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Value Chain Analysis of Lowland Bamboo Products: The Case of Homosha District, Northwestern Ethiopia

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Abstract
Ethiopia is well endowed with bamboo resources and products. To date, however, the contribution of these resources for local and national economies was below its potential. In the Homosha district, despite the abundant and valuable lowland bamboo resources, the livelihood of smallholder farmers in the area was desperate. This study, therefore, was initiated to analyze the value chain of lowland bamboo products from Homosha district (Benishangul Gumuz region). Primary data were collected via household survey from 124 household heads who harvest bamboo products, as well as 10 local traders, 11 craftspersons and 30 end users in three villages via key informant interviews, focus group discussions market assessment and stakeholder consultation workshops. Field observations supplemented by informal discussions were employed to complement and verify the findings. Secondary data comprises various documents on the study area and related materials from the internet were used. It was found that there were three market channels in value chain of lowland bamboo products. The first channel was the channel that directs bamboo products from harvester to local traders to end users/consumers; the second channel directly connects bamboo harvesters and end users/ consumers, while the third channel connects harvesters and end users/consumers via craftspersons. The largest numbers of bamboo culm bundles were transacted through the first channel, while, the third channel, in which relatively more value addition is carried out, stands last in terms of the volume of bamboo transacted. Moreover, it was found that bamboo products have different market concentration ratio, ranging from 51 % for raw bamboo culms to 79 % for bamboo baskets. The transactions of bamboo culms and products took place under a tight oligopoly. Analysis of the market conduct showed that bamboo traders and end users had higher bargaining power in price setting for bamboo products than harvesters with an unequal value addition on the different knots of the value chain. That is, local traders collecting bamboo culms altogether added lowest value per bamboo culm as compared to craftspersons that convert raw bamboo into different products and resulted in highest marketing margin. Value chain of lowland bamboo showed a poor diversification in products and was rather dominated by middlemen. This calls for improving the marketing of lowland bamboo. Attention should be given to three up-grading interventions: (1) widen the market linkage by increasing the bargaining power of the harvesters, (2) improve the market conduct, to make the market more competitive and transparent, and, (3) increasing the capacity of the marketing actors to create innovative value added products of bamboo to the market.
Keywords: Concentration ratio, Marketing channels, Marketing margin, Oxythenanthera abyssinica, Value chain actors, Value addition

1. Introduction

Bamboo subsumes woody grasses distributed widely in tropical, subtropical and mild-temperate zones, except Antarctica (Inga and Camille, 2011). It is one of the fastest growing and highest yielding renewable resource (INBAR, 2006). The recent classification describes about 1200 bamboo species exist in the world (Bystriakova et al., 2004). Among which 38 species are found in Africa; of which fivespecies are found in the mainland of Africa and the remaining 33 species are found in Madagascar.

Specifically, Ethiopia has got two bamboo species, both of them are native to the country, namely lowland bamboo (*Oxythenanthera abyssinica* [A. Richard] Munro) and highland bamboo (*Yushania alpina* [K. Schumann] Lin) which was formerly named as *Arundinaria alpine* (Kalbessa et al., 2000, Starke, 2014).No specific and precise data about the area of bamboo in Ethiopia are available (Starke, 2014). According to Embaye et al. (2005), Ethiopia has over one million hectares of highland and lowland bamboo resources in Africa. Separately, it is estimated that lowland bamboo and highland bamboo covers 850,000 hectares (85%) and 350,000 hectares (15%) of Ethiopian bamboo resources, respectively (INBAR, 2011). Notably, Benishangul Gumuz Regional State is characterized as an area with the largest natural stands of lowland bamboo coverage that comprise 48 % of the total lowland bamboo resources of the country (Anonymous, 1997). The very difference of the two native Ethiopian bamboos is shown in Fig. 1. The lowland bamboo has a completely solid culm, with high bulk density and greater stability while the highland bamboo has a hollow culm, which is easier to process (Starke 2014).

Fig 1. Transversal section of highland bamboo *Yushania alpina* (left) and lowland bamboo *Oxythenanthera abyssinica*
Source: Starke (2014, p. 3)

Although Ethiopia is well known in bamboo resources, the use of this resource is usually limited to traditional house construction, fences, and some rudimentary furniture and household utensils (Kalbessa et al., 2000; INBAR, 2006). In Ethiopia there are new bamboo products under development, e.g. thermal modified panels (Starke, 2014), bamboo flooring and sealing panels from Adal (personal communication) or the establishment of production of cement bound bamboo fiber board (plant in Asosa), but up to now all developments do not create significant impact on the bamboo culm production. This shows that despite their potential, Ethiopian bamboo resources are continued to be utilized and managed on a low level (INBAR, 2007). Notably, in Homosha district, despite the abundant and valuable lowland bamboo resources, the livelihood of smallholder farmers in the area is desperate. This means, that the communities in the district are not able to employ the bamboo resource for the benefit of their livelihoods. Rather, huge areas of bamboo forests have been progressively converted to enable large scale agricultural investment in Northwestern western Ethiopia (Anonyms, 1997). In Ethiopia, to compensate the temporarily lost bamboo income opportunity due to mass flowering, many communities convert the recovering bamboo forest area into agriculture fields or grazing pastures (Sertse et al. 2011).

Moreover, further study was not done on the value chains of lowland bamboo resources, nor identified the constraints in the whole system that inhibited bamboos' potential for benefit of livelihoods of smallholder farmers in particular and its contribution for the national economy in general. This is true for the Benishangul Gumuz region and especially for the Homosha district. There bamboo is not considered as significant non-timber forest product and is seen as underutilized. This study, therefore, was initiated to analyze respective value chains of lowland bamboo products. The study addressed the following objectives: (i) identifying actors and their functions in the value chain of lowland bamboo, (ii) mapping the market channels of lowland bamboo products, and (iii) investigating the market structure, conduct and performance for lowland bamboo products. In addressing these objectives, a detailed account of bamboo value chain is provided with deepened knowledge about bamboo product marketing and bamboo related income. This paper will also contribute towards understanding the wider issues of the marketing channels and value chain of lowland bamboo products in Ethiopia and beyond.

2. Methodology

The study was conducted in Homosha district in Asosa zone, Benishangul Gumuz Regional State (BGRS). The district is located at a distance of 711 km from Addis Ababa to Northwestern and 36 km from the regional capital, Asosa to the West. The total land area of the District is 48,325 hectares and comprises 15 villages. Data collection for the study was carried out in the three villages Tumet, Ashura and Jima (Fig. 1).

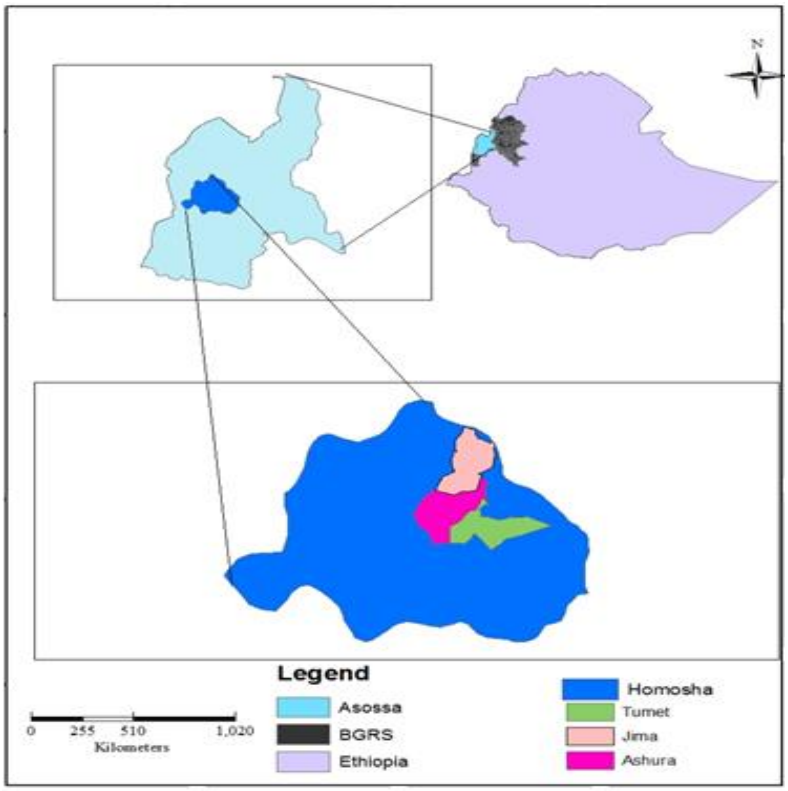

Fig2: Map of study area

In the study area lowland bamboo is harvested from natural stand. For bamboo production there is no further bamboo management in place, rather destructive activities like intensive browsing and frequent fires, which suppresses bamboo growth and regeneration. The recent large scale flowering and dying of bamboo is seen as a possible reaction of the bamboo stands on the harsh conditions created by unsustainable resource (Forest Research Center of Ethiopia, personal communication).

The study employed multi-staged sampling techniques for primarily data collection. In the first stage the study area, Homosha district, was selected purposively based on the availability of bamboo resources, its production and marketing activities. In the second stage, three villages, namely Tumet, Ashura and Jima, were purposively selected for the study due to the high intensity and level of bamboo harvesting and marketing activities. In the third stage sample households were randomly selected for sampling of household surveys.

Secondary data employed in this study were documented sources from the study area and other related materials from the internet. Primary data were collected by household surveys, focus group discussions, key informant interviews, field observations, market assessments and a PIP[1]stakeholder consultation workshop[2]. For the household surveys a questionnaire with both closed and open questions was prepared, adapted with individual checklists for bamboo culm harvesters, local traders, craftspersons, and end users of bamboo products. Additionally individuals from different sectors as well as local people with knowledge and experience about bamboo products marketing were selected as key informants and then interviewed on the issues related to lowland bamboo products marketing. Also focus group discussions were held in each selected villages with separate groups of elders, youth and women.

The sample size was determined by considering margin of error (8%) by using the formula by Israel (1992) which was estimated as:

$$n = \frac{N}{[1 + N(e^2)]}$$

Where n is the sample size, N is the total household size of the district and e is the level of precision. The sample size is proportional to the household size of each selected villages.

[1]PIP is participatory innovative platform -an actor-centered method for upgrading forest/natural resource based value chains with focus on empowerment and cooperation of involved actors, supporters and regulators. See: Asmamaw and Auch (2016).
[2]CHAINS Workshop on bamboo value chain held at Wondo Genet College of Forestry and Natural Resource, Hawassa University on March 23-25, 2015.

Table 1: Sample size distribution of bamboo user households in the selected villages.

Name of Village	Number of households	Sample households	Sample craftspersons	Sample traders	Sample end users
Tumet	223	61	3	5	10
Ashura	108	30	4	2	10
Jima	119	33	4	3	10
Total	450	124	11	10	30

Craftspersons, local traders, and end users were purposively selected from Tumet, Ashura and Jima villages and interviewed. Due to the absence of registers it was not possible to indicate the proportion of these actors that the samples represent. However, in order to get representative results all craftspersons and local traders identified by the snowball method were interviewed.

Data were analyzed using both quantitative and qualitative analysis. Survey data were analyzed quantitative with descriptive statistics (tables, minimum, maximum, frequency, percentages, means, ratios and standard deviations). Data collected during focus group discussions, key informant interviews, and participative observations were analyzed qualitatively, with regard to value chain structure and pattern as well as interactions and relationships of actors.

Definition of indicators and management ratios used for analysis

Market channels: Refers the flow of bamboo products that reaches from the point of product origin to the consumer with the purpose of moving products to their final consumption destination.

Value chain: indicates full range of activities, which are required to bring bamboo products from conception, through the different phases of production delivery to final consumers.

Market concentration: refers to the number and size of distribution of buyers and sellers in a market.

Market margin: Marketing margin refers to the difference between prices of bamboo product/products obtained by market actors at two different market levels in various market channels. Gross Market Margin (GMM) is the difference between the prices of product/products before marketing costs are deducted between two market levels. However, net marketing margin is difference between the prices of product/products after marketing costs are deducted between two market levels. Total Gross Marketing Margin (TGMM) is the sum of marketing margins obtained at different market levels before marketing costs deducted.

Market transparency: Refers to the degree of getting market information, which enables value chain actors to make a decision on the selling and buying of bamboo culms and manufactured bamboo products.

Bamboo culm harvester: Refers to members of local households harvesting bamboo culms from natural forest, either for domestic consumption or for sale

Local traders: Denotes households whose members buy and sell bamboo culms and/or related manufactured bamboo products locally.

Craftspersons: Households producing traditional bamboo products using their skills and indigenous experience, under use of simple tools and working materials.

End users: End users or final consumers are the ultimate/last users of bamboo culms and/or manufactured bamboo products (no reselling of products).

Market concentration ratio *(CR):* The degree of market concentration of lowland bamboo culms were estimated using the "concentration ratio" (CR). The CR is calculated by taking the annually sold bundle of bamboo culms and products manufactured from bamboo culms by value chain actors and it is used to identify type of market structure of bamboo products in the study area.

3. Results

Tables 2 and 3 present the socioeconomic characteristics of the studied groups. Result shown in Table 2 varies with the respondent's group membership; age and experience were significantly different at 1% significance level. Average ages of local traders, craftsperson and producers were 40, 50 and 38 years, respectively. The average family size of local trader was lowest for traders (6 members) and highest for craftsperson (9) and harvesters (8). Harvesters have an average experience of 4.5 years in harvesting bamboo culms for sell. Nevertheless, the information from local elders shows that they had long experience in harvesting bamboo for domestic utilization. Amongst the studied groups the local traders had the shortest experience with 3.3 years for commercial bamboo culm trading. Longest experience showed craftsperson with 16.6 years in manually processing of bamboo products for sell.

Table 2: Socioeconomic characteristics of main actors (*continuous variables*)

	Harvesters (N=124)		Local traders (N=10)		Craftsperson(N=11)		
Variable	Mean	Std. deviation	Mean	Std. deviation	Mean	Std. deviation	t-test
Age [years]	40	10.71	38	9.88	50	15.29	-2.201***
Family size[no.]	8	1.10	6	3.02	9	5.00	-1.228
Experience [years]	4.52	4.39	3.3	0.82	16.64	11.52	3.489***

Note: N is sample size of respondents. *** is statistically significant at 1% significance level.

Results from Table 3 show that from all interviewed bamboo harvesters about 75% belong to male-headed households and 25% belong to female-headed ones. On the contrary, all the interviewed local traders and craftsperson were male. Gender of the household heads of studied actors had a significant difference at 5% significance level. About 89.5% and all (100%) of the interviewed harvesters and craftsperson were married, whilst, the remaining 11.5% of harvesters were unmarried. Only 41% of harvesters had access to extension services for bamboo management and utilization, however, none of craftsperson had access to extension services related to bamboo product designing and processing. This shows a significance difference at 1% significance level. About 12% of harvesters and 40% of local traders had marketing linkages. Similarly, 40% of both studied harvesters and local traders had access to market information. Marketing linkage and access to market information revealed significant difference at 1% significance level. Regarding education level, about ¾ and ½ of the interviewed craftspersons and local traders have not received formal education. Education level showed significance difference at 5% significance level.

Table 3: Socioeconomic characteristics of main actors (*categorical variables*)

Variable	Category of variable	Direct actors						x^2-test
		Harvesters (N=124)		local traders (N=10)		craftsperson (N=11)		
		N	%	N	%	N	%	
Gender	Female	31	25.0	0	0	0	0	6.68**
	Male	93	75.0	10	100	11	100	
Marital status	Unmarried	13	10.5	2	20	0	0	2.62
	Married	111	89.5	8	80	11	100	
Access to extension services	Yes	51	41.1	3	30	0	0	16.2***
	No	73	58.9	7	70	11	100	
Marketing linkage	Yes	15	12.1	4	40	0	0	19.16***
	No	109	87.9	6	60	11	100	
Access market information	Yes	50	40.3	4	40	0	0	9.0***
	No	74	59.7	6	60	11	100	
Formal education level	None	52	41.9	5	50	8	72.7	6.65**
	Primary school	54	43.5	2	20	2	18.2	
	Secondary school	18	14.5	3	30	1	9.1	

Note: N is sample size of respondents. *** and ** are statistically significant at 1% and 5% significance level, respectively.

The quantity of commercialized bamboo culm bundles supplied by male- and female-headed households was statistically and significantly different at 1% significance level (Table 4). More culms were supplied by male-headed households. As well, the quantity of bamboo culms supplied by harvesters with different services (access to extension service, access to market information and marketing linkage) were significantly different at 1% significance level from harvesters without these services.

