and polyester blend. This indicates that the air permeability is not affected by the type of fiber, whereas, it is affected by the thickness of the chemical bonded nonwoven samples. Lower thickness value has higher air permeability. The thermal insulation value increases with the decrease in nonwoven fabric air permeability

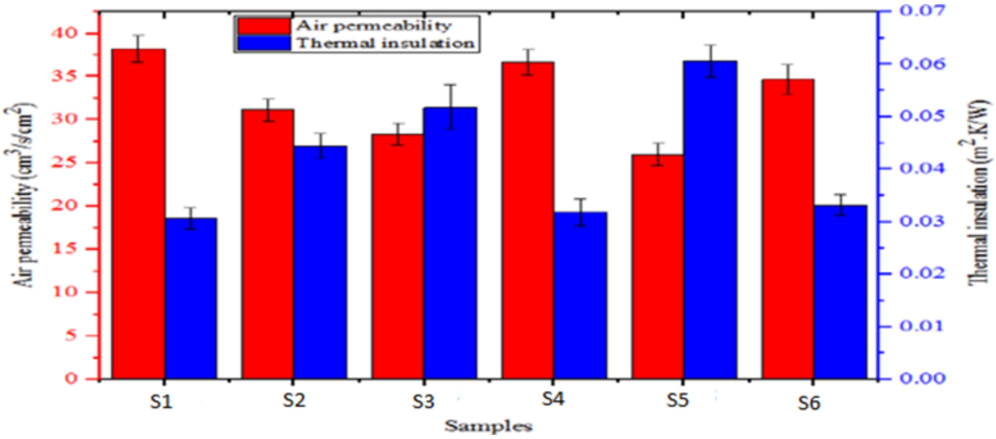

Figure 10: Influence of Air Permeability on Thermal Insulation

3.1.4. Influence of Thermal Conductivity on Thermal Insulation

As thickness of the developed nonwovens increases, the thermal conductivity decreases, which resulting in higher thermal insulation value as shown in figure 11.

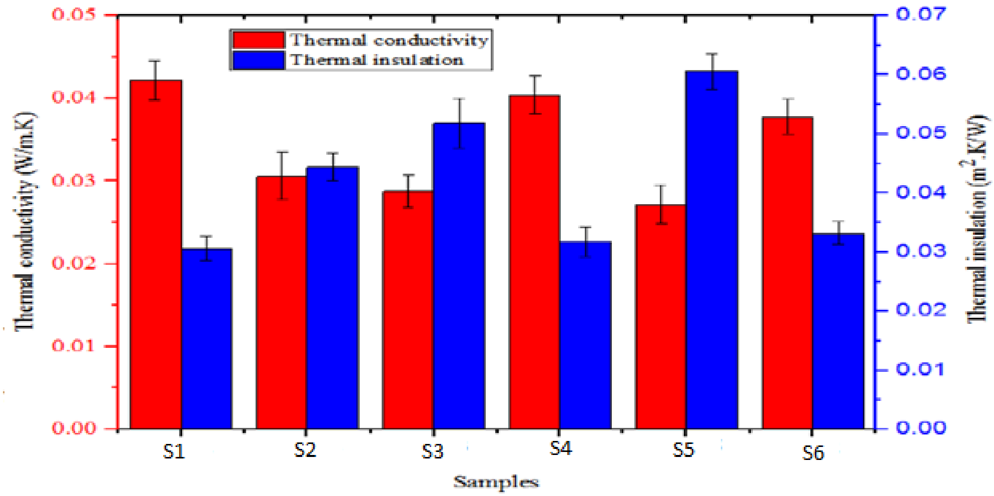

Figure 11: Influence of thermal conductivity on thermal insulation

From figure 11, it is observed that, the developed nonwoven samples were analyzed based on their thermal conductivity related to the thermal insulation property. Low values of the thermal conductivity of developed nonwovens indicated that higher thermal insulation. This was necessary to conduction of the hotness through the materials. By the increases in temperature, the thermal conductivity shows an increases trend for samples which have lower thickness, and the thermal conductivity shows a decreasing trend for samples which have higher thickness value of nonwovens which were produced from recycled cotton fiber and recycled polyester fiber, which was providing the best thermal insulation properties. From figure 11, it is clearly explained, the thermal conductivity of cotton and polyester blended sample S5 which was developed from 30% recycled cotton and 70% recycled polyester has a value of 0.0272 W/m.K which has a thermal insulation value of 0.0606 m2.k/W was higher than that of S1, S2, S3, S4 and S6. Sample S1, which was developed from 100% recycled cotton knitted fabric waste has a maximum thermal conductivity value of 0.0422 W/m.K. Subsequently, a high value of thermal conductivity leads to a smaller thermal insulation value as shown in figure 11 and table 6. Thermal conductivity of a nonwoven structure is a very significant property for determining the thermal insulation properties of the developed chemical bonded nonwoven structure. It is known that lower thermal conductivity leads to better thermal insulation application. Similar finding was obtained by (Eyüpoğlu, Merdan, Dayıoğlu, & Kılınç, 2017).

3.2. Thermal Resistance Performance of Developed Nonwovens

The chemical bonded nonwovens while tested for the thermal resistance, it indicated that the increase in thickness and fabric weight of the manufactured samples leads to increases the thermal resistance performance. The average thermal resistance values of six chemical bonded samples were shown in figure 12. The chemical bonded nonwoven of recycled cotton and polyester with a proportion of 30% recycled cotton and 70% recycled polyester have the higher thermal resistance value as compared to the other samples and sample which was developed from 100% recycled cotton shows lower thermal resistance values. These results also tell that the thermal resistance increases as the thickness and fabric weight increases. On the other side, as the thermal resistance increases, the air permeability and thermal conductivity decrease.