Table 4: Association between quantities supplied for sale and some socioeconomic activities

Variable	Variable category	Harvesters (N=124)	Mean of bamboo Culm bundles supplied to market	Standard deviation	t-test
Access to market information	No	74	36.3	21.5	-2.9***
	Yes	50	49.9	31.5	
Marketing linkage	No	109	36.4	21.6	-7.2***
	Yes	15	80.9	28.6	
Gender	Female	31	21.5	15.6	5.4***
	Male	93	48.5	26.3	
Access to extension services	No	51	21.4	8.5	-9.2***
	yes	73	56	26	

Note: *N is sample size of harvester households, *** indicates all values are significantly different at 1% significance level.*

3.1 Market structure of lowland bamboo products

In the studied value chain of lowland bamboo, harvesters, local traders, craftspersons and end consumers were identified as actors of the bamboo value chain. These value chain actors are divided into two groups: direct actors and indirect actors.

Direct actors

The direct actors are those who were involved in marketing activities of bamboo culms and/or bamboo products manufactured from culms in the chain. These include harvesters, local traders, craftspersons and end users.

Harvesters: Harvesting and transportation of bamboo culms from natural stands is done manually, including the transport of culms on foot. The activity is done with family labor of the harvester households, so they do not need liquid cash to pay additional labor. In the study area bamboo is mostly harvested during the dry season from November to April, when farm activities are off. Farmers use bamboo harvesting as a seasonal activity to complement agricultural activities. For marketing the bamboo culms are tied together, one bundle contains ten single bamboo culms and it is the locally marketing unit. In Homosha the local market demand for lowland bamboo culm and other bamboo products was low, because the natural bamboo resource is freely accessible to the community. Bamboo commercialization in Homosha is an activity that provides farmers the opportunity to earn some cash, although it is unattractive because bamboo culms are sold at very low prices. None of the farmers have own bamboo plantations ready for harvest, they all harvest standing bamboo from the natural bamboo forest, usually without paying fees for a harvesting permits. Only recently some few farmers have started to plant bamboo in their home garden for domestic use purpose only.

Local traders: All responding traders participated in bamboo culm trading only; there was no evidence for trade of crafted bamboo products to other areas. Their role in the lowland bamboo value chain is buying bamboo culms from harvesters and bundling the culms to larger lots for buyers seeking larger amounts at once. Local traders participated in bamboo trading mainly during the dry seasons. Like the harvesters their livelihoods mostly depends on agriculture, complemented by bamboo trading. Bamboo product trader reported difficulties in finding appropriate working premises. Aside of the sector's poor recognition, low market demand, lack of knowledge about culm handling, lack of financial capability and poor infrastructure affects value chain improvement.

Craftspersons: These actors manufacture several traditional products from bamboo culms by using indigenous crafting skills and simple tools. Their main products were mats, tables, chairs, traditional beehives and baskets. Craftsperson sold their products at directly to consumers, without intermediaries. Most of the time the craftspersons produced bamboo products for their stock and only sometimes they produced upon request. In Homosha, both quality and types of the bamboo products was extremely low. Despite the fact that bamboo processing is based on a longstanding traditional knowledge, the performance of the craftsperson in the study area was poor. The lifetime of the products is short not more than a couple of month, due to poor working quality and lack of treatment against borers and fungi. This results in poor reputation of and low demand for bamboo products. High wastage of raw bamboo material was observed during study. There is lack of efficient utilization (high wastage) of bamboo culms by craftspersons. By removing the upper and bottom part of the culm, rural craftspersons used only around 1/3 (middle part) of the whole bamboo culm.

End users: End users purchased bamboo culms and/or bamboo related products for domestic use. Most are from the local place, but some come from outside the study area to purchase culms for construction of their fences, houses and cattle barns. Crafted bamboo products were bought directly from the craftspersons, without intermediaries. In general consumers perceived bamboo products as of low quality and short durability, even

below their real quality and durability. Due to this the local users show only reserved preference to them, which resulted in a comparatively low demand for it.

Indirect actors

Indirect actors are supporters and regulating organizations and agencies. For the study area only two were identified as being present and visible; while the many other institutions with impact could not identified during the field work.

District Office of Agriculture and ***District Office of Custom and Revenue:*** They provide regulation services for direct value actors. Local communities request the Agricultural Office for permission to cut specified number of bamboo culms. The Agricultural Office provides the permission. By issuing harvesting permits Agricultural Office have some control over the bamboo utilization by community members. Correspondingly, District Office of Custom and Revenue monitors and regulates bamboo marketing in Homosha slightly by collecting permit fee from users who take bamboo to other areas. But in general, bamboo culm harvest and marketing were informal.

Market channels of lowland bamboo products

Three marketing channels of lowland bamboo products were identified, as displayed in (Fig. 2). Compared to the large potential of the bamboo resource in the in Homosha district, the marketing channels were quite short and few in number. About 3,995 bamboo culm bundles, 262 mats, 61 tables, 155 chairs, 170 traditional beehives and 113 baskets were transacted by the interviewed respondents. The percentages indicate the volume of bamboo products transacted in 2014 in the respective channels. The red line indicates the organizations that control the bamboo marketing and utilization through the permit system. District Agricultural Office controls bamboo management and utilization community by providing permission for communities to harvest based on their request as well, District Office of Custom and Revenue monitors and regulates bamboo marketing in Homosha by collecting permit fee from users. But in general, bamboo culm harvest and marketing were informal. The green one shows the flow of raw bamboo culms, starting from the forest through different actors to the final users. The black line represents the flow of products from bamboo produced by craftsperson to the final users.

Market channel 1: Harvesters → Local traders → End users

This channel is the most important channel in which about 49% of bamboo culm bundles were transacted to local traders. These local traders concentrated bamboo culms together in particular places and resold these culms to end users. End users came from different places outside the study area. This may explain the high number of bamboo culms transacted through this channel.

Market channel 2: Harvesters → End users

This channel is found to have nearly the same importance of the first channel; about 46% bamboo culm bundles are transacted through it. It is the shortest of the identified channels in with which harvesters directly sell to end users, without any middlemen.

Market channel 3: Harvesters → Craftspersons → End users

This channel transacts the smallest amount of bamboo culm bundles. From the total transected culm bundles, about 5% culm bundles were traded through this channel. Craftspersons produce various products from the purchased bamboo. All production is directly sold locally to end users.

Market concentration ratio **of bamboo culms and products**

For the market channel 1 the value of CR_4 (market concentration ratio of the four leading local traders) was 50.88%. This indicates that in the district bamboo culm trading is characterized by a rather concentrated market, categorized as "tight oligopoly". This means that the bamboo trading activity is concentrated in the hands of some few local traders, while, due to the unrestricted open-access resources of bamboo forests, many harvesters are in the market arena, heavily competing against themselves. Since the absolute market demand is limited, only few traders have participated in the bamboo culm trading.

For the market channel 2 the CR4 value is about 17.04%. This indicates that bamboo culm marketing through channel 2 is characterized as competitive. All the interviewed respondents were engaged in bamboo culm selling. The market concentration ratio for the channel 3 products was estimated by using the four leading suppliers (craftspersons) of the products. The concentration ratios for the various products of the four leading suppliers (CR_4) ranged between 64.15 and 79.17% (Table 5). Since the values were larger than 50% market structure is categorized as "tight oligopoly" or "concentrated" suppliers as that of raw bamboo culms. The market of the considered bamboo products was characterized by a tight oligopoly market structure, meaning the supply of these bamboo products was concentrated in the hands of few craftspersons. Due to the high labor input and the low local price in the study area bamboo processing results as an activity with low return on labor. So, craftspersons have no incentive to invest in bamboo processing and in the area only few craftsperson produce bamboo products and supply for sale. This results in the oligopolistic market structure of bamboo products in Homosha district. Baskets and tables manufactured from raw bamboo have a fairly high degree of market concentration. This is attributed to the fact that some craftspersons were specialized in the production of these particular bamboo products.

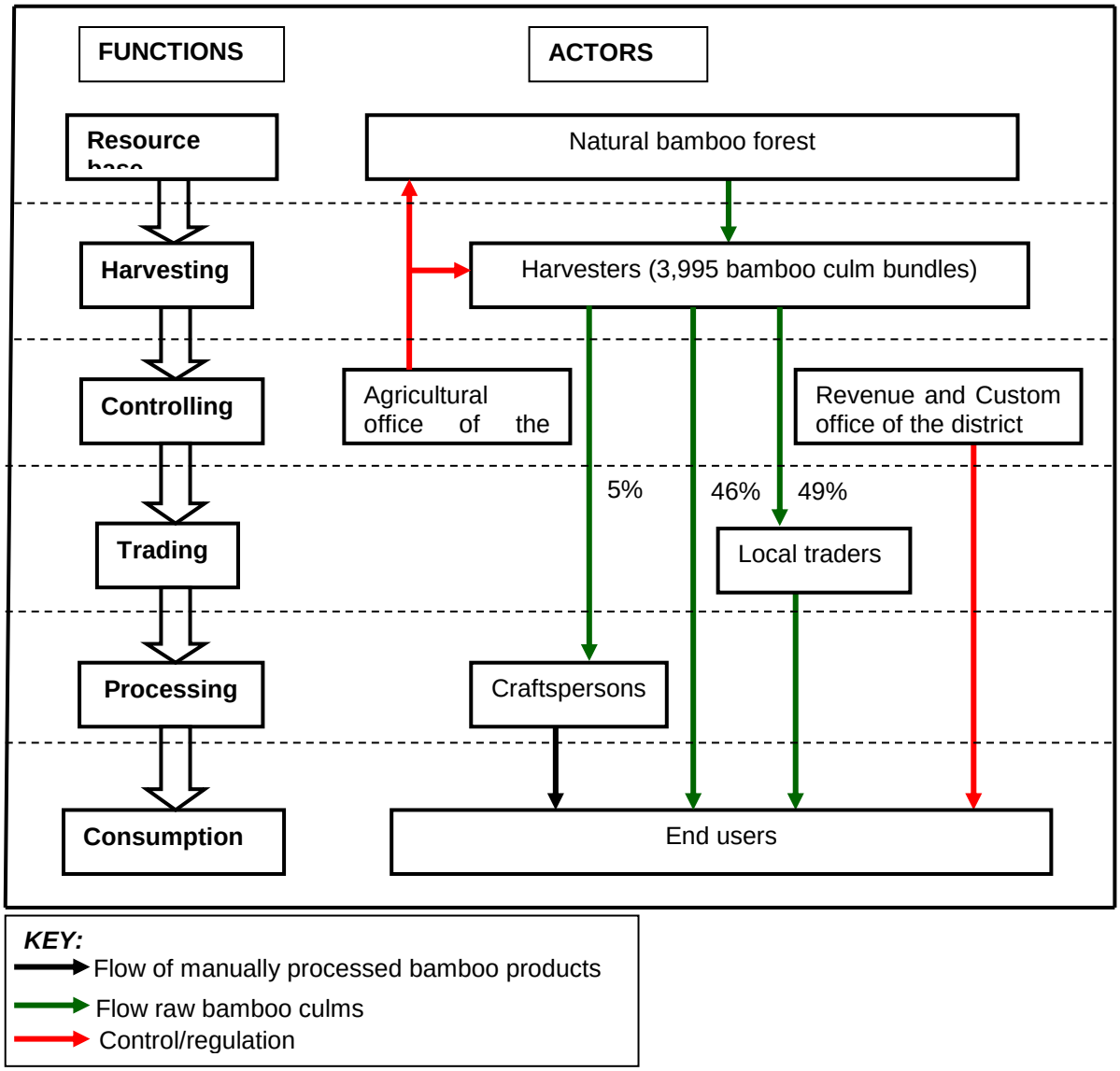

Fig 3: Bamboo product market channels

Table 5: Concentration ration of different products produced from bamboo

Bamboo products	Market concentration ratio (CR4) [%]
Mats	64.15
Tables	75.41
Chairs	71.61
Traditional beehives	74.12
Baskets	79.12

Degree of transparency

Market transparency or information dissemination, enables value chain actors to make evidence based decision on selling or buying bamboo related products for a certain price. Bamboo market information is supplied mostly by local traders through personal contact in the form of dialoging with harvesters. The results show that 59.70% of local traders and 40.30% of harvesters had access to bamboo market information, while the remaining respondents had none.

3.2Market conduct

Harvesters and local traders participated in bamboo harvesting and marketing mostly during the dry season (November to April). Compared to local traders, bamboo culm harvesters had low bargaining power and hence were price taker. The bargaining power of the harvesters is low due to quasi unlimited local supply, low local demand and lack of access to market information. Regarding the terms of payment, about 83% of the harvesters

indicated that payments for bamboo sales were received in cash. Only 17% of producers sold on credit base. About 75% of craftspersons sold products for cash, while the remaining 25% accepted credit. However, local traders only sold in cash, none on credit. For advertisement, harvesters, local traders and craftspersons usually displayed their products on roadsides or in open areas, to attract buyers and interested buyers purchase from there.

3.3 Market performance

The figures in Table 6give the performance of bamboo culm marketing in the different channels, evaluated with the marketing margins.

Market channel 1: Bamboo harvesters sold each bamboo culm to local traders for averagely 0.1059 USD. At this stage harvesters received the value of 0.1059 USD per culm for their labor, since they harvest largely informally without other monetary cost; so the financial value of the standing culm is considered as zero since the cost for growing the culm were externalized. Local traders finance the storage and concentration of bamboo culms for resale to end users, their selling price is at averagely 0.1475 USD per culm. Similar to harvester, local traders have practically no additional cash expenses for marketing costs, only the payment to purchase the culm. Thus, averagely a trader obtains a margin of 0.0416 USD per bamboo culm, which is covering the costs for advance financing the culms and their profits. The gross margin for local trader is estimated to 28 % of end user's price. This relative small marketing margin discourages local traders to engage in bamboo marketing. A harvesters' share of the end user price accounted for 72%.

Market channel 2: This was the shortest channel in which harvesters and end users interact without any other market actor in-between. Bamboo was sold for averagely 0.1222 USD per culm; all end users' price was earned by the harvester, so its share was 100%.

Market Channel 3: Harvesters sold bamboo culms to craftspersons for averagely 0.0960 USD per culm. After transforming these raw bamboos into different products, craftspersons sold it to end users. At this stage they added comparatively high value to bamboo culm in each product.

Table 6: Market performance of bamboo culms across market channels

		Bamboo culm marketing channel		
Actors	**Determinants**	**I**	**II**	**III**
Harvesters	Selling price [USD]	0.1059	0.1222	0.096
	Harvester's share [%]	71.78	100	14.11
	TGMM [%]	28.20		85.89
Local traders	Selling price [USD]	0.1475		
	Total cost [USD]	0		
	Gross market margin [USD]	0.0416		
	GMM_T [%]	100		
	Net market margin [USD]	0.0416		
Craftspersons	Selling price of bamboo culm [USD]			0.6068
	GMM_{Crp}[%]			100
	Net market margin [USD]			0.5846
Final consumer price [USD]		0.1475	0.1222	0.6806
Total Gross Marketing Margin (TGMM) [USD]		0.0416		0.5846

TGMM = total gross marketing margin, GMM_{Crp} and TMM_T = total marketing margin of craftsperson and local traders, respectively.

The monetary cost of production of mats, traditional beehive and basket were the money spent for the bamboo culm purchase. Regarding mats, the craftsperson's' additional input was splitting bamboo and weaving them together. For chairs and tables the production costs on top of the bamboo culms and the craftsmen's labor are the expenses for nails and mounting materials, averagely 0.9897 and 0.8413 USD per chair and table, respectively. Cost for replacement of tools for processing was negligible, as craftspersons use most tools dually for farming activities and bamboo processing. The results showed that higher profit was earned (high value addition) when bamboo culms were processed to mats, baskets and tables (Table 6). Lower profits gained per bamboo culms when it was converted to traditional beehives. In average the partial selling price for one bamboo culm was about 0.6806 USD in the studied products. In the considered products the average profit per bamboo culm employed was estimated to be 0.5846 USD.

Table 7: Average values used to estimate market performance bamboo culm in theproducts produced by craftsperson from bamboo

Cost items	Mats	Baskets	Beehives	Chairs	Tables	Average
Average number of bamboo culms required to produce one unit [no.]	2.14	2.33	2.21	2.57	2.42	
Family labor used to produce one unit [hour]	3	6	5	9	7	
Cost of nails and mounting materials per furniture [USD]				0.9897	0.8413	
Cost of purchasing per culm[USD]	0.0990	0.0891	0.0792	0.1089	0.1039	0.0960
Total cost [USD]	0.0000	0.0000	0.0000	1.2696	1.0928	
Selling price per furniture[USD]	1.6600	1.5635	0.6223	2.1540	2.0243	
Selling price per culm[USD]	0.7757	0.6710	0.2816	0.8381	0.8365	0.6806
Market margin per culm [USD]	0.6767	0.5819	0.2024	0.7292	0.7326	0.5846
Profit per furniture[USD]	1.6600	1.5635	0.6223	0.8844	0.9315	
Profit price per culm[USD]	0.7757	0.6710	0.2816	0.3441	0.3849	0.4915

4. DISCUSSION

4.1 Market structure of lowland bamboo products

Actors and their role in the value chain of lowland bamboo products

INBAR (2011) identified in Asosa area harvesters, cooperatives, urban housing developers, transporters, private processing industries, trans-boundary harvesters to Sudan and consumers as value chain actors in bamboo marketing. These bamboo value chain actors were hardly organized and only loosely connected, due to low market price and demand for bamboo products. Additionally, Levang et al. (2005) report that the bamboo utilization of Ethiopian communities is generally isolated, not integrated with potential markets and their natural bamboo habitats often lack management. The present study identified harvesters, local traders, craftsperson, custom and revenue office of the district, consumers and agricultural office of the district. The fewer value chain actors in the Homosha area here could be attributed to the following factors: First, the fact that currently more bamboo traders and processing units are found near and in Asosa town than in the remote areas of the Homosha district. Second, the cooperatives organized in 2009/2010 were dispersed nowadays. Third, to some extent the Agriculture Office imposed restrictions on illegal bamboo harvesting and transporting as well as on Sudanese trans-boundary harvesters.

Harvesters: All the interviewed households harvest bamboo culms from natural forest during dry season, either for home consumption or for sale. Belcher et al. (2005) have got similar findings; forest products are utilized for both home consumption or sold and traded as needed. In Homosha, the income generated from traded bamboo culms was used to complement the agriculture dominated livelihood activities of harvesters. Bamboo is an important non-timber forest product (NTFP) that provides more regular income to harvesters than most agricultural crops which depends on seasons and favorable weather conditions (Sertse et al. 2011). By this bamboo is contributing to the household's resilience and can be considered as an asset with relevance for climate change adaptation. Many rural African communities rely on local NTFP harvest to complement their farming activities, in order to achieve more resilient livelihoods. However, their contribution to individual households ranges widely (Shackleton and Shackleton, 2004; Tesfaye et al., 2011). According to Hunde and Brias (2009), lowland bamboo stands in Asosa area are often found on very steep slopes, which are difficult to reach and harvesting is a labor intensive business. In the study area harvesters use family labor for bamboo harvesting and transporting, giving to family members in the working age some income opportunities.

Since bamboos were mostly informal, quasi unrestricted harvested from natural forest, there was only a low local market price for bamboo products, and due to the remoteness of the place only a low demand. Martin et al. (2007) found a similar situation in Laos. In Houaphanh province, where bamboo from natural forests had a low demand at the provincial bamboo market, because these bamboo resources were more or less freely available to most of the people and processing industries were far. Nevertheless, bamboo commercialization in Homosha provides farmers the opportunity to earn some cash, although it is not attractive as bamboo culms are sold at very low prices. Similarly, Emana (2010) found that in Northwest Ethiopia, Benishangul Gumuz Regional State, the role of bamboo production as income generation activity is limited due to the low price and remoteness, meaning that a transport to the nearby urban areas was not financially viable. Consequently, due to lack of adequate utilization, after flowering in 1997/98hundreds of hectares of natural bamboo forests in Metekel Zone (Benishangul Gumuz Region) were left to decay on the site. Since many substitute products for household

items and construction materials are on the market, in Sheka in Southwestern Ethiopia the decline of bamboo prices have resulted in reduced contributions of bamboo production to household incomes (Belay et al., 2013).

Local traders: In Benishangul Gumuz Region bamboo is traded at the local level for different purposes, including house construction, fencing, construction of cattle barns, furniture (stools, chairs, mats, etc.), baskets, grain stores, tools and vessels, but also for fuel. Young bamboo shoots are consumed as vegetable during food gaps in June and August (Emana, 2010). Cross border trade of bamboo raw materials and products into other East African countries was extremely limited and fluctuated significantly from year to year (Adnew and Statz, 2007). This imposed challenges on bamboo trading and marketing expansion generally in Ethiopia and specifically in Homosha.

Even if ample bamboo resources exist in Sheka, processors in Addis Ababa and Hawassa showed that it was not listed as a source of raw material by any of the interviewees Belay et al., (2013). The reason for not choosing Sheka as a raw material source was its remoteness (700km from Addis Ababa and 975km from Hawassa) and poor road conditions. Traders and processors had no incentive to travel over long distance on poor roads when they could obtain sufficient raw materials from nearby areas with cheaper transportation costs. Medium-sized bamboo-manufacturing enterprise in Addis Ababa obtained culms from many other locations, Awi, Sidama and Guragie were the first, second and third major sources of raw materials, respectively based on relative proximity and better road access to the city. In the same way, in Homosha bamboo culms were harvested from distant and poor road access areas and it was not easy to travel to the center of the country due to remoteness. This discouraged individuals from investing in bamboo culm trading activities. Additionally, in Homosha district, due to low margins, the income earned by traders were minimal, hence, only few individuals run bamboo culm trading business. Local traders had about 3 years of experience in bamboo culm trading. The commercial bamboo sector in Africa is considered to be inefficient due to a lack of skills regarding the ways of doing business, poor infrastructure, and weak and inconsistent market demand (Ingram et al., 2010).Other studies confirm that bamboo culm trading in Ethiopia is locally limited to production areas. For instance, Adnew and Statz (2007) indicated that in Ethiopia the supply and demand of bamboo culms are highly localized and confined, and the market system is on a small base in terms of market connections (geographic locations, distribution, customers).

Craftsperson: The Lack of treatment against borers and fungi lead to very short lifespan of bamboo products in Ethiopia, this cause poor reputation of and low demand for bamboo products. Various technologies (treatments) available to increase a product's service life, but these are not practiced and hardly known by the rural communities in Ethiopia (Embaye, 2003).Consequently, local bamboo product processors have hardly opportunities to earn higher income (Anonyms, 1997). High susceptibility to biodeteriorating agents (termites, beetles and fungi) is among the major challenges in processing, value addition, marketing and rational utilization of the bamboo resource in Ethiopia (Tolera and Mulatu, 2015). This has been lacking strong attention and action of processors, other stakeholders and end users. In Homosha district craftspersons are selling traditionally processed bamboo products at a comparative low price as well as processing and marketing of bamboo products in Asosa area is not well organized and market actors were not allied thoroughly, which is seen as caused by the low price of bamboo products in rural markets which do not pay back the organization cost (Zenebe et al., 2014). The limited market in Homosha is not incentivizing craftsperson's to increase their small scale production for realizing the benefits of the economy of scale. Craftspersons of Homosha district engaged in production of baskets and simple household furniture (Tolera and Mulatu, 2015). There only exists a very limited local market for bamboo handicrafts, which is not further developed or organized in a systematic way to create market linkage between manufacturers and suppliers. Thus, bamboo-based handicrafts producing for the market are not as widespread in the rural communities. This due to lack of access to road, transport, awareness on market orientation, business plan development and entrepreneurship, market promotion, support in establishing local market areas, working spaces, credits facilities, costumers' handling and support experiences sharing events from existing organized groups ((Tolera and Mulatu, 2015))

Consumers: Due to the short services life of bamboo products, consumers perceived bamboo products as non-durable and poor quality products. Such consumer perception is seen as main hindrance for realizing the potential demand in Ethiopia (Adnew and Statz, 2007).

Marketing channels of lowland bamboo products

The findings confirm that in general, the market channels for bamboo products in Ethiopia consist of short chains (INBAR, 2006; Getachew and Wubalem, 2014). As compared to industrially manufactured bamboo products, manually produced bamboo products have short and few market channels. For industrial bamboo processing with machines are various options available. The market for such products is considered as not saturated and with potential for growth (von Reitzenstein, 2004). There is also a strong interest from designers and architects to use bamboo as a sustainable innovative industrial material (Von Reitzenstein, 2004; CORPEI, 2005). Hence, the market demand for industrial bamboo products is high and increasing over time. Bamboo marketing in Homosha district was informal, despite the marketing of bamboo products was monitored and

regulated with a permit/license system by government agencies. According to UNIDO (2006), this was a characteristic for all Ethiopia. In spite of the fact that regional government has formulated regulations for bamboo resource utilization and management in 20111/12, these regulations were not well implemented on ground because of both inadequate resources to enforce and less attention for the resource. This is confirmed from Yemiru et al. (2010); they found the Ethiopian government has implemented regulations to reduce access and reliance on timber products due to widespread deforestation; however these regulations are rarely enforced due to lack of resources.

Degree of transparency and market information dissemination

From interviewed respondents about 59.70% of local traders and 40.30% of harvesters had market information. According to Marshall et al. (2006) lack of market information constrains producers, processors and traders from advancing within NTFP value chains. Value chain actors in study area were not benefiting from bamboo resources due to poor information accessibility regarding bamboo marketing. In Bolivia, households with market information were found to achieve significantly higher values than households with no market information (Marshall et al., 2006).

4.2 Market conduct

Most of the interviewed harvesters and craftspersons were price takers. Harvesters had less negotiation in price setting and sell culms for the price determined by local traders. In this regard, studies in Awi zone (Northwestern Ethiopia) and Sidama Zone(Southern Ethiopia)showed that due to increasing demand and presence of sufficient alternative buyers, farmers had got a more powerful position in prices negotiations (Belay et al., 2013).

4.3 Market performance of bamboo products

Local traders obtained a margin of 0.0416 USD per culm. This may be seen as a small portion per culm, since culms are sold in bundles or even truck-loads, the total margin for the trader can be still substantial due to the economy of scale. Their value adding was limited to bundling and interim financing only, further grading, transport and or preservation treatment could not be found. Similarly, KEFRI (2008) indicated that bamboo culms sold in timber yards in Nairobi were not processed nor preserved, and the added value for plain re-distribution of such products was very low. The value chain actors of bamboo products in the study area are not well networked, because value chain actors were not sturdily interdependent (interconnected) in running bamboo businesses or market. The gross margin for local trader is estimated to 2.82% of end user price. Other research on the value chain of bamboo in Ethiopia confirms that the use of bamboo resources in the country is sub-optimal (Ensermu et al. 2000). Especially the traders, with their central position in the value chain, have room for increasing both value added and profits.

Comparing the three channels, it is obvious that the highest margin per bamboo culm is realized in Channel III, with highest value added per culm. This is to explain to the fact that only in this channel raw bamboo was converted into products for final use before selling it to end users. Craftsmen producing chairs and tables added more value to the bamboo than those who produced basketry and traditional beehives. Similar ranking was found from Andargatchew (2008).

From an actor's point of view, the total margin earned as return on labor is arbitrative. To explain the real profitability of a single actor, and of the products the actor's inputs of personal and/or family labor has to be considered. A trader may spend only some seconds per culm to buy and resell it in bulk to, e.g. a lorry driver. So, despite the profit per culm is comparatively small, the total profit within some hours of a day may be quite high, just due to the economy of scale. In opposite, a chair maker may spend a whole day to process some few culms, the value added allocated to some culms may be high, but the picture change if is related to his labor input, his income created on a day may be quite low compared to the one of the trader. To determine the profitability and contribution to income and livelihoods the results need to be complemented with labor and capital inputs, which is a challenging job rather considered as too resource intensive (Angelsen, 2011) nevertheless, the study clearly proves the high benefits of processing products local instead of exporting unprocessed.

The development of the bamboo sector may provide one option to answer the existing socioeconomic problems, especially unemployment. In channel III, the total Gross Marketing Margin was 85.89 % which implies higher end users' price share for craftspersons (Table 6). On the other hand, harvesters have lowest share of end users' price (14.11 %). This indicated the highest margin was achieved by craftspersons in the channel. Rather than selling raw bamboo culms, processed bamboo products benefited local the communities.

In average, harvesters achieved for the same product, the raw bamboo culm, most by selling it direct to end users, while craftspersons paid the least price to them. The abundance of the product and the unrestricted access may lead to the comparative low price of raw culms, making the export to other regions more attractive than the local processing. This can be attributed to the commodity itself, for construction and fuel purpose the culms have been processed respective burned on the end user's site only. But it may be also an attribute that the labor in the region may be better to use for other activities than to processing bamboo. Share of the total end

users' price for harvesters was highest in channel I accounted about 71.78% except in channel II which has no value chain actors' interventions between the harvesters and end users. This higher harvesters' share is indicated in channel I and implied lower marketing margin for local traders (2.82%).

5. Conclusion and Recommendations

This study was conducted in Homosha District in order to analyze the value chain of lowland bamboo products. In the study region bamboo was harvested from natural stands. Similar to other forest products, farmers use and sell bamboo culms and bamboo related products for income generation. Actors of the value chain include harvesters, local traders, craftspersons and end users. Three marketing channels were identified and characterized as short and confined to local levels. End users came from different places outside the study area to purchase bamboo, so a high number (46% of total harvested in studied villages) of bamboo culms go from harvesters to end users through local traders. This explains the high number of bamboo culms transacted through this channel. Like the marketing channels of other NTFPs, the value chain of lowland bamboo products in the study area has few actors and channels. Except the channel that connects harvest to end users, the remaining channels were characterized as a tight oligopoly market, implying that only few local traders and craftspersons dominated the market. Besides, in the majority of the cases, price of bamboo products was determined by buyers, not by suppliers. A harvester gets the best price when he directly sells to end users or as second choice to local traders. Among all studied value chain actors, craftspersons add highest value to a bamboo culm.

The studied value chains were delimited to the district of Homosha. Further studies would be required to study the value chain segment of the bamboo culms leaving the region via the traders and end user buyers. Nevertheless, bamboo is an asset of very high potential, already available and continuously renewable for innovative activities and businesses to benefit the local community. The fact that currently the final bamboo products were not traded like the raw culms is an indicator for their lack of competitiveness and is in the same time a big potential for improvements and innovations to boost, upgrade and upscale the local bamboo industry. Government, development partners and especially the actors themselves need to participate in organizing actors to gain more power in the market and to create competitive products and innovative production processes to achieve access to attractive, national markets. A strong processing industry would employ more people and would facilitate to establish a sustainable management by the institutions in charge.

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Revisiting the Evolution and Application of Assignment Problem: A Brief Overview

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Abstract:
The assignment problem (AP) is incredibly challenging that can model many real-life problems. This paper provides a limited review of the recent developments that have appeared in the literature, meaning of assignment problem as well as solving techniques and will provide a review on a lot of research studies on different types of assignment problem taking place in present day real life situation in order to capture the variations in different types of assignment techniques.
Keywords: Assignment problem, Quadratic Assignment, Vehicle Routing, Exact Algorithm, Bound, Heuristic etc.

1. Introduction

There are several important areas of economic analysis in which progress depends on the advancement of methods for solving or analyzing problems in the efficient allocation of individual resources. In the subject 'operation research', the assignment problem is very challenging and interesting that can represents many real-life problems.

The optimal assignment problem is a classical combinatorial optimization problem. It entails optimally matching the elements of two or more sets, where the dimension of the problem refers to the number of sets of elements to be matched. A simple explanatory example of the problem is matching a number of persons and objects on a one-to-one basis where each person has a specific benefit associated with being matched to a certain object. The optimal matching corresponds to an assignment of persons to objects that maximizes the sum of benefits. When there are only two sets, as will be the case for most of the variations we will consider, they may be referred to as ''tasks'' and ''agents''. Therefore, ''tasks'' may be jobs to be done and ''agents'' the people or machines that can do them. Assignment Problem is a method for matching the "Tasks" (jobs) to the "Agent" (man, machine of facility) which can produce the most efficient outcome. AP can be categorized in to three groups – AP model with at most one task per agent, AP model with multiple tasks per agent, AP model for multi-dimensional assignment problem.

The assignment problem is special case of transportation problem and a linear zero-one programming problem in which the objective is to assign a number of resources to the equal number of activities at a minimum cost (or maximum profit).The assignment problem deals in allocating the various resources (items) to various activities (receivers) on a one to one basis in such a way that the resultant effectiveness is optimized. These types of problems are linear programming applications that can be solved using the simplex method. It is a one of the well-studied optimization problems in Management Science and has been widely applied in both manufacturing and service systems. Assignment problems can also be solved by transportation method .Possibly, the first documented algorithmic method for finding a solution to the assignment problem aside from the brute force approach is the Hungarian method. The method was developed by H. W. Kuhn (1955) and based on the work of two Hungarian mathematicians, Evgary and Konig in the honour of which Kuhn named the algorithm the Hungarian algorithm although the name ''assignment problem'' seems to have first appeared in a 1952 paper by Votaw and Orden(1952), what is generally recognized to be the beginning of the development of practical solution methods for and variations on the classic assignment problem.

The fundamental idea behind the Hungarian method is that the optimal assignment is conserved by the addition of a scalar to any row or column. This can easily be understood when considering that any assignment contains only one element from each row and one element from each column. The translation of a whole column (respective row) by a constant corresponds to a translation of the optimal assignment by that same constant as any assignment must still contain one element from that column (respective row). The Hungarian method uses this principle to transform a matrix into a sparse matrix by subtracting the minimal elements from each row and column, resulting in multiple zero entries while not affecting the optimal assignment of the matrix. When the matrix is sufficiently sparse ,an assignment of zeros entries that correspond to the minimal assignment would be possible and choosing such an assignment would solve the assignment problem for the matrix of interest. Konig's theorem gives an algorithmic method to check whether the matrix has been reduced to a sufficiently sparse matrix.