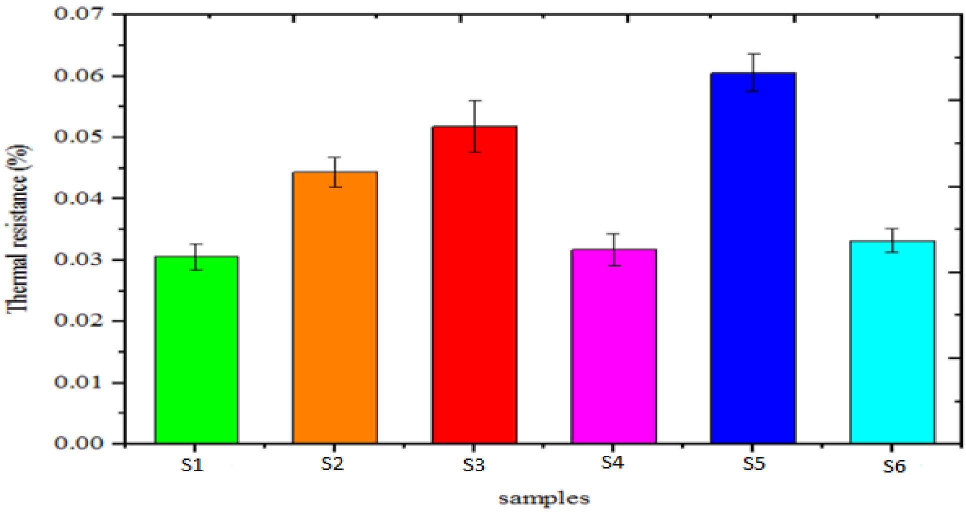

Figure 12: Thermal resistance of developed nonwovens

Thermal resistance values of all the developed samples in different blending proportions and pure 100% cotton and polyester have been shown in figure 12. From figure 12 it can be observed that samples, S1, S2, S3, S4, S5 and S6 which were developed from recycled cotton and polyester knitted fabric waste fibers with a value of 0.0306, 0.0444, 0.0518, 0.0318, 0.0606 and 0.03320 m2. K/W. From the six samples S5 which was developed from 30% recycled knitted fabric cotton waste fibers and 70% recycled knitted fabric polyester waste fibers, sample S5 indicates better thermal resistance performance as compared to all other manufactured nonwoven samples. The thermal resistance depended on the nonwoven fabric thickness and fabric weight of the nonwovens. Recycled cotton and polyester knitted fabric waste based on nonwoven samples can indicate that while the polyester composition in the blending ratio increases, the thermal resistance value of the samples becomes increased. Since sample S5 has best thermal resistance performance as compared to all other samples of S1, S2, S3, M4 and S6 chemical bonded nonwovens.

4. Conclusions and Recommendations

From this research work, the physical properties and thermal insulation characteristics of chemical bonded nonwovens developed from recycled cotton and recycled polyester knitted fabric waste fibers and with different blending ratios as 50/50 C/P, 70/30 C/P, 30/70 C/P and 60/40 C/P nonwoven samples were examined. In this research work, knitted fabric cotton and polyester wastes were opened, mixed and grinded by using grinding machine located in Debre Birhan blanket factory PLC. The recycled fiber of chemical bonded nonwoven thermal insulating materials were produced by using the fibers recycled from the knitted fabric waste of cotton, polyester and cotton/polyester blend were taken. Totally six samples of knitted fabric recycled cotton, recycled polyester and recycled cotton/polyester blended chemical bonded nonwovens have been produced. From the six samples 30% recycled cotton and 70% recycled polyester chemical bonded nonwoven showed highest average value of thermal insulation with a value of 0.0606 m^2. k/W.

The results have been indicated that with higher thickness and increased layer nonwoven containing recycled cotton and polyester knitted fabric wastes are good samples to be used in insulation applications since they exhibit lower thermal conductivity and higher thermal insulation results. It can be generally observed that for the highest value of thickness (3.692 mm) and nonwoven layer, the highest thermal insulation result was achieved in 30% recycled cotton and 70% recycled polyester samples with a value of 0.0606 m^2.k/W. And sample S1, which was developed from 100% recycled cotton waste fiber has a minimum value of 2.094mm thickness and 0.0306 m^2. k/W thermal insulation values. The reason was higher nonwoven fabric weight and thickness values compared to all other nonwoven samples. It is known that, nonwoven fabric weight, thickness and layer have a significant impact on thermal insulation behavior of nonwoven materials. The result of this study shows that, knitted fabric recycled cotton and polyester blended fibers can be used in insulation function without influencing their thermal properties. So, this type of nonwovens can be applicable for thermal insulation materials in the automotive, furniture and clothing industrial applications.

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Optimization of the Conductance of Graphene-ink-coated Fabric used for Wearable Electronics Application

[Seblework Mekonnen, Gurumurthy B Ramaiah, Bahiru Melese, Eshetu Solomon, Mekdes Gedilu][5]

Abstract

Graphene Conductive Ink is used mainly for coating on fabrics and other substrates to develop conductive fabrics which can find applications in many wearable electronics applications. In this research, graphene material properties and conductive behavior of graphene coated and surface modified polyester fabrics is analyzed and discussed. Box –Behnken type of experimental design is used in this study which is applied in circumstances when the number of experimental runs is limited and the predictions are to be of higher order. This design consists of 3 nodes which is a 2nd order fitted equation. The Independent variables used in this study are Concentration of graphene ink (0.05-0.10gm), Surface area (1-3 Sq cm), and Coating thickness (0.55-1mm). To develop and generate Box-Behnken design, Minitab software is used. The Minitab B&B design is based on quadratic equations of second order. The ANOVA and model summary show that concentration of graphene ink (gm) and coating thickness directly influence the conductivity levels of coated material ($p<0.05$). However, in the optimization part, the goal was to maximize the response and formulations of conc. of graphene ink coating(gm)(0.1gm) and surface area (3 sq.cm) and coating thickness (1 mm) predicted conductivity of 3.9425 Siemens/cm with a composite desirability value of 1 showing the case as ideal one. The model accuracy showed R^2 value of 99.58 %. Box and Behnken design performed well in this study. Sensor test using Arduino integration and Led was tested and showed good results for coated fabrics.

Keywords: *Graphene Conductive ink, Wearable Electronics, Conductance, Surface area*

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1. Introduction

Conductive textile materials (CTMs) have been widely used as flexible smart fabrics because of their low weight, high elasticity, high stretch capacity, and recoverable deformation. The CTMs also have great strength, exceptional tear resistance, excellent flexibility, and comfort qualities. (2018) (M. Yang et al.) Typically, conductive textiles are produced by melting metal wires directly into the fabric's threads or by sparingly coating the strands with conductive substances like conductive polymers. The majority of methods include coating or encasing cotton cloth in conductive material in order to make it conductive [1-2].