König's Theorem suggests that the recursive subtraction of smallest elements from the rows and

columns of a matrix will clearly result in the presence of a large number of zeros in the matrix (at least one in each row and column). If a selection of zeros from the matrix can be made corresponding to an assignment (a selection of zeros such that the position of each zero corresponds to a one in an associated permutation matrix) the algorithm terminates. We can consider this as covering all zero entries in the matrix by drawing lines through the rows and columns. The minimum number of lines needed to cover all zeros in the matrix is then known as its cover and when the cover equals the order of the matrix an assignment of zeros is possible. Determining whether such an assignment is possible is simple enough to see when matrices are small but could be very difficult for large matrices. Obviously, there exists a need for an algorithmic method to find the cover and Konig's theorem allows the development of exactly such an algorithm. The Theorem suggests that for every rectangular matrix containing zeros as some of the entries, the number of zeros in a largest independent set of zeros is equal to the number of lines in a smallest cover of the zeros.

There are a number of decision making situations where assignment technique can be successfully used. For example, assignment of available sales-force to different regions; vehicles to routes; product to factories; contracts to bidders; machines to jobs; development engineers to several construction sites and so on. Management generally makes assignment on a one to one basis in such a manner that the group maximizes the revenue from the sales, the vehicles are deployed to various routes in such a way that the transportation cost is minimum and so on.

In assignment problems, supply in each row represents the availability of a resource such as a man, vehicle, product, salesman etc and demand in each column represents different activities to be performed, such as jobs, routes, factories, areas etc for each of which only one man or vehicle or product or salesman respectively is required. Entries in the square being costs, times or distances. The essential characteristic of the assignment problem is: *n* resources are to be assigned to n activities such that each resource is allocated to each activity and each activity is performed by one resource only. The allocation is to be done in such a way so as to maximize the resultant effectiveness.

Assignment problem is completely degenerate form of a transportation problem. The units available at each origin (resource) and units demanded at each destination (activity) are all equal to one. That means exactly one occupied cell in each row and each column of the transportation table, i.e only n occupied cells in place of required n+n-1=(2n-1).The assignment problem is concerned with the concept of finding an optimal one-to-one matching between two sets. Therefore, analysts aware of what these variations are so that they can more easily determine which variation most closely match their current problem. An assignment is obtained when we match an element from set 1 to an element from set 2 in a one-to-one fashion. Mathematically the assignment problem can be viewed as a bijective mapping of a finite set into itself, i.e. a permutation. This can be represented by a permutation matrix or an element from any set isomorphic to the set of permutation matrices such as the set of all possible permutations of the set of numbers $\{1,2,...,N\}$.

Various approaches have been developed to find efficient solutions to the assignment problem. To name a few of the more important ones: the Hungarian method by Kuhn and Munkres was of the first. Dantzig solved the problem using linear programming and more recently Bertsekas (1990) developed the Auction Algorithm that solves the problem very efficiently. Another interesting approach by Kosowsky and Yuille(1991) manages to find a solution to the assignment problem using an approach related to statistical physics. It is referred to as the Invisible hand algorithm. The assignment problem is of great theoretical importance as it embodies a fundamental linear programming structure. It is possible to reformulate important types of linear programming problems such as the linear network flow and shortest path problems to take the form of an assignment problem.

The assignment problem finds many applications; the most obvious being that of matching such as the matching of operators and machines or delivery vehicles and deliveries. There are however numerous other interesting applications. Van Wyk(2001) shows that the graph matching problem can be rewritten to take the form of an optimal assignment, it turns out that many such optimizations procedures that are concerned with finding a closest approximation of an element in some vector space can be wholly or partly reformulated as assignment problems. Another such example by Imai et.al.(1986) is the approximation of piecewise linear functions or human face detection by Ying,Z,et.al(1999). W ästlund,J(2003) shows that the shortest path problem can be reformulated as an assignment problem. Such algorithms are used in the determination of routing tables for telecommunication networks or optimal routes in GPS navigation systems. Some other applications of the assignment problem include tracking moving objects in space [Burkard, R.E et.al(1998)], the matching of moving objects[Brogan, W(1989)] and scheduling of an input queued switch[S. Chuang(2002)]. The importance of the assignment problem is quite clear from the above and various very successful solutions to the problem already exist.

In this article, we will briefly discuss the meaning of assignment problem, solving techniques and present a survey of some developments and researches in the said field.

General Mathematical model of Linear Assignment problems:

The linear assignment problem (LAP) is one of the basic and fundamental models in operations research, computer science, and discrete mathematics. In its most well-known interpretation, it answers the question of finding an assignment of n workers to n jobs that has the lowest total cost, if the cost of assigning worker i to task j equals cij . Apart from the straightforward applications, such as personnel assignment problems, the LAP frequently arises as a part of other optimization problems, such as quadratic assignment problem, multidimensional assignment problem, traveling salesman problem, etc. Other applications of the LAP, including earth-satellite systems with TDMA protocol, and tracking objects in space are considered in Burkard (1985) and Brogan (1989).

With the information about the number of assignment $i(i=1,2,3\ldots\ldots\ldots..,n)$ performing the same number of jobs j (j=1,2,3,……. n) and the pay off measure $\boldsymbol{c_{ij}}$ available for each assignment ,the objective is to determine the strategy that minimizes the total cost or maximizes the total utility.

The general data matrix for assignment problem is shown in table-1. It may be noted that this data matrix is the same as the transportation cost matrix except that the supply (or availability) of each of the resources and the demand at each of the destinations is taken to be one. It is due to this fact that the assignments are on a one to one basis.

The assignment problem can be conveniently represented in the form of n x n matrix

$[c_{ij}]_{nxn}$ known as cost or effective ;where x_{ij} represents the assignment of resource (facility) i to activity(job) j and c_{ij} is the cost associated with assigning i th facility (person) to j th job.

Table-1

Resources(workers)	Activity(Jobs)				Supply (Available)
	J_1	J_2	…..	J_n	1
W_1	C_{11}	C_{12}	…….	C_{1n}	1
W_2	C_{21}	C_{22}	……	C_{2n}	1
…	……	…..	……	…..	…..
W_n	C_{n1}	C_{n2}	……	C_{nn}	1
Demand(Required)	1	1		1	n

Further, it is also assumed that $\boldsymbol{x_{ij}}$ =1, if $\boldsymbol{i}$ th resources (person) is assigned to $\boldsymbol{j}$ th activity (job) and $\boldsymbol{x_{ij}}$ =0, otherwise.

The unique version of the assignment problem is discussed in almost either management science/operations research or production and operations management. Pentico (2007) proposes a survey of what appear to be the most useful variations of the assignment problem that have developed in the literature over the past 50 years. As usually described, the problem is to find a one-to-one matching between n tasks and n agents, the objective being to minimize the total cost of the assignments.

In this section, we will briefly present the papers that take the competency constraint into account.

2. Evolution of assignment problem:

Classical Assignment Problem:

The mathematical model of the assignment problem can be stated as :

$$\text{Minimize Total Cost}=Z=\sum_{i=1}^{n}\sum_{j=1}^{n} = \boldsymbol{c_{ij}\,x_{ij}}$$

subject to constraints:

(i) $\sum_{j=1}^{n} \boldsymbol{x_{ij}} = 1$ for all $\boldsymbol{i}$(resource availability)

i.e each person should be assigned to one and only one job.i.e

$\boldsymbol{x_{i1}+x_{i2}+\ldots\ldots\ldots..+x_{in}=1;\ i=1,2,\ldots\ldots\ldots n}$

(ii) $\sum_{i=1}^{n} \boldsymbol{x_{ij}} = 1$ for all $\boldsymbol{j}$(activity requirement)

i.e each job must be assigned to one and only one person i.e

$\boldsymbol{x_{1j}+x_{2j}+\ldots\ldots\ldots..+x_{nj}=1;\ j=1,2,\ldots\ldots\ldots n}$

(iii) $\boldsymbol{x_{ij}}$ =0 or 1, for all $\boldsymbol{i}$ and $\boldsymbol{j}$.

This mathematical model of assignment problem is a particular case of the transportation problem for two reasons: (i) the cost matrix is a square matrix and (ii) the optimal solution table(matrix) for the problem would have only one assignment in a given row or a column.

Minor modifications of the basic problem structure are easily handled with the standard solution procedures. A problem in which the objective function is to be maximized can be easily converted into a minimization problem by either (a) multiplying all of the c_{ij}s by -1, or (b) replacing each c_{ij} by $c_{max} - c_{ij}$, where c_{max} is the maximum of the c_{ij}s, thus converting the problem to one of minimizing ‘‘regret’’. A problem that is not balanced (i.e., one for which the numbers of tasks and agents differ) can be easily converted into a balanced problem by adding a sufficient number of ‘‘dummy’’ tasks or agents (whichever is in shorter supply) with costs of 0. One may also use non-zero costs for assignments using dummy tasks or agents to reflect differences based on which agents or tasks are not assigned. It is worth noting that the classic AP is mathematically identical to the weighted bipartite matching problem from graph theory, so that results from that problem have been used in constructing efficient solution procedures for the classic AP.

2.1. The classic assignment problem recognizing agent qualification

Caron et al.(1999) take an initiative to interest in the classic assignment problem recognizing agent qualification. In their work on a particular version of the assignment problem with side constraints, Caron et al. use a mathematical model for a variation of the classic assignment problem in which there are m agents and n tasks, not every agent is qualified to do every task, and the objective is utility maximization.

$$\text{Maximize} \quad Z = \sum_{i=1}^{m} \sum_{j=1}^{n} = c_{ij}\, x_{ij}$$

$$\text{Subject to :} \quad \sum_{i=1}^{m} q_{ij}\, x_{ij} \le 1, \quad j = 1\ldots\ldots\ldots n .$$

$$\sum_{i=1}^{n} q_{ij}\, x_{ij} \le 1, \quad i = 1\ldots\ldots\ldots m$$

$$x_{ij} = 0 \text{ or } 1$$

where $x_{ij} = 1$ if agent i is assigned to task j, 0 if not, $q_{ij} = 1$ if agent i is qualified to perform task j, 0 if not, and c_{ij} = the utility of assigning agent i to task j (with $c_{ij} = 0$ if $q_{ij} = 0$). The first set of constraints ensures that no more than one qualified agent is assigned to any task and the second set of constraints ensures that no agent is assigned to more than one task. Note that even if m is greater than or equal to n it may not be possible to assign a qualified agent to every task or to give every agent a task for which it is qualified. Minimization problems can be handled using either of the methods suggested above for handling maximization problems for the standard classic AP.

2.2. The k-cardinality assignment problem

Mauro Dell Amico and Silvano Martello(1997) have taken into consideration a generalization of the assignment problem in which an integer *k* is given and one wants to assign *k* rows to *k* columns so that the sum of the corresponding costs is a minimum. The problem can be seen as a 2-matroid intersection, hence is solvable in polynomial time; immediate algorithms for it can be obtained from transformation to min-cost flow or from classical shortest augmenting path techniques. They introduce original preprocessing techniques for finding optimal solutions in which $g \le k$ rows are assigned, for determining rows and columns which must be assigned in an optimal solution and for reducing the cost matrix. A specialized primal algorithm is finally presented. The average computational efficiency of the different approaches is evaluated through computational experiments. Therefore, Mauro Dell Amico and Silvano Martello (1997) explain a variation on the classic AP in which there are m agents and n tasks, but only k of the agents and tasks are to be assigned, where k is less than both m and n. The mathematical model for the k-cardinality assignment problem is:

$$\text{Minimize} \quad Z = \sum_{i=1}^{m} \sum_{j=1}^{n} = c_{ij}\, x_{ij}$$

$$\text{Subject to:} \quad \sum_{i=1}^{m} x_{ij} \le 1 , \; j = 1,2,\ldots\ldots n$$

$$\sum_{j=1}^{n} x_{ij} \le 1 , \; i = 1,2,\ldots\ldots m$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} = k$$

$x_{ij} = 0$ or 1

where $x_{ij} = 1$ if agent i is assigned to task j, 0 if not, c_{ij} = the cost of assigning agent i to task j, and k is the number of agent-task assignments that must be made. Dell Amico and Martello suggest as a potential application for this model the situation in which workers are to be assigned to machines, but only a subset of the workers and machines need to be assigned. They also suggest that it can be used to solve sub-problems in the problem of assigning time slots on a communications satellite being used to transmit information from m earth stations to n different earth stations.

The k-cardinality assignment problem is an interesting generalization of the assignment problem, having applications in personnel scheduling and as a sub-problem in the solution of more complex problems, such as the SS/TDMA time slot assignment problem. We have developed, for the first time, efficient preprocessing techniques and a primal algorithm. Their computational tests show that the proposed approach is the fastest method available for the problem solution. It solves dense instances having up to 250000 entries, for all values of k, with very short running times. Future developments could concern the specialization of our algorithmic techniques to the case of sparse matrices, in order to solve instances with much higher values of *m* and *n*.

2.3 The Generalized Koopamans- Beckmann quadratic assignment problem (QAP)

The Quadratic Assignment Problem (QAP) was originally introduced in 1957 by Tjalling C. Koopmans and Martin Beckman who were trying to model a facilities location problem. Since then, it has been among the most studied problems in all combinatorial optimization. Many scientists including mathematicians, computer scientists, operations research analysts, and economists have used the QAP to model a variety of optimization problems. They first introduced the quadratic assignment problem (QAP) as a mathematical model for the location of indivisible economical activities. The QAP stated as a facility location problem is to assign N facilities to N locations such that the total interaction cost of all possible flow-distance products between the locations to which the facilities are assigned plus the allocation costs of facilities to locations are minimized. Given the flow matrix:

$F = [f_{ik}] \in R^{N\times N}$ where f_{ik} is the flow from facility i to facility k, the distance matrix $D = [d_{jn}] \in R^{N\times N}$ where d_{jn} is the distance from location j to location n, and the cost matrix $B = [b_{ij}] \in R^{N\times N}$ where b_{ij} is the allocation cost of placing facility i at location j, the QAP in Koopmans-Beckmann form can be modeled as:

$$\min \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=1}^{N}\sum_{n=1}^{N} f_{ik} d_{jn} x_{ij} x_{kn} + \sum_{i=i}^{N}\sum_{j=1}^{N} b_{ij} x_{ij}$$

Subject to:

$$\sum_{i=1}^{N} x_{ij} = 1 \qquad j=1,\ldots,N$$

$$\sum_{j=1}^{N} x_{ij} = 1 \qquad i=1,\ldots,N$$

$$x_{ij} \in \{0,1\} \qquad i,j=1,\ldots,N$$

Each assignment of facilities to locations is represented by an $N \times N$ solution matrix $X = [x_{ij}]$ where x_{ij} =1if facility i is being placed at location j or x_{ij} = 0 otherwise.

Notice that $X = [x_{ij}]$ is a permutation matrix.

A natural application in location theory was used by Dickey and Hopkins (1972) in a campus planning model. The problem consists of planning the sites of n buildings on a campus, where b_{kl} is the distance from site k to site l, and a_{ij} is the traffic intensity between buildings i and j. The objective is to minimize the total weekly walking distance between the buildings. In addition to facility location, QAPs appear in applications such as

layout problems, backboard wiring, computer manufacturing, scheduling, process communications and turbine balancing. In the field of ergonomics, Burkard and Offermann (1977) showed that QAPs can be applied to typewriter keyboard design. The problem is to arrange the keys on a keyboard such as to minimize the time needed to write some text.

In contrast to linear assignment problems, quadratic assignment problems remain among the hardest combinatorial optimization problems. The inherent difficulty for solving QAPs is reflected by their computational complexity. Sahni and Gonzalez [Sah1976] showed that QAP is *NP*-hard and that even finding an approximate solution within some constant factor from the optimum value cannot be done in polynomial time. These results hold even for Koopmans-Beckmann QAPs with coefficient matrices fulfilling the triangle inequality [Queyranne (1986)].

From the theoretical point of view, it is because of the high computational complexity: QAP is NP-hard, and even finding an approximate solution is a hard problem. Moreover, many well-known classical combinatorial optimization problems such as the traveling salesman problem, the graph partitioning problem, the maximum clique problem can be reformulated as special cases of the QAP. From the practical point of view, it is because of the diversified applications of the QAP. The techniques which can be used to find the optimal solution are limited to branch and bound and cutting planes methods: with current hardware, problems of order greater than 20 cannot be solved in an acceptable time (Burkard et al., 1994). For this reason, in recent years many heuristic algorithms have been proposed which, though not ensuring that the solution found is the best one, give good results in an acceptable computation time (Maniezzo *et al.*, 1994).