It is possible to create cotton fabrics with outstanding conductive properties and durable conductivity by coating the created conductive substance onto cotton fibers. In order to accomplish the needed conductive qualities, the current research aims to apply a coating approach to create conductive cotton fabric utilizing graphene conductive ink [3]. The major goal of the research is to make cotton cloth more electrically conductive by printing graphene-conductive ink on it.

High conductivity can be found in graphene, which is carbon in the form of membranes only one atom thick. The research team's method relies on the dispersion of extremely thin graphene sheets—each less than one nanometer thick—in a water-based dispersion. During printing and deposition on the fabric, the individual graphene sheets in suspension are chemically altered to stick well to the cotton fibers, resulting in a thin and uniform conducting network of numerous graphene sheets [4-5]. The key to this remarkable sensitivity to motion-induced strain is this network of nanometer-sized flakes. It has been demonstrated that a straightforward smart cotton fabric with graphene coating used as a wearable strain sensor can accurately detect up to 500 motion cycles, even after more than 10 washing cycles in a typical washing machine [6].

The process of applying covering substance is commonly known as surface coating. This process is used for specific material to accomplish a particular aim, enhancing acid and alkali resistance, hardness, chemical shielding, penetration, etc. The coating may be applied for functional, decorative, or a mix of the two functions [7, 8, 9]. Application of functional coatings can be applied on substrate to impart important properties including adhesion, corrosion resistance, wettability, wear resistance, and electrical conductivity. Surface coatings for textiles can either be chemical or physical, depending on the form of crosslinks they form with the fibers. If the coating is done on the fiber surface, the chemical reaction is confined to the surface only. When coating synthetic and natural fibers, adhesion and wetting of the fiber surface as well as thickness of coating are essential elements to attain high-quality completed product [10, 11]. The fiber and matrix should keep their intermolecular distances consistent for better adhesion and wetting properties. In this research paper, conductive cotton fabrics were created by covering them with graphene ink by coating technique. The cotton fabric coated with graphene ink has improved conductance values. Utilizing Box and Behnken optimization techniques, the conductance of cotton fabric coated with graphene ink were evaluated as functions of concentration, thickness, and surface area [12, 13, and 14].

This research also focusses to optimize the conductance levels of developed samples and explore the possibility of developing wearable electronics from developed samples. optimize the electrical properties of cotton fabric coated with graphene ink using Box and Behnken Design. In this research few of the research questions that was used to evaluate were, Does the amount of graphene ink have an impact on how conductive cotton fabric is coated, Does the thickness of the coating have an impact on the conductive qualities of coated fabrics and how does the surface area of cotton fabrics covered with graphene affect their conductance.

2. Materials and Methods

Graphene-conductive ink was procured from Techinstro Nagpur, India for this research. All other chemicals required for the preparation of the coating bath were procured from fine chemical suppliers located in Addis Ababa, Ethiopia. The materials used in this study are shown in Figure 1. Graphene conductive, shown in figure 1a , is used for coating the cotton fabric by the manual printing method. These conductive ink coatings on fabrics give better conductivity values due to the formation of a uniform layer of coating and better graphene particle adhesion properties. The surface area, thickness of the coating, and amount of graphene loaded on the coating surface alter the conductive properties. Conductive inks are used for making circuit boards, sensors, and other printed electronic components. Fig. 1 b shows the graphene-conductive ink-coated fabric. Graphene-conductive ink was procured from Techinstro Ltd. The ink prints beautifully and adheres well to a variety of surfaces, including PET, acrylic, fabric, paper, silicon wafers, quartz, glass, metals, and many more. Any design or pattern can be printed in multiple layers on any substrate.

Figure 1 a) Conductive Ink b) Bleached Cotton fabric.

The fabric specifics are shown in Table 1.

Table 1. Cotton Fabric Construction Particulars

Fabric Construction Parameters	**Value**
Warp count (Ne)	34.74
Weft count (Ne)	65.61
(EPI) – Ends Per Inch	27
(PPI) – Picks Per Inch	16
(GSCm) – Grams per square cm	0.023

Conductive graphene ink coating experiments are carried out using the Box and Behnken design of an experimental plan generated using MINITAB software (figure 2 & 3) (Table 2). Factors affecting the conductivity of the coated fabric are carefully selected and developed. Measurement of the conductivity of the coated fabric is carried out as per the standards of ASTM

Measurement of Conductive property of coated fabrics

The conductive property of graphene ink-coated fabrics is measured using ASTM D-254/AATCC 76 and S11.11 ESD Associations Test Method (Electrostatic Discharge Association) test methods, which aim to determine the surface resistivity of materials. An ohm per square is the unit used for measuring resistance. Surface resistivity is the electrical measurement in ohms per square area measured across a coated material's square area. This measurement aims to determine the electron movement opposition over a material, which is then normalized to a unit square. In this measurement, the electrons are assumed to be flowing over a surface with a uniform coating. When we measure resistance, which is usually a measurement from point to point, Resistance is dependent on cross-section, length, size, etc. In figure 4, a, the measurement of resistance over a material with similar dimensions is shown. A square area of the material is considered. The electrodes are attached at two ends, and their resistance is measured in ohms. If it is 1 cm or 1 inch on a side, and the multi-meter (figure 4 c & d) measures 1 ohm, then we say that the surface resistivity is 1 ohm/square. The thickness gauge (Figure 4 b) is used to measure the thickness of the coated material.

Experimental Method

Coating of Graphene Ink by Manual Coating Technique

The Box-Behnken type of experimental design is usually applied in circumstances when the number of experimental runs is limited and the predictions are to be of higher order. This design consists of 3 nodes, which is a second-order fitted equation. From box-behnken experimental design, the optimum characteristics that influence the electrical conductance of graphene-coated ink are ascertained. The independent variables used in this are concentration of graphene ink (gm), surface area (sq cm), and coating thickness (mm) (shown in Table 2 and 3). Samples for different combinations of these variables were developed and tested for their electrical conductivity expressed in Siemens/cm. Here electrical conductance is used as a response variable to find the main effects and interaction effects with independent variables. To develop and generate Box-Behnken designs, Minitab software is used. The Minitab B&B design is based on quadratic equations of second order. Conductance, which is also called "electrical conductance," is a material's capacity to let the passage of electricity through it. A material's conductance is determined by how easily an electrical current may flow through it. Electrical resistance is denoted by the letter R, and conductance is its inverse. Ohm^{-1} (mho), ohm per meter, or siemens is the SI unit for conductance.