2.4 The generalized quadratic assignment problem (GQAP)

The generalized quadratic assignment problem (GQAP) studies a class of problems that optimally assign *M* entities to *N* destinations subject to the resource limitation at each destination. These problems arise naturally in yard management, where containers are to be located in the storage areas with limited capacity, and in distributed computing where processing tasks are to be assigned to processors with limited computing resources. The GQAP is a generalization of the QAP that multiple entities can be assigned to a single destination if only such assignment does not violate the resource capacity at destinations.

Lee and Ma (2004) proposed the first formulation of GQAP. Their study involves a facility location problem in manufacturing where *M* facilities to be located among *N* fixed locations given the space constraint at each possible location, with the objective to minimize the total installation and interaction transportation cost. The formulation of the GQAP is then:

$$\min \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{M}\sum_{n=1}^{N} f_{ik} d_{jn} x_{ij} x_{kn} + \sum_{i=1}^{M}\sum_{j=1}^{N} b_{ij} x_{ij}$$

subject to:

$$\sum_{i=1}^{M} S_{ij} x_{ij} \le S_j \qquad \text{j=1,….,N} \qquad \text{……} \quad (1)$$

$$\sum_{j=1}^{N} x_{ij} = 1 \qquad i = 1,...,M, \quad . \quad \text{….} \quad (2)$$

$$x_{ij} \in \{0,1\} \qquad =1,...,M; j=1,..., N, \quad \text{…….} (3)$$

where

M = the number of facilities,

N =the number of locations,

f_{ik} =the commodity flow from facility i to facility k,

d_{jn} =the distance from location j to location n,

b_{ij} = the cost of installing facility i at location j,

s_{ij} =the space requirement if facility i is installed at location j,

s_j = the space available at location j,

x_{ij} = binary variable, x_{ij} =1, if facility i is installed at location j.

The objective function sums the costs of installation and quadratic interactivity. The knapsack constraints (1) impose space limitations at each location, and the multiple choice constraints (2) ensure that each facility is to be installed at exactly one location.

2.5. A Quadratic 0-1 Formulation

Quadratic 0-1 Formulation is one more variant formulation of QAP problem. Initially, this formulation was used by Koopmans-Beckman**.**It is formulated using an n x n matrix is a permutation matrix X= $[x_{ij}]$ that represents permutations $\pi \in S_n$ by 0-1 form .To be considered a permutation matrix, it should satisfy the three following conditions:

$$\sum_{i=1}^{n} X_{ij} \quad ,j=1,\ldots..,n.$$

$$\sum_{j=1}^{n} X_{ij} \quad ,i= 1,\ldots..,n.$$

$$X_{ij} \in \{0,1\} \quad , i,j =1,\ldots,n.$$

If the three conditions are satisfied, then QAP can be formulated as:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} f_{ij} d_{kl} X_{ik} X_{jl}$$

Subject to:

$$\sum_{i=1}^{n} X_{ij} \quad ,j=1,\ldots,n.$$

$$\sum_{j=1}^{n} X_{ij} \quad ,i=1,\ldots,n.$$

$$X_{ij} \in \{0,1\} \quad ,i,j=1,\ldots,n.$$

There are massive numbers of realistic applications that can be modeled as QAPs. Koopmans and Beckmann (1957) first proposed QAP as a mathematical model regarding the economic activities. Since then , it has appeared in numerous practical applications: Steinberg (1961) used QAP to minimize the number of connections between components in a backboard wiring, Heffley (1972, 1980) applied it to economic problems, Francis and White (1974) formulated a decision framework for assigning a new facility (police posts, supermarkets, schools) for serving a given set of clients, Geoffrion and Graves (1976) concentrated on scheduling problems, Pollatschek et al. (1976**)** mentioned QAP to define the best design for typewriter keyboards and control panels, Krarup and Pruzan (1978) applied it to archeology**.** Hubert (1987) experimented it in statistical analysis, Forsberg et al. (1994) applied it in the reaction chemistry analysis and Brusco and Stahl (2000) used it in numerical analysis. Inspite of the fact that the facilities layout problem is the most popular application for QAP, Dickey and Hopkins (1972) applied QAP to the assignment of buildings in a University campus, Elshafei (1977) in a hospital planning and Bos (1993) in a problem related to forest parks. Benjaafar (2002) introduced a formulation of the facility layout design problem for minimizing work-in-process (WIP). Ben-David and Malah (2005) looked into a special case of QAP called index assignment in order to minimize channel errors in vector-quantization. Vector-quantization is used when mapping images or speech to digital signals. A similar mapping problem is also found when configuring the layout of micro arrays, which is a problem in bioinformatics presented as a QAP by de Carvalho Jr. and Rahmann,S.A (2006). A more modern application of the same problem is the design of keyboards on touch screen devices **(**Dell'Amico et al., 2009). The main difference in this approach is that on a touch screen only one finger is used, and the letters can be placed anywhere on the screen instead of in a rectangle as with normal keyboards.

The following table-2 presents the survey on quadratic assignment problem which has been collected from several theses as well as from published articles in journals.

Table 2: A Survey on Quadratic Assignment Problem

author	title	university	objective
T.A. Johnson(1992)	New linear programming-based solution procedures for the quadratic assignment problem	Clemson University, Clemson, USA,	Introduce new solution procedures based on linear programming. The linear formulation derived in this thesis theoretically dominates alternate linear formulations for QAP.
T. Mautor(1992)	Contribution to solving problems implanation: sequential and parallel algorithms for the quadratic assignment	Pierre et Marie Curie university, France	Focus on parallel implementations and exploits the metric structure of the Nugent instances to reduce the branching tree considerably.
Y. Li(1992)	Heuristic and exact algorithms for the quadratic assignment problem.	The Pennsylvania State University, USA	Introduce beside other ideas lower bounding techniques based on reductions, GRASP and a problem generator for QAP.
F.Malucelli(1993)	Quadratic assignment problems: solution methods and applications.	University of Pisa, Pisa, Italy,	Propose a lower bounding technique for QAP based on a reformulation scheme and implemented it in a branch and bound code. Some new applications of QAP in the field of transportation were also presented.
E. Cela(1995)	The quadratic assignment problem: special cases and relatives.	Graz University of Technology, Graz, Austria	Investigate the computational complexity of specially structured quadratic assignment problems, and consider a generalization of QAP, the so called biquadratic assignment problem
S.E. Karisch(1995)	Nonlinear approaches for the quadratic assignment and graph partition problems	Graz University of Technology, Graz, Austria	Present nonlinear approaches for QAP. These provide the currently strongest lower bounds for problems instances whose distance matrix contains distances of a rectangular grid and for smaller sized general problems.
M. Rijal(1995)	Scheduling, design and assignment problems with quadratic costs	New York University, New York, USA	Investigate structural properties of the QAP polytope. The starting point is the quadric Boolean polytope.
Q. Zhao(1996)	Semi definite programming for assignment and partitioning problems	University of Waterloo, Waterloo, Canada	Investigate semi definite programming approaches for the QAP. Tight relaxations and bounds are obtained by exploiting the geometrical structure of the convex hull of permutation matrices.
A. Bouras(1996)	quadratic assignment problem of small rank: models, complexity, and applications	Joseph Fourier university, Grenoble, France	Consider special cases of QAP where the coefficient matrices have a low rank, especially rank one, and propose a heuristic based on matrix approximations by matrices with low rank.
V. Kaibel(1997)	Polyhedral combinatorics of the quadratic assignment problem	University of Cologne, Cologne, Germany	Investigate the QAP polytope and derived the first large class of facet defining inequalities for these polytopes, the box inequalities..
Gunes Erdogan (2006)	Quadratic assignment problem: linearizations and polynomial time solvable cases	BILKENT UNIVERSITY, Turkey	Focus on “flow-based” formulations, strengthen the formulations with valid inequalities, and report computational experience with a branch-and-cut algorithm.
Thomas Stützle(2006)	Iterated local search for the quadratic assignment problem	Darmstadt, Germany	Present and analyze the application of ILS to the quadratic assignment problem (QAP).
Yi-Rong Zhu(2007)	Recent advances and challenges in quadratic assignment and related problems	the University of Pennsylvania	Contribute to the theoretical, algorithmic and applicable understanding of quadratic assignment and its related problems.

author	title	university	objective
Tao Huang(2008)	Continuous Optimization Methods for the Quadratic Assignment Problem	the University of North Carolina at Chapel Hill	Study continuous optimization techniques as they are applied in nonlinear 0-1 programming. Specically, the methods of relaxation with a penalty function have been carefully investigated.
Franklin Djeumou Fomeni(2011)	New Solution Approaches for the Quadratic Assignment Problem	University of the Witwatersrand	Propose two new solution approaches to the QAP, namely, a Branch-and-Bound method and a discrete dynamic convexized method.
Francesco Puglierin(2012)	A Bandit-Inspired Memetic Algorithm for Quadratic Assignment Problems	University of Utrecht	Propose a new metaheuristic for combinatorial optimization, with focus on the Quadratic Assignment Problem as the hard-problem of choice, a choice that is reflected in the name of the method, BIMA-QAP.
Wu et al. (2012)	Global optimality conditions and optimization methods for quadratic assignment problems	School of Science, Information Technology and Engineering, University of Ballarat , Victoria, Australia Department of Mathematics, Shanghai University,China	Discuss some global optimality conditions for general quadratic {0, 1} programming problems with linear equality constraints, and then some global optimality conditions for quadratic assignment problems (QAP) are presented.
Duman et al. (2012)	Migrating Birds Optimization: A new metaheuristic approach and its performance on quadratic assignment problem	Ozyegin University, Department of Industrial Engineering,Istanbul, Turkey Dogus University, Department of Computer Engineering, Istanbul, Turkey Marmara University, Department of Computer Engineering, Istanbul, Turkey	Propose a new nature inspired metaheuristic approach based on the V flight formation of the migrating birds which is proven to be an effective formation in energy saving. Its performance is tested on quadratic assignment problem instances arising from a real life problem and very good results are obtained.
Benlic et al.(2013)	Breakout local search for the quadratic assignment problem	University of Angers,france	Present breakout local search (BLS) for solving QAP. BLS explores the search space by a joint use of local search and adaptive perturbation strategies.
Klerk et al.(2014)	Symmetry in RLT-type relaxations for the quadratic assignment and standard quadratic optimization problems	Department of Econometrics and OR, Tilburg University, The Netherlands Centrum Wiskunde & Informatica (CWI), Amsterdam, The Netherlands	Show that, in the presence of suitable algebraic symmetry in the original problem data, it is sometimes possible to compute level two RLT bounds with additional linear matrix inequality constraints.
Axel Nyberg (2014)	Some Reformulations for the Quadratic Assignment Problem	Department of Chemical Engineering Abo Akademi University , Finland	Reformulate the Quadratic Assignment Problem for optimization

Source: Collected and compiled by author

2.6. Vehicle Routing Problem (VRP):

Vehicle routing problem (VRP) is a generic name specified to a whole class of problems involving the design of optimal routes for a fleet of vehicles to provide service to a set of customers subject to side constraints. The VRP is a vital problem in the physical delivery of goods and services. In reality, numerous variants of the VRP exist, depending on the nature of the transported goods, the quality of service required, and the characteristics of customers and vehicles. Some typical obstacles are heterogeneous vehicles located at different depots, customers mismatched with certain vehicle types, customers accepting delivery within specified time windows, multiple-day planning horizons and vehicles performing multiple routes. In all cases, the objective is to supply the customers at minimum cost.

The simplest and most studied member of the VRP family is the capacitated VRP (CVRP). In the CVRP, all customers must be satisfied, all demands are known, and all vehicles have identical, limited capacity and are based at a central depot. A fleet of identical vehicles located at a central depot has to be optimally routed to supply a set of customers with known demands. The objectives are to minimize the vehicle fleet and the sum of travel time while the total demand of commodities for each route may not exceed the capacity of the vehicle which serves that route. .Each vehicle can perform at most one route and the total demand of the customers visited by a route cannot exceed the vehicle capacity.

Another important variant of the VRP is the VRP with time windows (VRPTW) that generalizes the CVRP by imposing that each customer is visited within a specified time interval, called time window. The objective is to minimize the vehicle fleet with the sum of travel time and waiting time needed to supply all customers in their required hour. A variety of exact algorithms and efficient heuristics have already been proposed for VRPTW by various researchers as shown in Table 3. In addition, Table 2 represents the various methods applying in exact algorithm, classical heuristic algorithms and metaheuristic algorithms for various type of VRP.Therefore, in the last decade, some innovative exact approaches for vehicle routing problems have been proposed, producing a significant improvement on the size of the instances that can be solved to optimality.

Table 3: Review of Vehicle Routing Problem with Time Window

Authors	Year	Methodologies
Dumas et all	1995	Time constraint routing and scheduling
Liu and Shen	1999	Route-neighborhood-based metaheuristic
Bent et al.	2003	Two-stage hybrid algorithm
Kim, et al.	2006	Capacitated clustering
Lysgaard	2006	Precedence constraints
Russell and Chiang	2006	Robust solution methods
Chena, Hsueh and Chang	2009	An elaborated solution Algorithms
Li, et al.	2009	Lagrangian heuristic

Source: Collected and compiled by author

2.7. Heuristics:

A heuristic technique, often called simply a *heuristic*, is any approach to problem solving, learning, or discovery that employs a practical methodology not guaranteed to be optimal or perfect, but sufficient for the immediate goals. Where finding an optimal solution is impossible or impractical, heuristic methods can be used to speed up the process of finding a satisfactory solution. Heuristics can be mental shortcuts that ease the cognitive load of making a decision. Examples of this method include using a rule of thumb, an educated guess, an intuitive judgment, stereotyping, profiling, or sense. More precisely, heuristics are strategies using readily accessible, though loosely applicable, information to control problem solving in human beings and machines. Heuristic technique is the procedure committed to the search of good quality solutions. Due to obvious complexities experienced in the development of exact solution procedures, a wide variety of heuristic approaches has been developed for QAP. Heuristic algorithms do not offer a guarantee of optimality for the best solution obtained. As a matter of fact, it is usual to find approximate algorithms treated as heuristic algorithms in the Combinatorial Optimization literature, as in Osman and Laporte (1996).These approaches can be classified into the following

categories: simulated annealing, Improvement methods, Construction methods, Greedy randomized adaptive search procedures Limited enumeration methods, Genetic algorithms, and Ant colonies, Metaheuristics, tabu search which are discussed below in a nut shell.

2.7.1. Simulated Annealing (SA)

This group of heuristics, which is also used for overcoming local optima, receives its name from the physical process which it imitates. This process, called *annealing* moves high energy particles to lower energy states with the lowering of the temperature, thus cooling a material to a steady state. Initially, in the initial state of the heuristic, the algorithm is lenient and capable of moving to a *worse* solution. However, with each iteration the algorithm becomes stricter requiring a better solution at each step. Simulated annealing (SA) is a generic probabilistic metaheuristic for the global optimization problem of locating a good approximation to the global optimum of a given function in a large search space. It is often used when the search space is discrete (e.g., all tours that visit a given set of cities). For certain problems, simulated annealing may be more efficient than exhaustive enumeration provided that the goal is merely to find an acceptably good solution in a fixed amount of time, rather than the best possible solution. The name and inspiration come from annealing in metallurgy, a technique involving heating and controlled cooling of a material to increase the size of its crystals and reduce their defects.

2.7.2. Improvement Methods (IM)

These methods belong to the larger class of local search algorithms. A local search procedure starts with an initial feasible solution and iteratively tries to improve the current solution. This is done by substituting the latter with a (better) feasible solution from its neighborhood. This iterative step is repeated until no further improvement can be found. Improvement methods are local search algorithm which allows only improvements of the current solution in each iteration. The most accepted improvement methods are the local search and the tabu search . Both methods work by starting with an initial basic feasible solution and then trying to improve it. The local search seeks an improved solution in the neighborhood of the current solution, terminating when no better solution exists within that neighborhood. The tabu search (TS) (initiated by SkorinKapov (1990), Taillard (1991) works similarly to the local search. However, the tabu search is sometimes more approving as it was designed to cope up with the problem of a heuristic getting trapped at local optima.

This group of heuristics, adopted by Burkard and Rendl (1984) ,Wilhelm and Ward (1987), which is also used for overcoming local optima, receives its name from the physical process that it imitates. This process, called annealing moves high energy particles to lower energy states with the lowering of the temperature, thus cooling a material to a steady state. Initially, in the initial state of the heuristic, the algorithm is lenient and capable of moving to a worse solution. With each iteration, the algorithm becomes stricter requiring a better solution at each step.

2.7.3. Construction Methods (CM)

Construction Methods create suboptimal permutations by starting with a partial permutation which is initially empty. The permutation is expanded by repetitive assignments based on set selection criterion until the permutation is complete. One of the oldest heuristics in use is a construction method algorithm [Buffa, Armour and Vollmann (1964)].

2.7.4. Greedy Randomized Adaptive Search Procedures (GRASP)

The greedy randomized adaptive search procedure (also known as GRASP) is a metaheuristic algorithm commonly applied to combinatorial optimization problems. GRASP typically consists of iterations made up from successive constructions of a *greedy randomized* solution and subsequent iterative improvements of it through a local search. The greedy randomized solutions are generated by adding elements to the problem's solution set from a list of elements ranked by a *greedy function* according to the quality of the solution they will achieve. To obtain variability in the candidate set of greedy solutions, well-ranked candidate elements are often placed in a *restricted candidate list* (also known as RCL), and chosen at random when building up the solution. This kind of greedy randomized construction method is also known as a semi-greedy heuristic, first described in Hart and Shogan (1987).

GRASP is a relatively new heuristic used for solving combinatorial optimization problems. At each iteration, a solution is computed. The final solution is taken as the one that is the best after all GRASP iterations are performed. The GRASP was first applied to QAP by Li, Pardalos, and Resende in 1994 . They applied the GRASP to 88 instances of QAP, finding the best known solution in almost every case, and improved solutions for a few instances.

2.7.5. Limited Enumeration Methods (LEM)

Limited enumeration is a procedure of operations research which corresponds to complete enumeration, but the algorithm is aborted when a time or node limit is reached. Enumeration methods can guarantee that the obtained solution is optimum only if they can go to the end of the enumerative process. However, it is possible that a good solution, or even an optimal solution, is found by the beginning of the process. It can be observed that the best the information used to guide the enumeration, the bigger the chances to find prematurely good quality solutions.

The method is based directly on the enumeration of sequentially organized full enumeration. Before the enumeration process starts, general heuristic methods are used. With them an initial solution is calculated. An upper bound of the initial costs is generated (enumeration limit). If, during the enumeration process, a solution is reached or exceeded, the calculation of this solution is stopped and we start to build another solution. It skips groups of branches of full enumeration. When during the enumeration process, a solution is found and the costs are below the existing bound, you continue with these new costs as the limit of the calculation. When the enumeration is done, the optimal solution is the last bound which was created. For the operation of the limited enumeration, it is very important to reduce that problem. It corresponds to the determination of costs lower limits on branching and bounding. By "reducing" of the problem, a separation of basic costs and solution-dependent costs is introduced. It should help to increase the cost during the enumerative structure of solution. Thus non-optimal solutions are seen early and large groups of branches of the full enumeration can be skiped.

The limited enumeration methods [West (1983), Burkard and Bonniger (1983)] are robustly related to exact methods like branch and bound and cutting planes. The inspiration behind these algorithms is that a good suboptimal solution may be produced early in an enumerative search. In addition, an optimal solution may be found earlier in the search while the rest of the time is spent on proving the optimality of this solution. There are several ways to limit enumeration of the search space**;** one approach is to impose a time limit. Enumeration stops when the algorithm reaches a time limit or no improvement has been made in a predetermined time interval. These pre-specified parameters can be problem specific. A second option is to decrease the requirement for optimality. For example, if no improvement has been made after a certain pre-specified time interval, then the upper bound is decreased by a certain percentage resulting in deeper cuts in the enumeration tree. Although the optional solution may be cut off, it differs from the obtained solution by the above percentage.

2.7.6. Genetic Algorithms (GA)

In the field of artificial intelligence, a genetic algorithm (GA) is a search heuristic that mimics the process of natural selection. This heuristic (also sometimes called a metaheuristic) is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.

Genetic algorithms [Fleurent and Ferland (1994), Tate and Smith (1985), Ahuja, Orlin, and Tewari (1998), Drezner, Z (2003), Yongzhong Wu and Ping Li(2007)] receive their name from an intuitive explanation of the manner in which they behave. This explanation based on Darwin's theory of natural selection. Genetic algorithms store a group of solutions and then work to replace these solutions with better ones based on some fitness criterion, usually the objective function value. Genetic algorithms are parallel and supportive when applied in such an environment.

2.7.7 Ant Colonies (AC)

The ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. This algorithm is a member of the ant colony algorithms family, in swarm intelligence methods, and it constitutes some metaheuristic optimizations. Initially proposed by Marco Dorigo in 1992 in his PhD thesis, the first algorithm was aiming to search for an optimal path in a graph, based on the behavior of ants seeking a path between their colony and a source of food.Ant Colonies are based on the principle that using very simple communication mechanisms, an ant group is able to find the shortest path between any two points. During their trips**,** a chemical trail (pheromone) is left on the ground. The role of this trail is guiding the other ants towards the target point. For one ant, the path is selected according to the quantity of pheromone. Moreover, this chemical substance has a decreasing action over time, and the quantity left by one ant relies on the amount of food found and the number of ants using this trail. Applied on QAP, the AC is based on a hybridization of the ant system with a local search method, each ant being associated with an integer permutation. Modifications based on the pheromone trail are then applied to each permutation. The solutions (ants) found so far are then optimized using a local search method, update of the pheromone trail simulates the evaporation and takes into account the solutions produced in the search strategy.

2.7.8. Tabu search

Tabu search is a local search algorithm that was introduced by Glover to find good quality solutions for integer programming problems. Its main feature is an updated list of the best solutions that were found in the search process. Each solution receives a priority value or an aspiration criterion. Their basic ingredients are: a *tabu list*, used to keep the history of the search process evolution; a mechanism that allows the acceptance or rejection of a new allocation in the neighborhood, based on the tabu list information and on their priorities; and a mechanism that allows the alternation between neighborhood diversification and intensification strategies.

2.8. Exact Algorithms:

Fukasawa et al. (2006) described an exact algorithm based on the SP model where the variables correspond to the set of q-routes, introduced by Christofides et al. (1981), while the constraints correspond to the set

partitioning constraints and valid inequalities , such as rounded capacity inequalities, framed capacity, strengthened comb, multistar, partial multistar, generalized large multistar and hypo tour inequalities, all presented in Lysgaard et al. (2004) for formulation R. Baldacci et al. (2008) proposed an exact algorithm based on model SP, strengthened by the following two types of valid inequalities.- Strengthened capacity inequalities, Clique inequalities. To attain optimality for QAP there are three main methods: the Branch and bound procedures, the cutting plane techniques, and the Dynamic programming

2.8.1 The Branch and Bound Method

The most important and used method to achieve optimality for QAP is the Branch and bound as it is more efficient technique. The Branch and bound procedures was firstly introduced by Gilmore in 1962 who solved a QAP of size 8 = n. The Branch and bound method was named as it is applied. All recent break-through in solving QAP are actually related to this approach. The main idea is as follows: we do not want to check all permutations; therefore we construct an optimal permutation step by step. We start with the empty permutation (i. e. no building is assigned) and successively extend it to a full (optimal) permutation. Throughout the procedure we need a good feasible solution for QAP (i. e. a good upper bound B). Therefore, to apply Branch and bound method; first, chose a heuristic procedure to get an initial feasible solution "suboptimal" and it is used as upper bound. Second, the problem is fragmented into sub- problems with a lower bound, then formulate search tree by repeating the fragmentation and lower bounding of each sub-problem .During iterations, an optimal permutation is being constructed. Branch and bound algorithms have been applied successfully to many hard combinatorial optimization problems, and they appear to be the most efficient exact algorithms for solving the QAP. The basic ingredients of branch and bound algorithms are bounding, branching, and the selection rule. Although many bounding techniques have been developed for the QAP the most efficient branch and bound algorithms for this problem employ the Gilmore-Lawler bound (GLB). The reason is that other bounds which outperform GLB in terms of bound quality are simply expensive in terms of computation time.

2.8.2 The Cutting Plane Method

The Cutting Plane Method has two classes: traditional cutting plane methods and polyhedral cutting-plane or branch-and-cut methods. Traditional cutting plane algorithms for QAP first used by Kaufman and Broekx in 1978 , these algorithms make use of mixed integer linear programming (MILP) formulations for QAP . Generally, the time needed for these methods is too large, and hence these methods may solve to optimality only very small QAPs. However, heuristics derived from cutting plane approaches produce good suboptimal solutions in early stages of the search. The polyhedral cutting planes or branch and cut algorithms make use of MILP formulations of QAP. The polyhedral cutting plane is not widely used in QAP because of the scarcity of knowledge about QAP polytypes.

2.8.3.The Dynamic Programming

The thought behind the dynamic programming method is reasonably straightforward. In broad-spectrum, to solve a given problem, different parts of the problem "sub problems" need to be solved, and then the solutions of the sub problems should be combined to reach an overall solution. Christofides and Benavent(1989) used a dynamic programming approach to solve a special case of QAP. Dynamic programming solves a problem of size n by starting from sub problems of size 1,2,…,n-1. After solving sub problems of size k it upgrades the solutions to size k+1. Problems may arise in dynamic programming if the solution to a sub problem or the upgrade procedure cannot be performed in polynomial time.

Table 4: Representative Exact algorithms, Classical Heuristic Algorithms and Metaheuristic Algorithms for VRP.

Authors	Year	Methodologies
Christofides and Eilon	1969	Branch and Bound
G. Laporte et al	1988	Branch and Bound
Martin Desrochers et	1992	Column Generation
Miller	1995	Branch and Bound
Hadjiconstantinou et al	1995	Set-partitioning
Ralph, T.K.	2003	Parallel Branch and Cut
Baldacci et al.	2004	Branch and Cut
Jin et al.	2008	Column Generation

Source: Collected and compiled by author

Table 5: Classical Heuristic Algorithms

Authors	Year	Methodologies
Dantzig and Ramser	1959	Constructive algorithm. First approach
Clarke and Wright	1964	Saving. Concurrent & sequential
Wren and Holliday	1972	Sweep Algorithm. Multiple depots
Lin and Kernighan	1973	Single-route improvement Sequential k-exchange
Gillett and Miller	1974	Sweep Algorithm. Single depot
Foster and Ryan	1976	Petal algorithm. Optimal petal solution
Mole and Jameson	1976	Sequential Route-Building Insertion position check
Christofides et al.	1979	Sequential Route-Building Sequential & Parallel construction
Fisher and Jaikumar	1981	Cluster-First Route-Second Generalized Assignment + TSP
Beasley	1983	Route-First Cluster-Second
Altinkemer and Gavish	1991	Matching Algorithm. Matching clusters
Ryan et al.	1993	Petal algorithm
Thompson and Psaraftis	1993	Multiple-Route Improvement b-cyclic k-transfer
Potvin and Rousseau	1995	Single-route improvement. Based on 2-opt
Bramel and Simchi-Levi	1995	Cluster-First Route-Second
Renaud et al.	1996	Single-route improvement
Kindervater and Savelsbergh	1997	Multiple-Route Improvement

Source: Collected and compiled by author

2.9. Metaheuristics

In computer science and mathematical optimization, a metaheuristic is a higher-level procedure or heuristic designed to find, generate, or select a heuristic (partial search algorithm) that may provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity. Metaheuristics sample a set of solutions which is too large to be completely sampled. Metaheuristics may make few assumptions about the optimization problem being solved, and so they may be usable for a variety of problems. There are properties that characterize most metaheuristics which are as follows: Metaheuristics are strategies that guide the search process.The goal is to efficiently explore the search space in order to find near–optimal solutions.Techniques which constitute metaheuristic algorithms range from simple local search procedures to complex learning processes.Metaheuristic algorithms are approximate and usually non-deterministic.Metaheuristics are not problem-specific.Compared to optimization algorithms and iterative methods, metaheuristics do not guarantee that a globally optimal solution can be found on some class of problems. Many metaheuristics implement some form of stochastic optimization, so that the solution found is dependent on the set of random variables generated. By searching over a large set of feasible solutions, metaheuristics can often find good solutions with less computational effort than optimization algorithms, iterative methods, or simple heuristics. As such, they are useful approaches for optimization problems. Metaheuristics are used for combinatorial optimization in which an optimal solution is sought over a discrete search-space. An example problem is the travelling salesman problem where the search-space of candidate solutions grows faster than exponentially as the size of the problem increases, which makes an exhaustive search for the optimal solution infeasible.

Table 6: Metaheuristic Algorithms

Authors	Year	Methodologies
Osman	1993	SA
Taillard	1993	TS
Gendreau et al.	1994	TS
Van Breedam	1995	SA
Rochat and Taillard	1995	TS
Xu and Kelly	1996	TS
Kawamura et al.	1998	ACO
Bullnheimer et al.	1999	ACO
Toth and Vigo	2003	TS
Baker and Ayechew	2003	GA
Mazzeo and Loiseau	2004	ACO

Source: Collected and compiled by author

2.10.The simultaneous assignment problem:

Yamada and Nasu(2000) discuss an application of a many-to-one three-dimensional AP that they call the simultaneous assignment problem. They discuss and provide both heuristics and algorithms for the problem of simultaneously assigning cadets at Japan's National Defense Academy to science/engineering departments and to branches of Japan's armed services, recognizing both the students' preferences (the objective function) and limits on the sizes of the classes and the numbers of cadets to be assigned to the different service branches.

2.11.Fuzzy assignment problem:

Fuzzy assignment problems have received great attention in recent years. Aggarwal et al(1987) developed two algorithms for solving bottleneck assignment problems. Costs in many real life applications are not deterministic numbers. The fuzzy assignment problem (FAP) is more realistic than the AP because most real environments are uncertain. In recent years, many researchers have begun to investigate AP and its variants under fuzzy environments. For instance, Chen, M.S(1985) solved a fuzzy assignment model that considers all individuals have same skills. He proposed a fuzzy assignment model that did not consider the differences of individuals, and also proved some theorems. Feng and Yang(2006)studied a two objective fuzzy k-cardinality AP. Sakawa et al.(2001),considered interactive fuzzy programming for two-level or multi level linear programming problems to obtain a satisfactory solution for decision making. Longsheng Huang and Guang-hui Xu(2005) proposed a solution procedure for the AP with restriction of qualification. By the max–min criterion suggested by Bellman and Zadeh(1970), the fuzzy assignment problem can be treated as a mixed integer nonlinear programming problem. Lin and Wen(2004) investigated a fuzzy assignment problem in which the cost depends on the quality of the job. Mich éal ÓhÉigeartaigh(1982) and Chanas et al.(1984)solved transportation problems with fuzzy supply and demand values. An integer fuzzy transportation problem was solved in Tada and Ishii(1996). Chanas and Kuchta(1996) proposed the concept of the optimal solution of the transportation problem with fuzzy coefficients expressed as L-R fuzzy numbers, and developed an algorithm for determining the solution. Additionally, Chanas and Kuchta(1998) designed an algorithm for solving integer fuzzy transportation problem with fuzzy demand and supply values in the sense of maximizing the joint satisfaction of the fuzzy goal and the constraints. Pandian and Natarajan (2010a,2010b) have introduced two different methods for solving the fuzzy transportation problem. Fractional programming is a particular type of non-linear programming in which the objective function to be optimized is the ratio of two other objective function. Wang(1987) solved a similar model by graph theory. Dubois and Fortemps(1999)proposed a flexible assignment problem, which combines with fuzzy theory, multiple criteria decision-making and constraint-directed methodology. They also demonstrated and solved an example of fuzzy assignment problem. Sakawa et al.(2001) dealt with actual problems on production and work force assignment of a housing material manufacturer and formulated two-level linear and linear fractional programming problems according profitability maximization respectively. By applying interactive fuzzy programming for two-level linear and linear fractional programming problems, they derived satisfactory solutions to the problems and compared the results. Majumdar and Bhunia(2007) proposed an elitist genetic algorithm to solve generalized assignment problem with imprecise cost/time. Ye and Xu(2008) proposed an effective method on priority-based genetic algorithm to solve fuzzy vehicle routing assignment when there is no genetic algorithm which can give clearly procedure of solving it. Liu and Gao(2009) proposed an equilibrium optimization problem and extended the assignment problem to the equilibrium multi-job assignment problem, equilibrium multi-job quadratic assignment problem and used genetic algorithm to solve the proposed models. Bai et al.(2009) proposed a method for solving fuzzy generalized assignment problem.

2.12.Frequency Assignment Problems:

Wireless communication is used in many different situations such as mobile telephony, radio and TV broadcasting, satellite communication, and military operations. In each of these situations a frequency assignment problem arises with application specific characteristics. Researchers have developed different modeling ideas for each of the features of the problem, such as the handling of interference among radio signals, the availability of frequencies, and the optimization criterion.

Frequency assignment problems (FAPs) first appeared in the 1960s. The development of new wireless services such as the first cellular phone networks led to scarcity of usable frequencies in the radio spectrum. Frequencies were licensed by the government who charged operators for the usage of each single frequency separately. This introduced the need for operators to develop frequency plans that not only avoided high interference levels, but also minimized the licensing costs. It turned out that it was far from obvious to find such a plan. At this point, operations research techniques and graph theory were introduced. Metzger(1970) usually receives the credits for pointing out the opportunities to use mathematical optimization, especially graph coloring techniques, for this purpose.