Figure 2. a) Experimental set-up b) Graphene conductive ink coated sample

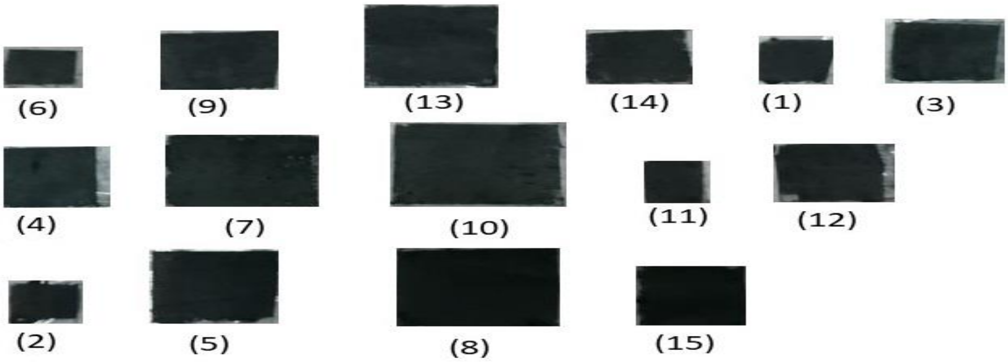

Figure 3 Process followed of preparation of Graphene conductive ink coated fabric by manual printing method

Table 2. Box and Behnken Design Experimental Variables

Variables and units	Min	Max
Concentration of Graphene Ink(gm)	0.05	0.10
Surface Area (Sq cm)	1	3
Coating Thickness (mm)	0.55	1

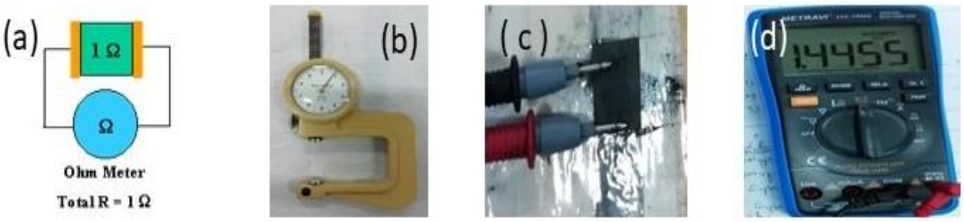

Figure 4. Measurement of conductive property of coated fabrics: a Electrical resistance measurement; b Thickness gauge; c Jumper cords placed on coated fabric for measurement of Electrical resistance; d Multi-meter used for measurement of electrical resistance

Table 3 Box and Behnken design: experimental results of independent variables and response variables

Run Number	Loading of Graphene] (gms)	Surface Area (sq cm)	Coating Thickness (mm)	Electrical Resistance(R,Ω/sq)	Electrical Conductanc (G,Siemens)
1	0.075	1	0.55	0.50	2
2	0.1	2	1	0.33	3
3	0.1	1	0.775	0.40	2.5
4	0.05	3	0.775	0.56	1.8
5	0.075	2	0.775	0.53	1.9
6	0.075	2	0.775	0.56	1.8
7	0.075	2	0.775	0.55	1.82
8	0.05	2	1	0.59	1.7
9	0.075	3	0.55	0.48	2.1
10	0.05	1	0.775	0.40	2.5
11	0.05	2	0.55	0.65	1.55
12	0.1	2	0.55	0.67	1.5
13	0.1	3	0.775	0.32	3.1
14	0.075	1	1	0.33	3.05
15	0.075	3	1	0.33	3

3. Results and Discussion

The direction and strength associated between concentration of graphene ink, surface area, coating thickness used, and conductance are described by a regression coefficient shown in Table 4 above and figure 5 & 6. The independent variables, like concentration of graphene and coating thickness (mm), show positive co-efficient. However, surface area shows a negative co-efficient.

The independent variables like concentration of graphene ink, coating thickness, and surface area show a standard error of the coefficient lower than the interaction effect standard error of the coefficient. Because of this, the model can estimate the coefficient for independent variables more accurately than it can estimate the interaction effects.

The null hypothesis is stated because there is no relationship between the independent variables, and the p-values and significance levels of the independent variables are used to test the null hypothesis and determine whether the independent variables have significant relationship with conductance (G) and each independent variable in the model. A p-value is typically evaluated using known value of alpha of 0.05. There exists a 5% probability for deciding if there is a significance level between the variables. The concentration of graphene ink and coating thickness are significantly correlated with the response variable conductance, as observed from p-values in the table below. Surface area and conductivity do not, however, significantly correlate. Thus, ion concentrations, ion type, and coating thickness are the two key determinants of conductance. Here, ion concentration is increased and a foundation for improved conductance is provided by graphene-conductive ink. In general, we are aware that conductivity is independent of the conductor's dimensions, i.e., its length, area, and volume.

Table 4 Coefficients, P-values of main effect factors, and interaction effect factors

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.8400	0.0365	50.42	0.000	
Conc of graphene ink(gm)	0.3188	0.0223	14.26	0.000	1.00
Surface Area(Sq cm)	-0.0062	0.0223	-0.28	0.791	1.00
Coating Thickness(mm)	0.4500	0.0223	20.14	0.000	1.00
Conc of graphene ink(gm)*Conc of graphene ink(gm)	0.0175	0.0329	0.53	0.617	1.01
Surface Area(Sq cm)*Surface Area(Sq cm)	0.6175	0.0329	18.77	0.000	1.01
Coating Thickness(mm)*Coating Thickness(mm)	0.0800	0.0329	2.43	0.059	1.01
Conc of graphene ink(gm)*Surface Area(Sq cm)	0.3250	0.0316	10.28	0.000	1.00
Conc of graphene ink(gm)*Coating Thickness(mm)	0.3375	0.0316	10.68	0.000	1.00
Surface Area(Sq cm)*Coating Thickness(mm)	-0.0375	0.0316	-1.19	0.289	1.00

The variance inflation factor (VIF) indicates the degree of correlations between the predictors in a model have increased the variance of a coefficient. In a regression study, the VIF is used to describe the level of multi-collinearity (correlation between predictors). Because multi-collinearity can make the regression coefficients more variable, it can be hard to figure out how much each associated predictor added to the answer. The VIF is interpreted using the following rules: If VIF = 1, there is no connection; if VIF is between 1 and 5, there is moderate correlation; and if VIF > 5, there is a strong connection. A VIF score greater than 5 denotes severe multi-collinearity, which makes it likely that the regression coefficient is underestimated. Multi-collinearity is related to higher Variance Inflation Factor (VIF) values. Higher values of VIF indicate levels of multi-collinearity that could have a detrimental effect on the regression model; the generally accepted cut-off value is 2.5. In this research and based on Table

4.3, the VIF was 1.00, which indicates that the association between independent and dependent variables is acceptable. In this research, a VIF of 1.00 indicates that regression results are reliable.

Model Summary

Table 5 Model summary for Box and Behnken Experimental Design

S	R-sq	R-sq(adj)	R-sq(pred)
0.0632060	99.58%	98.82%	94.90%

The difference between the data's values and the values used to fit the data is measured as the standard deviation, or S. The units of the variable are used to measure S. The standard deviation is represented by the letter S. The units of the reaction are used to measure S. S is a metric for evaluating how effectively the model captures the response. S measures the deviation of the variables against the fitted values of the response variable that is expressed in the units of the response variable. Lower the value of S means the better the model describes the response variable.

The variation of model's response is interpreted by seeing the R^2 value (Table 5). The total variation in the model is represented by One minus the fraction between the error sum of squares and the overall sum of squares. To determine how well the model fits we use R^2. The greater the R^2 number the better the model fits. R^2 always ranges from 0% to 100%. The percentage of the Conductance(G)s fluctuation can be explained by the model, known as adjusted R^2. When comparing models with various numbers of predictors, adjust R^2. Even when there is no actual improvement to the model, R^2 always rises when a predictor is added. The number of predictors in the model is taken into account by the adjusted R^2 score to aid in model selection.

Analysis of Variance

Concentration of graphene ink, surface area, and coating thickness were used as independent variables in this study. The response variable was conductance. The Analysis of Variance table shows the different p-values obtained during data analysis and optimization. From the table, the p-values for the concentration of graphene ink (gm) and coating thickness (mm) were found to be significant since their p-values were 0.05. However, surface area was not significant. So, from the analysis, one can consider eliminating the not-significant factors from the model (Table 6).

When the data have replicates, which are several observations with the identical x-values, Minitab will display the lack-of-fit test. Replicas display "pure error" since only random chance could account for variations in the observed response values. Compare the p-value (P-value) to your significant level to see if the model correctly fits the data. A known alpha value of 0.05 as threshold value is typically effective. A value of 0.05 indicates that there is only a 5% risk that can be incorrectly. concluded about the model misfits.

Conclusions are drawn that the model does not adequately match the data if the p-value is equal to or less than 0.05. One might need to add terms or alter the data to achieve a better model. P-value >: No proof that the model does not match the data is present. One cannot draw the conclusion about the data and model fit if the p-value is greater than 0.05. From the Analysis of Variance Table, we can see a lack-of-Fit value of 1.71. This value is > α. The model values show whether the model fits the data well, or whether we cannot draw the conclusion that it does not. We can observe that the analysis of variance table's lack-of-fit value is 1.71. This value exceeds zero. The model values suggest that the model fits the data well, or we cannot draw the conclusion that the model does not.

A response surface can be described by an equation that demonstrates the relationship between the response and its contributing components. We can use a regression analysis to create a model of the response surface if we measure the response for various combinations of factor levels. The Response in Response Surface Methodology the response function Y = f (X1, X2... XQ) + is approximated. Below is a response surface equation that links independent variables and conductance (G) (equation 1). The equation contains variables with P values under 0.05. To increase the precision of the regression equations, additional variables that have a P value > 0.05 and are not significant are eliminated.

Regression Equation in Uncoded Units

G(conductanc e- Siemens)	=	8.102 - 63.95 Conc of graphene ink(gm) - 4.62 Coating Thickness(mm) + 0.6175 Surface Area (Sq cm)*Surface Area (Sq cm) + 13.00 Conc of graphene ink(gm)*Surface Area(Sq cm) + 60.00 Conc of graphene ink(gm)*Coating Thicknes s(mm)

-----(1)

Table 6. Main effect and Interaction effects ANOVA

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	4.73260	0.52584	131.63	0.000
Linear	3	2.43313	0.81104	203.01	0.000
Conc of graphene ink(gm)	1	0.81281	0.81281	203.46	0.000
Surface Area (Sq cm)	1	0.00031	0.00031	0.08	0.791
Coating Thickness(mm)	1	1.62000	1.62000	405.51	0.000
Square	3	1.41572	0.47191	118.12	0.000
Conc of graphene ink(gm)*Conc of graphene ink(gm)	1	0.00113	0.00113	0.28	0.617
Surface Area (Sq cm)*Surface Area(Sq cm)	1	1.40790	1.40790	352.42	0.000
Coating Thickness(mm)*Coating Thickness(mm)	1	0.02363	0.02363	5.92	0.059
2-Way Interaction	3	0.88375	0.29458	73.74	0.000
Conc of graphene ink(gm)*Surface Area (Sq cm)	1	0.42250	0.42250	105.76	0.000
Conc of graphene ink(gm)*Coating Thickness(mm)	1	0.45563	0.45563	114.05	0.000
Surface Area (Sq cm)*Coating Thickness(mm)	1	0.00563	0.00563	1.41	0.289
Error	5	0.01997	0.00399		

Lack-of-Fit	3	0.01437	0.00479	1.71	0.390
Pure Error	2	0.00560	0.00280		
Total	14	4.75257			

The adjusted sums of squares have nothing to do with the order in which the terms are added to the model. No matter what order words are put into the model, the adjusted sum of squares measures how much of the difference a term can explain. For instance, the adjusted sum of squares for conductance (G) in a model with three factors—concentration of graphene ink (gm), surface area (sq. cm), and coating thickness (mm)—shows how much of the remaining variation the term for surface area explains provided that concentration of graphene ink and coating thickness (mm) are also included in the model.