The literature on frequency assignment problems, also called channel assignment problems, has grown quickly over the past years. This is mainly due to the fast implementation of wireless telephone networks (e.g., GSM networks) and satellite communication projects. But also the renewed interest in other applications like TV broadcasting and military communication problems inspired new research. These applications lead to many different models, and within the models to many different types of instances. However, all of them share two common features:

(i) A set of wireless communication connections (or a set of antennae) must be assigned frequencies such that data transmission between the two endpoints of each connection (the receivers)
is possible. The frequencies should be selected from a given set that may differ among connections.

(ii) The frequencies assigned to two connections may incur interference to one another, resulting in quality loss of the signal. Two conditions must be fulfilled in order to have interference of two signals:

(a) The two frequencies must be close on the Electromagnetic band (or harmonics(Doppler effects of one another).

(b) The connections must be geographically close to each other, so that the interfering signal is powerful enough to disturb the original signal.

Until the early 1980s, most contributions on frequency assignment used heuristics based on the related graph coloring problem. First lower bounds were derived by Gamst and Rave(1982) for the most used problem of that time . The development of the digital cellular phone standard GSM (General System for Mobile Communication) in the late 1980s and 1990s led to a rapidly increasing interest for frequency assignment for a discussion of the typical frequency planning problems in GSM networks). But also projects on other applications such as military wireless communication and radio/TV broadcasting contributed to the literature on frequency assignment in recent years. So far, we only discussed Fixed Channel Assignment (FCA), i.e., static models where the set of connections remains stable over time. Opposite to FCA, Dynamic Channel Assignment (DCA) deals with the problem, where the demand for frequencies at an antenna varies over time. Hybrid Channel Assignment (HCA) combines FCA and DCA: a number of frequencies have to be assigned beforehand, but space in the spectrum has to be reserved for the online assignment of frequencies upon request.

Wireless communication is used in many different situations such as mobile telephony, radio and TV broadcasting, satellite communication, and military operations. In each of these situations a frequency assignment problem arises with application specific characteristics. Researchers have developed different modeling ideas for each of the features of the problem, such as the handling of interference among radio signals, the availability of frequencies, and the optimization criterion.

This survey gives an overview of the models and methods that the literature provides on the topic. We present a broad description of the practical settings in which frequency assignment is applied. We also present a classification of the different models and formulations described in the literature, such that the common features of the models are emphasized. The solution methods are divided in two parts. Optimization and lower bounding techniques on the one hand, and heuristic search techniques on the other hand. The literature is classified according to the used methods. Again, we emphasize the common features, used in the different papers. The quality of the solution methods is compared, whenever possible, on publicly available benchmark instances.

2.13. The Multicommodity Multilevel Bottleneck Assignment Problem

The Multilevel Bottleneck Assignment Problem is defined on a weighted graph of L levels and consists in finding $L-1L-1$ complete matchings between contiguous levels, such that the heaviest path formed by the arcs in the matchings has a minimum weight. The problem, introduced by Carraresi and Gallo (1984) to model the rostering of bus drivers in order to achieve an even balance of the workload among the workers, though frequently cited, seems to have never been applied or extended to more general cases.

2.14.Range Assignment Problem in Ad Hoc Networks:

Recent emergence of affordable, portable, wireless communication and computation devices, and concomitant advances in the communication infrastructure, have resulted in the rapid growth of mobile wireless networks. Among these, *ad hoc networks*, i.e. networks of mobile, untethered units communicating with each other via radio transceivers, are receiving increasing attention in the scientific community. *Ad hoc* networks, also called *multi-hop packet radio networks*, can be used wherever a wired backbone is not viable, e.g. in mobile computing applications in areas where other infrastructure is unavailable, or to provide communications during emergencies. When designing protocols for *ad hoc* networks, the following characteristics peculiar to these networks have to be taken into account:

- *shared communications*: since the stations in the network communicate via radio transceivers, the most natural communication paradigm is one-to-many: when a unit transmits, all the units within its transmitting range receive the message. On the contrary, wired networks use selective transmission (one-to-one) as the natural communication paradigm.
- *energy constraints*: since the stations are equipped with limited energy supplies, one of the primary goals is to reduce the overall energy consumption of the network, thus increasing its lifetime. Routing, broadcast and clustering protocols explicitly designed for ad hoc networks have been recently proposed in the literature. Some of these protocols are designed for energy-efficient operation in an existing network topology, while others attempt to deal with the effects of mobility, and still others consider both of these aspects. It should be observed that further energy can be saved if the network topology itself is energy-efficient, i.e. if the transmitting ranges of the units are set in such a way that a target property (e.g. strong connectivity1) of the resulting network topology is guaranteed, while the global energy consumption is minimal. For this reason, *topology control* protocols have been recently introduced in the literature. Informally speaking, a topology control protocol is an algorithm in which units adjust their transmitting ranges in order to achieve a desired topological property, while optimizing energy consumption. The problem of ensuring strong connectivity while minimizing some measure of energy consumption has also been considered in a more theoretical framework, where it is referred to as the *range assignment problem*. In particular, it has been shown that determining an optimal range assignment is solvable in polynomial time in the one-dimensional case, while it is NP-hard in the two and three-dimensional cases .

2.15.Logic Cuts for the Multilevel Generalized Assignment Problem

In the multilevel generalized assignment problem (MGAP), agents can perform tasks at more than one efficiency level (Mar á A. Osorio et.al, 2003). Important manufacturing problems, such as lot sizing, can be easily formulated as MGAPs; however, the large number of variables in the related 0-1 integer program makes it hard to find optimal solutions to these problems, even when using powerful commercial optimization packages. The MGAP includes a set of knapsack constraints, one per agent, that can be useful for generating simple logical constraints or logic cuts. The method exploit the fact that logic cuts can be generated in linear time and can be easily added to the model before solving it with classical branch and bound methodology.

2.16.A Branch-and-Cut Algorithm for the Multilevel Generalized Assignment Problem

The multilevel generalized assignment problem (MGAP) consists of minimizing the assignment cost of a set of jobs to machines, each having associated therewith a capacity constraint (Pasquale Avella, Maurizio Boccia, and Igor Vasilyev, 2013). Each machine can perform a job with different efficiency levels that entail different costs and amount of resources required. The MGAP was introduced in the context of large manufacturing systems as a more general variant of the well-known generalized assignment problem, where a single efficiency level is associated with each machine. In this method, a branch-and-cut algorithm is proposed whose core is an exact separation procedure for the multiple-choice knapsack polytope induced by the capacity constraints and single-level execution constraints.

3. Conclusion

The focal impetus behind this research presentation is the constant interest in assignment problem shown by a great deal of researchers worldwide for the theory, applications and solution techniques of this problem. This article depicts fundamentals of different kinds of assignment problem and some solving techniques, highlights some efforts on solving AP. This paper can be directed towards assisting potential researchers in this field to develop new assignment solution technique as well as modeling real world applications by getting an over view about assignment problem and developments in the field of optimization.

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Impact of Evaluation System on Organizational Performance: An Empirical Investigation on Banking Sector

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Abstract
From the last past decade every organization is struggling for its survival and growth to have competitive edge. This study is conducted to analyze and investigate the impact of evaluation system on organizational performance. This involves discovering the relationship between evaluation system and organizational performance as now a day with the increase in organizations are focusing on managing and sustaining its performance by taking different measures. The research is conducted on banking sector and this study focuses on primary data which has been collected through questionnaire with a five point likert scale. The study used convenience sampling technique to confine the response of bankers. The data that has been collected is analyzed and assessed through statistical package for social sciences (SPSS).the results of the data has been examined through by each and every step and I have found the results. This study concluded that there is insignificant relationship between organizational performance and evaluation system that means there are many factors that help the organization to improve its performance and profitability but not the evaluation system in particular because there are less chances of factual results in different evaluation systems used by the organizations and many organizations conduct it just as a formality and afterwards and no follow-up is there regarding the evaluation system results so the organizations need to focus on purely those factors that has a significant impact on its performance and profitability and try to work on those factors for its growth and attainment of its goals.
Keywords: Evaluation system, Organizational performance, performance appraisal, behaviorally anchored rating scale

1. Introduction

1.1 Background of the Study

In today's time organizations are in greater pressure regarding its employee performance as well as gaining a competitive edge over its competitors. Every organization business management is based on its performance that how it manages the performance of its employees and evaluate the performance.

The world of performance evaluation is gradually changing from what it was just a decade ago. As management matters to performance and effectiveness, and that performance is the ultimate goal of public management systems and actions," (Moynihan & Pandey, 2005) that is why it's necessary to keenly focus on it. The proper ecvaluati0on of employees help in turning good talent into great talent. While few companies are now focusing on adapting new trends that is focusing on evaluating through different mediums such as performance appraisal, 360 degree feedback. There are many reasons due to which the lack of performance occurs such as less attention has been paid to related issues, notably sickness absence management, lack of evaluation and monitoring (e.g. Taylor *et al*, 2010). Companies try to adapt new trends of performance evaluation so that it can survive in this competitive world where everyone is running towards success. It is necessary to cope up with the changes that have occurred (Thompson, 2012) and that is why Organizations should focus on frequent conversation with employees and evaluate the performance through it because it will help them to keep aware of staff members need, work and abilities and how they are performing. The performance can be evaluated through performance appraisal, 360 degree feedback, BARS etc.

1.2 Research Objectives

By conducting this research, researcher will try to explore

1. The evaluation system now a day's organization is using for managing its performance as world is changing and people are trying to adapt change to survive in this competitive world in which everyone is running towards success.
2. What strategies and ways Organization is using for managing performance of its key personnel.
3. To explain them about how to better manage performance through evaluation and what key indicators will be beneficial for them.
4. To provide understanding with the relationship between performance evaluation system and performance and output of organization.

1.3 Problem Statement

In today's business world it's really important for organizations to manage its performance by using its resources properly. The key personnel of organization is a necessary source of organization in achieving its objectives so

it's really important to evaluate their performance by using right and efficient system and adapting new ways of examining their employees performance to have a positive impact on their performance that will lead to an outstanding performance of organization. Organizations need to know, realize and understand the importance of evaluation system that will help them in better performance and also adaptation of methods of evaluation will help them in managing their performance more effectively so this study is aimed to examine the impact of evaluation system on organizational performance.

1.4 Hypothesis

H0: There is no impact of evaluation system on organizational performance.

1.5 Scope of the study

This study is tasked to investigate the impact of evaluation system on the performance of the organization. It will help the organization in understanding and adapting the new trends of evaluation. It is bounded to banking sector.

1.6 Theoretical framework

Independent variable

Evaluation System

- Performance Appraisal
- 360 degree feedback
- Behaviorally anchored rating scales (BARS)

Dependent variable

Organizational Performance

- Profitability
- Output
- Growth

The above theoretical framework explains that organizational performance is a dependent variable whereas evaluation system is an independent variable that how the organization evaluates the performance of its key personnel. Organizational performance includes profitability, output, growth etc which indicates the overall performance of organization. On the other hand different evaluation methods are used by organization such as performance appraisal, 360 degree feedback; BARS (behaviorally anchored rating scale etc. This research is conducted to find put the relationship between organizational performance and evaluation system.

2. Literature Review

According to (Armstrong and Baron, 1998) "managing the performance of an organization is a strategic and integrated approach to delivering sustained success to organizations by improving the performance of the people who work in them and by developing the capabilities of teams and individual contributors". It is already known that organizational performance is directly linked with its key personnel performance. As per Kotter and Heskett (1992) an effective performance of an organization requires an equal participation of manager and other key employees of organization. Evaluation system is really necessary for an organization to adapt in order to monitor and maintain its performance. Verweire and Van den Berghe (2004) define organizational performance as "the measurement and reporting system that quantifies the degree to which managers achieve their objectives".

The scope and method of evaluation changes and varies between organizations with a variation between qualitative and quantitative forms (Beardwell and Claydon, 2010). There are different types of evaluation system such as performance appraisal, 360 degree feedback, balanced scorecard, BARS etc. firstly the method that was used for evaluation was the balanced scorecard which was based on degree of achievement a person have with an organizational strategic goals the balanced scorecard keep companies looking and moving forward instead of backward (Kaplan and Norton 1996).a properly constructed balanced scorecard can help the management with an ideal tool in reacting to a difficult business environment and also support the organization towards better performance (Gupta,Sarkar and Samantha, 2004) The second popular evaluation system is 360 degree feedback which is used by different organizations (Newbold 2008) and although is used recently.

The success of any organization depends on the quality and characteristics of its employees. Organizations are unable to achieve its goals and objectives without them. The performance appraisal tool is used by the organizations to evaluate the performance of employees, it deals with what needs to be done by the people in the organization in order to meet the purpose and objective of the job (Armstrong, 2006) 360 degree feedback is also used by the organizations to see and find out the strength and weakness of employees for his further guidance.

The significant purpose of such evaluations is that the organizations can lead towards continuous improvement in its performance and growth (Armstrong 2004). Performance appraisal is a kind of traditional and straight forward method in which the manager reviews the performance of its subordinates on annual basis.

(Bach 2005).Some authors felt performance appraisal as having a limited organizational impact. Sometimes the failure of organization in managing its performance is because organizations don't focus in evaluation process properly and also the other reason is the system they are using for the assessment of employees. It needs o focus as much time on developing people as by evaluating them (Randall, 2006). A proper evaluation system is necessary for monitoring performance. And performance management effectiveness increases when there is ongoing feedback, behavior-based measures are used so it's important to think critically and use all the mediums and sources effectively and efficiently for managing the performance. Both managers and employees should recognize the importance of performance evaluation (Barr; 1993).

Performance evaluation can play a valuable role in effecting the grand negotiation between the needs of the individual and needs of the organization (Zedeck; 1983). Performance evaluation is defined as a process of assessing and communicating with employees in how they can improve their performances. This not just allows them to evaluate their own performances, also affects their efforts and futures (Byars and Rue, 2008). A fair and effective performance evaluation system is based on consistent standards of practice (Gunzenhauser, and Fielding, 2010).according to experts; an effective performance evaluation system has a great deal of advantages to offer organizations and employees (Gary et al., 1996). It is really important for the organizations to understand the importance of evaluation system and its impact on overall organizational productivity and growth.

3. Methodology

3.1 Data and variables

This research project deals with primary data to be collected. Data is collected by using questionnaire.
Dependent variable: Organizational performance
Independent variable: Evaluation system

3.2 Sampling technique

In this research the convenience sampling technique is used by giving questionnaire to people who were easily accessible in banking sector.

The questionnaires were distributed in the following banks:

#	Organization name
1	Bank Al Habib
2	Silk Bank
3	Faysal Bank
4	MCB Bank
5	Allied Bank
6	Habib Bank Limited
7	Dubai Islamic Bank
8	Meezan Bank
9	Sindh Bank
10	Summit Bank
11	United Bank Limited
12	Bank Alfalah

3.3 Sample size

The sample size of 12 questionnaires was used in the study. The total number of questionnaires given and received back was equal i.e. 12

3.4 Model

The aim of the research is to find out the impact of evaluation system on organizational performance that is why Regression Model is used in which evaluation system is an independent variable X and organizational performance is a dependent variable Y.

4. Results and Discussion

4.1 Reliability Statistics

Cronbach's Alpha	N of Items
.713	8

Cronbach's alpha is used to check the reliability of the questionnaire. Its lenient cut off is 0.6 and strict cut off is 0.7.As we are getting 0.7, this shows that the questionnaire is reliable.

4.2 Correlation

Correlations

		ES	OP
ES	Pearson Correlation	1	.418
	Sig. (2-tailed)		.177
	N	12	12
OP	Pearson Correlation	.418	1
	Sig. (2-tailed)	.177	
	N	12	12

Correlation tells us about the interdependence between two variables. Here we are getting 41.8% correlation between evaluation system and organizational performance which is insignificant at 1% as sig value is more than 0.05, hence the evaluation system and organizational performance are not interdependent on each other.

4.3 Regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.418[a]	.175	.092	.46364

a. Predictors: (Constant), ES

R square is also known as coefficient of determination which shows goodness of fit of the model. Here it is 17.5 % which means changes in evaluation system dictates 17.5% changes in organizational performance. The difference between R square and adjusted R square is more than 5% which shows a sample error.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.455	1	.455	2.115	.177[b]
	Residual	2.150	10	.215		
	Total	2.604	11			

a. Dependent Variable: OP

b. Predictors: (Constant), ES

Anova shows significance of the model and significance of goodness of fit. The cutoff of F is 4 which shows the significance of F (equality of variance).here F statistic obtained is 2.115 which is less than 4 , this shows that it is insignificant and sig value is also greater than 0.05 which shows the it is insignificant.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.422	1.150		2.106	.061
	ES	.408	.280	.418	1.454	.177

a. Dependent Variable: OP

The above table shows the impact of evaluation system on organizational performance. The coefficient of evaluation system is positive that is 0.4908 which suggest that there is direct relationship between evaluation system and organizational performance. If evaluation system increase by one unit, organizational performance will also increase by 1unit.this relationship is statistically insignificant as t value is 1.4 which is less than two this insignificance is also shown by sig value which is greater than 0.05 so we conclude that it is insignificant.