Normal Probability and Residuals versus order plot

Minitab depicts the standardized effects versus the normal scores, probabilities, or percentages. A normal distribution with one standard deviation is shown by the line. On the graph, effects are marked as significant if their p-values are less than 0.05. Figure 4.4 labels the normal plot of the Minitab normalized effects graph. There are no outliers visible on the normal probability curve. The residuals in this normal probability plot seem to commonly follow a straight line. To ensure the validity of the test results, the normalcy assumption must be met. The premise that the residuals don't depend on one another is tested using the residuals vs order plot. Independent residuals do not exhibit any patterns or trends when arranged chronologically. Scattering of the points could suggest that residuals are interrelated and therefore not independent because they are close to one another. On the plot, the residuals should ideally cluster randomly around the center line.

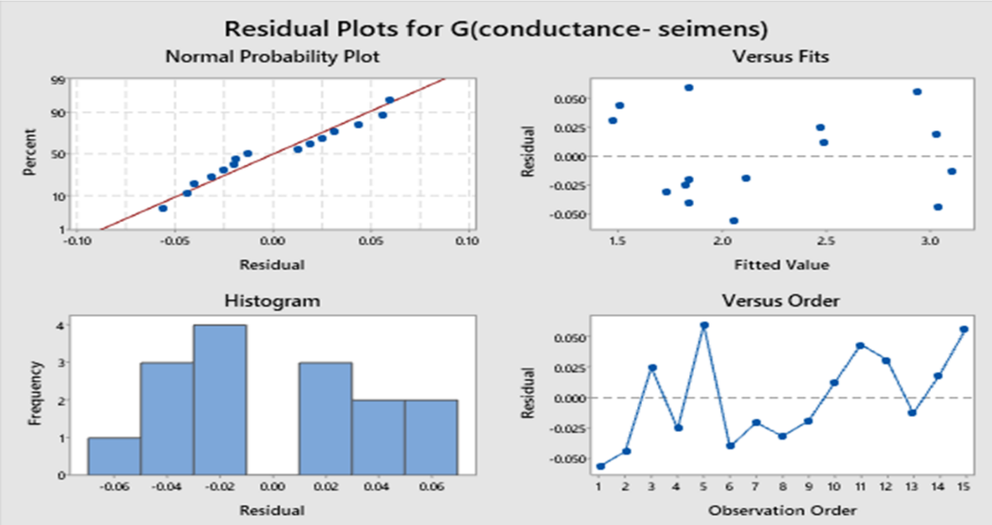

Figure 5 Normal probability and residuals plot

Main Effect Plots

Main effects plot is used compare changes in one or more factors relationship with the response. When the response is affected differently by various degrees of a portion, there is a primary effect. In a main effects plot, a line connecting each factor level to the response mean is graphed. Form figure, conductance (G) is compared by analysing the effects of concentration of graphene ink, surface area, and coating thickness (Figure 6). Because the line is not horizontal, the conductance of the graphene ink and coating seems to be affected. Surface area shows an initial decrease in conductance and then a gradual increase. There is no main effect when the line is horizontal (parallel to the x-axis) The factor level has an identical impact on the result, a constant response mean is observed for all factors. When the line is not horizontal there is a main effect in the conductance. The amplitude of main effect increases with as slope increases. Main effect graphs do not show interactions. To see how several components, interact, an interaction plot is shown in figure 7.

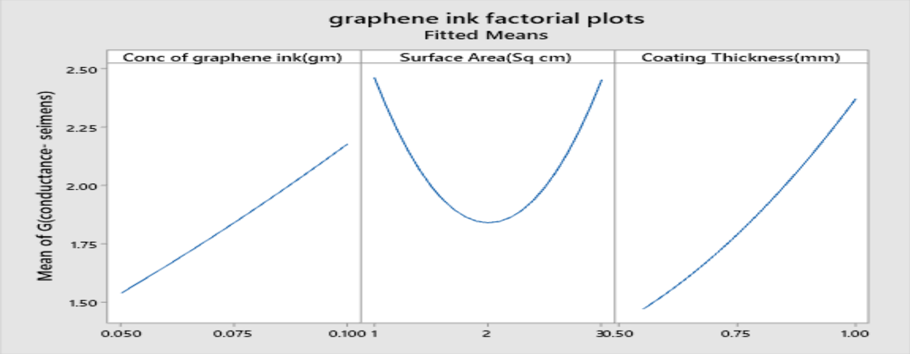

Figure 6 Graph of main variable effects

Interaction effect plots

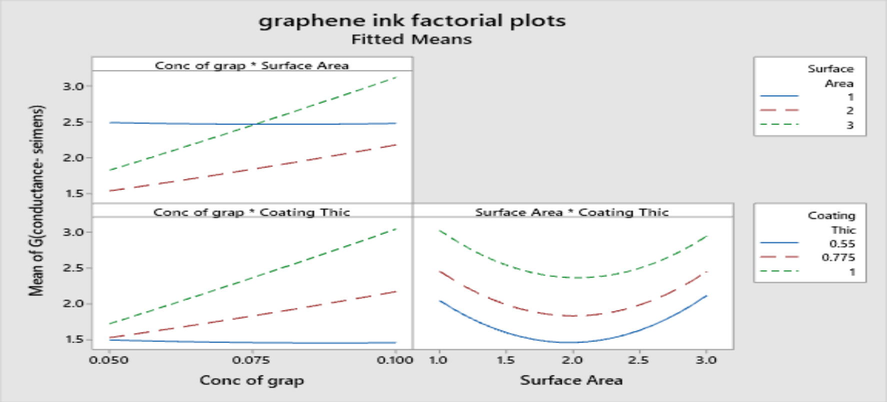

Figure 7 Graph of Interaction effects

The relation between a continuous response and categorical components is influenced by the value of the second categorical factor. The x-axis in this picture contains means for the levels of one factor and separate lines for each level of one component. Lines that are not coordinated (parallel) do not interact. The degree of the lines' non-parallelity affects how strong the interaction is (Figure 4.6). When evaluating the main effects, you must take the interaction effects into consideration if they are significant. The lines in this interaction plot are not straight. This interaction effect shows that the value of conductance (G) is influenced by the link between the amount of graphene ink and coating time.

Contour Plots

To visualize the behaviour of a response variable and two predictor variables, we use a contour plot. A contour plot gives the observer a two-dimensional viewpoint by joining all spots with the same reaction to form contour lines with continuous responses. Contour plots can be used to investigate the safe operating conditions and expected response values. The elements of a contour plot is listed below: Using contour lines and color bands on a contour that reflect the response value ranges, predictors on the y- and x-axes linked with response value. The space between data points is created by Minitab via interpolation. This contour map demonstrates the correlation between the conductance and concentration of graphene ink used to develop the samples (Figure 8). A greater effect is indicated by darker areas. A ridge indicates higher response that extends from the upper middle to the lower right of the graph.

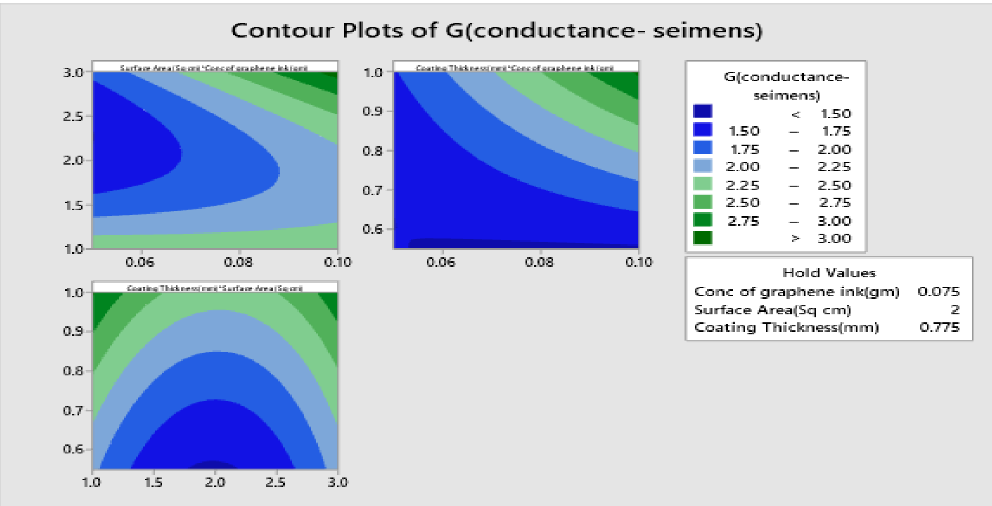

Figure 8 Graph of contour plot

Surface Plots

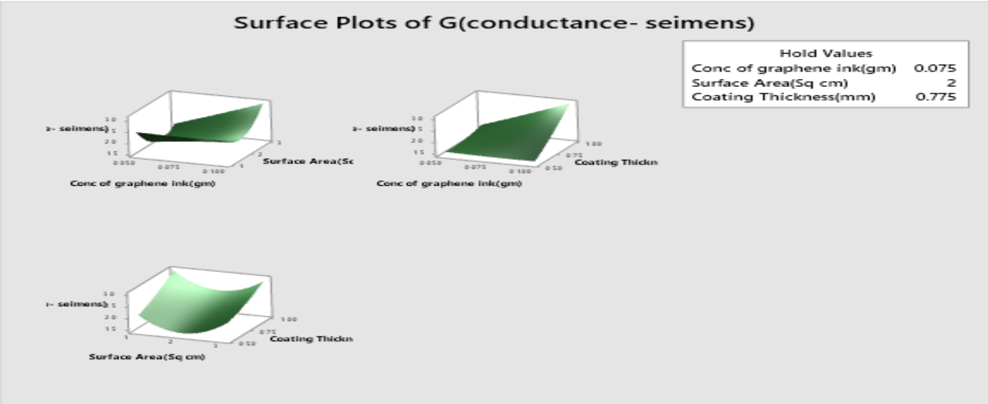

Figure 9 Surface plots of conductance

A three-dimensional graph called a surface plot is used to identify the response results and operational settings that produce the best outcomes. The following components are found in a surface plot: A continuous surface depicting the fitted response values on predictors(z-axis) on the y and x axes. The influence of graphene ink concentration, coating thickness, and surface area on conductance values is depicted in Figure 1 as 3D surface plots. The local maxima or minima are produced by combining of x and y that correspond to the peaks and valleys. Surface area between the data points is shown in Minitab by interpolation. The statistically significant quadratic factors in the model cause the response surface to curve (Figure 9). The plot's upper right corner has the highest cotton conductance values, which are correlated with high graphene ink concentration (gm) and coating thickness (mm) values. The fitted response values for conductance are calculated by Minitab using the values of conc of graphene ink (gm) at 0.075 g, coating thickness at 0.0775 mm, and surface area at 2 mm.

Optimization of Conductance (G)

Process optimization is the study of involving and coordinating the coating parameters so that an optimized set of properties is obtained without altering the process constraints. Maximizing the response is the main goal of this optimization activity. All other variables and process conditions are maintained constant in this optimization.

Table 7 Optimization parameters

Response	Goal	Lower	Target/ Upper	Weight	Importance
G(conductance-siemens)	Maximum	1.5	3.1	1	1

The purpose of response optimization is to maximize the target response, which is conductance, as shown in Table 7. Other criteria for response optimization are goal, target, upper limits, Wright, and importance.

Table 8 Starting values

Variable	Setting
Conc of graphene ink(gm)	0.05
Surface Area(Sq cm)	1
Coating Thickness(mm)	0.55

Table 8 above displays the many experimental configurations that were used to forecast the response, or Conductance(G), for a stored model. The optimization method for achieving the highest conductance value is shown in Table 9. When the prediction model is set at a graphene ink concentration of 0.1 gm, coating surface area of 3 sq. cm, and coating thickness of 0.55 mm, the optimal solution for highest conductance value is shown in detail in Table 9.

Table 9 Optimization Solution

Solution	Conc of graphene ink(gm)	Surface Area (Sq cm)	Coating Thickness(mm)	G(conductance-seimens) Fit	Composite Desirability
1	0.1	3	1	3.9425	1

Given the given parameters, the predictors' ideal settings are determined using the optimization plot. The fitted values for the predictor settings are shown on the optimization plot. To check whether the range of anticipated values for a single future value fits within allowable bounds for the procedure, one should however look at the prediction intervals in the output (Table 7, 8, 9). The composite desirability for the conductance data is 1. The response values for each level of independent variables are displayed in the first column of the graph. The objective is to maximize conductance (G), and the present variable settings are as follows: concentration of graphene ink = 0.05 gm, surface area = 1 sq cm, coating thickness = 0.05 mm. It has a predicted value of 3.9425 siemens and a desirability of 1 for each individual (Figure 10).

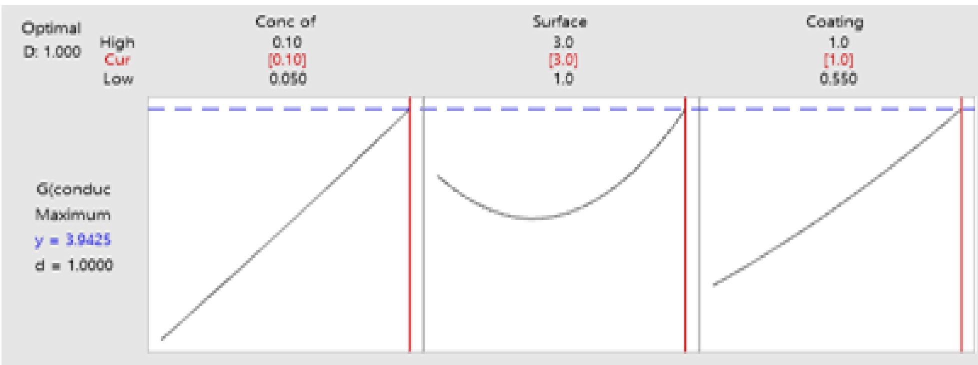

Figure 10. Optimization plot for Conductance

Arduino Integration Test

The popularity of Arduino has increased with the invention of various sensors. Some of the most prominent of them are the temperature and humidity sensors, the photo-resistor, the sound sensor, the ultrasonic sensor, the water sensor, the flame sensor, and so on. One of the things that makes an Arduino so useful is how easy it is to get sensor values. A physical value, such as the amount of light or the temperature, can be converted into an electrical value using a sensor. For instance, a thermocouple produces a voltage that is inversely proportional to its temperature.

Figure 11. Graphene ink-coated fabric connected with jumper wires

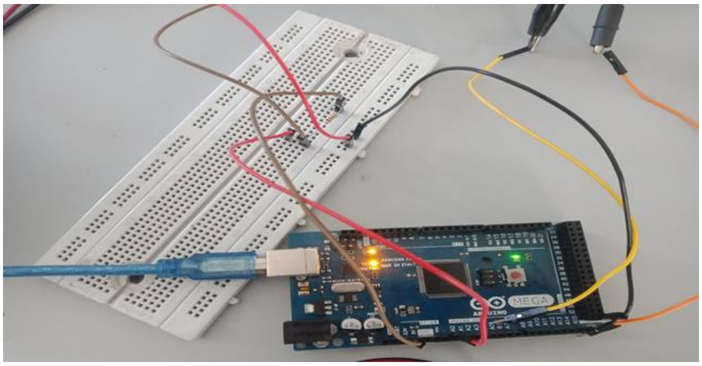

Figure 12. Arduino connected with USB port of computer and breadboard circuit

The continuous integration platform designed for Arduino development is shown in Figures 11 and 12. The connections were made using an Arduino Uno and breadboard. The circuit was tested before connecting to graphene-coated samples. Arduino devices are connected to the computer via USB. The signals and outputs for the graphene ink-coated sample proved the ability of the graphene-coated cotton fabric and its sensor capability (Figure 13).

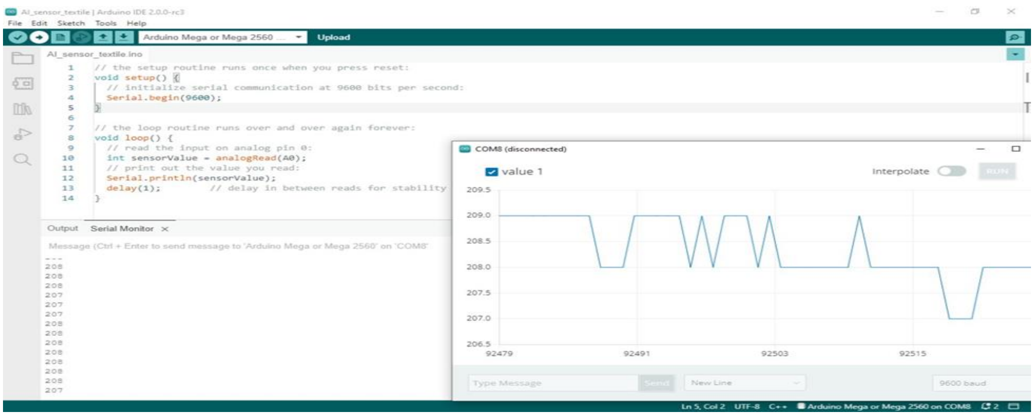

Figure 13. Arduino program code and output for graphene ink coated fabric

4. Conclusions and implications

The conductivity levels depend on the conductive polymers, their material states, coating methods, substrates, and the concentration of graphene loaded on the fabric substrate. Cotton fabrics loaded with various concentrations of graphene and their surface areas coupled with thickness influence electrical conductivity levels. From the results, the surface coating variables like concentration of graphene ink, coating thickness, and surface area significantly affect the conductance levels of the coated fabric. A conductance of 3.9425 siemens is obtained at optimized values of the independent variables, which are: the weight of the graphene ink (gm), the surface area (sq cm), and the coating thickness (mm). It is possible to obtain higher conductivity levels on fabric through surface modification processes. In this research, the test samples were coated with graphene conductive ink by manual coating according to Box and Behnken's design plan. The electrical conductance values showed an expected effect relationship with the independent variables like concentration of graphene ink and thickness of coating. However, in the case of the surface area, i.e., the area of graphene coating, the relationship showed a parabolic curve effect. The electrical conductance decreased when the surface area was between 1 and 2. When the surface area increased to 3, the electrical conductance values also increased. There is less variation in the response that is explained by the model, as seen by the high percentage of R^2 value in the model summary from the box and Behnken design study.

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