4.4 Discussion

The aim of this research is to determine the impact of devaluation system on organizational performance. In order to have a better understanding and concept of this study and to assess the evaluation system impact on organizational performance, primary data was collected by floating questionnaire through convenience sampling and the conclusion of this research was drawn through these questionnaires. The result findings show that evaluation system has no interdependence on each other and both have insignificant relationship with each other which means that if one change the other won't change, it will remain same.

5. Conclusion and Recommendations

5.1Conclusion

By considering the data analysis and result findings of the study, the hypothesis H0 has been accepted because of the reason that according to the results there is insignificant relationship between evaluation system and organizational performance.

Every organization has its own evaluation system that it follows to evaluate the performance of its employees. It's not necessary that after evaluating their performance, the organization provide them with a proper feedback. Organizational performance is based on the satisfaction of employees with the organization, the employees want discrimination free environment that more of the organizations fail to provide them. There are many factors that may cause the organizational performance but not evaluation system as it's not necessary that every organization don't implement the results of evaluation system in their organization, they just conduct it as a formality so we can conclude that there is no impact of evaluation system on organizational performance because organizations can't rely on evaluation system because the chances of error during conduction of evaluation system is high.

5.2 Recommendations

After conducting the study, analysis and interpretation, A few recommendations are there that needs to be kept in mind. First of all the organizations for the enhancement of its performance need to satisfy its key personnel by providing them smooth environment and motivate them on their performance so that it will enhance the overall performance and profitability of the organization. Discrimination free environment encourages the employees to show positivity towards fulfilling organizational goals and lead the organization towards success. purely relying on evaluation system regarding the performance of organization is not an intelligent practice because sometimes organizations only deal it as a formality rather than carefully conducting it so organizations need to focus on all those factors that can enhance its performance with little bit chances of error. The organizations need to find out the factors that have a significant impact on organizational performance so that it will help them to focus on those factors and enhance its performance, overall profitability, growth and output of the organization.

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Questionnaire

Hi, this is Aqsa kanwal, studying MS at Hamdard University, Karachi. You are requested to share your opinion. Your identity will remain anonymous and information will be used for research purpose only. I will discard the information provided by you after it has been transcribed.

Please put a check where you think is suitable given that (1) is the lowest degree of agreement and (5) is the highest degree of agreement.

#	**Questions**	**1**	**2**	**3**	**4**	**5**
1	My bank is aware of the factors used to evaluate employee's performance					
2	I have good understanding with performance evaluation system.					
3	My organization operates a formal performance evaluation system.					
4	Evaluation system is an important factor in better performance of organization.					
5	The evaluation system my organization is using currently is appropriate and relevant.					
6	The evaluation system is objective, air and credible.					
7	Evaluation system has a positive impact on organizational performance.					
8	Evaluation results are communicated to employees in timely manner.					
9	Employees are treated respectfully during evaluation system.					
10	Discrimination free evaluation motivates the employees toward better performance that ultimately impacts organizational performance.					
11	Evaluation system has a positive effect on profitability and growth of organization.					
12	Evaluation system is helpful in providing concise picture of different level of employees.					
13	The proper performance evaluation system could be able to generate a feedback for continuous improvement of work.					
14	The evaluation system used in this bank works well and does not need to change.					
15	Performance evaluation techniques more impacts on my performance, incentives and morale.					
16	It helps me to perform my work well that ultimately benefit my organization growth and profitability.					

17 Qualification:
18 Gender:
19 Work experience:

Thank you very much for answering above questionnaire.

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Fault Detections and Diagnosis of Electrical/ Electronic Appliances Training Requirement of Technical Colleges as a Tool for Empowering Electrical Engineering Trade Students in Nigeria

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Abstract
The major purpose of the study was to investigate the fault detection and diagnosis training requirement of technical colleges as a tool for empowering electrical/electronics trade students. Two research Questions were answered. The study adopted a descriptive survey design. The population for the study was ninety two (92) comprised of all sixty six (66) electrical /electronics technical college teachers in Oyo and Ogun states and 24 electrical/electronics technologists which were sampled in the two states using purposive sampling techniques. The internal consistency of the instrument was ascertained using Cronbach Alpha method and reliability coefficient obtained for the instrument was 0.89. Structured questionnaire containing 153 items was designed and used for data collection. Mean and standard deviation were used to analyze research questions. The findings of the study revealed that ability to detect faulty components, ability to diagnose appliances components, ability to work with multiple technologies and keep up to date with new technologies are required for the training electrical/electronics students on fault detection and diagnosis of electrical/ electronic appliances in Nigeria technical colleges. The findings of the study also revealed that magnifying lens, oscilloscope, personal computer, screwdrivers, drills soldering iron, fire extinguishers, and first aid box among others are the required instrument training electrical/electronics students on fault detection and diagnosis of electrical/ electronic appliances in Nigeria technical colleges. It was recommended that necessary effort should be made by stakeholders of education and curriculum development to integrate the relevant skills on fault detection and diagnosis of electrical/electronic appliances into the curriculum of electrical/electronic students of technical colleges of Nigeria.
Keywords: Appliances, Fault detection and Diagnosis, Repair, Technical Colleges, Technicians and Technologists.

Technical and Vocational Education and Training (TVET) is a conglomeration of school and training based type of learning experiences which aims to inculcate in students practical skills, scientific know how, social and academic traits and entrepreneurship fitness to enable students to be self dependent or perform excellently in world of work. International Labour Organization (2010) claimed that TVET is a range of learning experience that are relevant for employability, portability of competencies and qualifications and recognition of skills, decent work opportunities and lifelong learning in and related to the world of work. Technical and Vocational Education and Training in an ideal situation offers career development opportunity to the students. TVET, according to Henry, Jack and Getrude (2014), plays an orientation role towards the world of work and its curriculum emphasizes on the acquisition of such employable skills, which is a fundamental necessity for driving the industrial and economic growth. The author stated further that TVET is a key to build this type of technical and entrepreneurial workforce which Africa needs to create wealth and emerge out of poverty. This is because Technical and Vocational Education and Training produces educated, skilled and motivated citizen who can profit society by creating enterprise or gain employment from employers. Okwelle (2011) submitted that Technical and vocational education and training is an integral part of National development strategies in many society because of the many impact on human resource development, productivity and economic growth.

The major aim of Technical and Vocational Education and Training is to produce citizen who can be self dependent and reliance. UNESCO in Henry, Jack and Getrude (2014) claimed that the objective of TVET is to train the workforce for self employment and the necessity to raise the productivity of the informal sectors.

Aklhilianand and Eci (2008) claimed that most commonly articulated goal of Technical and Vocational Education and Training are to:

Facilitate economic development by transmitting to local citizen certain value, knowledge and attitudes that necessary to perform certain skill in modern sector of economy;

Provide young people with the skills needed for employment in a wide range of job categories including self employment and wage employment;

Promote a work ethic and sensitize learners to the importance of practical work skills and dignity of manual labour;

Promote sustainable development, save the environment and improve the quality of living;

Alleviate unemployment as well as poverty;

Reduce the mass movement of school learners from rural to urban area;

And provide an alternative route to higher academic education for secondary learners (page 5) .

Due to immerse impact of Technical and Vocational Education and Training (TVET) to the development of advanced or developed nations, countries in Africa invested in it. Henry, Jack and Getrude (2014) reported that in countries of sub Saharan Africa, in particular government are renewing efforts to promote TVET with the conviction that development of the skills enhances productivity and sustain competitiveness in the global economy. Specifically, Nigeria government invested in TVET programme through the establishment of technical colleges among others.

Technical college is a version of senior secondary schools that is established to produce young man power that can gain employment or create an enterprise. Abdulrauf (2012) defined technical colleges as institutions where specific knowledge and practical skills required for specific trade, employment or professional craftsmen, technicians, or similar level in business and industry are imparted or taught. Technical college give admission to students who have attained age of fourteen and above and successfully completed three years of junior secondary education or its equivalent (United National Education Social and Cultural Organization, UNESCO and National Board for Technical Education, NBTE (2001). UNESCO and NBTE (2001) claimed that the aim of technical colleges is to give training and impact the necessary skills leading to the production of craftsmen, technicians and other skilled personnel who will be enterprising and reliant. Various courses including electrical engineering trades are offering at technical colleges (Federal Republic of Nigeria, 2004).

Engineering is the field or discipline, practice, profession and art that relates to the development, acquisition and application of technical, scientific and mathematical knowledge about the understanding, design, development, invention, innovation and use of materials, machines, structures, systems and processes for specific purposes. Engineering, according to James (2008), is a profession in which knowledge of the mathematical and natural science gained by study, experience and practices are applied with the judgment to utilize economically natural and man -made materials. Thus, electrical engineering trade includes a profession where technical, mathematical and scientific knowledge, skill and attitude are acquired through study, experience and practice to develop, design, create, manufacture and repair system, device and appliance that use high and low electric power or signal. Electrical engineering trade according to Yekinni (2015) covers electricity/electronics subjects which includes series of tasks and skills which technical college (electrical/electronics) student are required to learn. The task and skills include appliance repair among others (Federal Republic of Nigeria, 2004).

Appliances are mechanically or electrically operated devices or machines used to perform specific task by transforming one energy to another. Frank (1978) defined appliances as utilization item of electric equipment usually complete in itself, generally other than industrial, normally built in standardize size or type that transform electrical energy into another form usually heat or mechanical motion, at the point of utilization. Also, Mark (2003) opined that appliances are pieces of equipment that draw electric or other energy and produce a desired work-saving or other result. Appliances exist in different form with different performance depending on their purpose of creation. In the process of appliances utilization, appliances become malfunctioning or faulty.

Fault is a deviation from a prescribed function of a system due to undesirable deviation in the property of a system. Fault according to Joseph (2009) is deviation between perfect performance and complete failure. Venkat; Raghunathan; Kewen and Surya (2003) opined that fault is generally defined as a departure from acceptable range of an observed variable as a calculated parameters associated with a process. Also, Rolf (1984) claimed fault as no permitted deviation of a characteristics property which lead to the inability to fulfill the intended purpose. A faulty or malfunctioning appliance occurs when the expected value of output is diminishing or equal to zero. Rolf (1984) claimed that plant is faulty when the limited value of measurable output signals is transgressed.

Malfunctioning or faulty appliances are most of time dumped into dustbin or abandoned in an unsecured area which is an act of resources mismanagement and thereby caused environmental pollution. The Environmental Protection Agency in Olaitan, Asogwa and Abu (2013) reported that about 50 million tons of electronics-wastes are produced every year especially from developing countries. Electronic waste in this content is electronics equipments, device, machine or appliances which are not functioning anymore because they are obsolete, or faulty. Thus, malfunctioning or faulty appliance can be revived if it is subjected to repair. However, this will reduce the act of electronics wastage.

Repair means the act of renewing, restoring or reviving a damaged item to sound condition. Frank (1978) defined repair as restoration or replacement of part or component of a material as necessitated by wear and tear, damage, failure or the like in other to maintain the specific item or material in efficient operating condition. Samson and Chris (2014) claimed that Repairs involves the activities taken for the restoration of a broken, damaged or failed component, device, equipment, part, or appliance to an acceptable operating or stable state. Thus, appliances repair means all routine action performed through which damage part or component of appliances are restored or replaced with the aim of restoring, reviving, renewing and maintaining the appliances

in a good operating condition. Appliances repairs are processes that involve examination of appliances, location and identification of faults In appliances and rectification of fault. Thus, appliances repair is basically fault detection and diagnosis (FDD).

Fault detection and diagnosis means monitoring the appliance to detect any failed or faulty components or part of appliances, quantifying the fault and determining its causes, assessing the sizes and the impact on system performance and finally making decision on how to respond to the fault. Fault detection and diagnosis according to Rolf (1984) is checking through a faulty/ malfunctioning system to see if a particular measurable or immeasurable estimated variables are within a certain tolerance of the normal value or not and location of the fault and establishment of the causes. Srinivas and Micheal (2005) claimed that the primary objectives of fault detection and diagnosis of a system is early detection of fault and diagnosis of their causes, enabling correction of faults before additional damage to the system or loss of services occurs. Fault detection and diagnosis of appliances connotes process of examining faulty/ malfunctioning appliances to locate and identify fault and their related causes, weighing the extent and consequences of the fault on the appliances performances and design appropriate decision to correct the identified fault using appropriate instruments to prevent additional damages on appliances and to prevent the occurrence of total loss of service to appliances.

The process of fault detection and diagnosis of appliances requires certain instruments for the task to be done effectively and efficiently. Instruments are tools, equipment or devices that are required to make some tasks easily accomplished. Stan (2001) claimed instrument to mean device for measuring electrical quantities or the performance of electronic equipment. Mark (2003) opined that instrument is a device for measuring and sometimes also recording and controlling the value of quantity under observation They are manipulated items needed to dismantle/assemble, test, measure, diagnose, repair and maintain safety during Fault detection and diagnosis of appliances. Thus, in Fault detection and diagnosis of appliances, specific safety, testing, measuring, dismantling/assembling and repairing tools, devices and equipments may be required.

Fault detection and diagnosis is a common term in industries with the aim of ensuring reliability and safety of industrial equipment. In houses and offices, where electrical and electronic appliances are use for social and commercial purposes among other, fault detection and diagnosis is also essential. The appliances may untimely breakdown due to personal, social and environmental factors. The faults or malfunctioning in appliance can be caused by poor handling, poor maintenance, poor design, age of an appliance, and inconsistence nature of Nigeria electricity. Luiz, Jefferson, Tiago, Marcelo, Eduado, and Renato (2011) claimed that hostile environment, poor operating condition, lack or insufficient maintenance, allied to an increasing occurrence of failures. Thus, fault detection and diagnosis is required to reduce electrical/electronic appliances waste. Gazette in Olaitan Asogwa and Abu (2013) opined that manufacturing companies such as Sony Erickson, Panasonic Motorola, Nokia and Samsung have certified that maintenance, servicing and repairing of electronics devices for re-use remain the best electronics waste management. The task of detecting and diagnosing fault on appliances lies on technicians. James (1994) opined that veteran equipment has worked at one time but because of a normal failure or abuse it no longer functions properly or has failed altogether. He stated further that majority of electronic technicians find employment in this kind of job.

Technical college students according to UNESCO and NBTE (2001) are training to become craftsmen, technicians and other skilled personnel who can be enterprising or gaining employment. Ohanu and Ogbuanya (2014) also stated that Technical colleges are concerned with production of technicians who are skilled in different fields of human endeavour. Thus, the task of fault detection and diagnosis of electrical /electronics appliances lies on technical colleges graduate specifically electrical engineering trade graduate of technical college called technicians. Technicians according to United Nations Educational, Scientific and Cultural Organization (2010) are those who involved in applying proven techniques and procedures to the solution of practical engineering problems. Author stated further that Technician: carry out supervisory or technical responsibility; are competent to exercise creative aptitudes and skills within defined fields of technology; contribute to the design, development, manufacture, commissioning, operation or maintenance of products, equipment, processes or services; and create and apply safe systems of work.

Ibezim, Ohanu and Shodeinde (2014) asserted that Electronics technicians are mostly trained in the technical colleges trained to carryout repair of electronic gadget/ appliances. Most of technicians in Nigeria are not so skilled on fault detection and diagnosis of all electrical /electronics appliances. This may be due to inadequate provisions of the skill requirements in the curriculum running in technical colleges. Ohanu (2012) stated that most electronic technicians lack knowledge and skills required to service, diagnose faults, and repair of electronics appliances such as LCD televisions.

For the goal of technical colleges to be well acknowledged, technical colleges ought to be upgraded and built with adequate capacity that will enhance them to give and inculcate adequate training and skills on fault detection and diagnosis to electrical engineering trade students.

Training is a process of subjecting learners into series of activities both practical and theories for such learner to gain competency in a specific occupational area. Olayiwola and Onaolapo (2000) claimed that training

is a process of imparting to someone the skills to perform some operations or set of operations (mental/ physical). Training according to Onuka (2008) is a skill acquisition process through which learners are taught new knowledge and skills and how to apply them. The author stated further that the objective of training individuals in an occupation is to assist them to acquire professional skills for establishing and or improving their business. Thus, technical college is required to subject students specifically electrical engineering trade students to standard learning experience (curriculum) that will enhance skill, knowledge and attitude of electrical/electronics student on fault detection and diagnosis of appliances. This will empower technical college graduates better in Nigerian society. However, the duty of imparting necessary skills and training at technical colleges' level lies on the hand of technical college teachers and workshop technologists.

Teachers are trained individuals who are professionally qualified to disseminate knowledge, skills and worthwhile value to learners with the aim of bringing positive changes in them. Ogbaunya and Usoro (2009) explained that technical teachers are those who obtained technical training/theories and practice of education that are related to the advancement of knowledge, skills and attitude among youths, who will later use the knowledge and skills acquired to improve and solve environmental problems. Teachers at technical colleges' level implement curriculum at the classroom level. However, technologists are trained individuals who are very verse practically and make use of mathematical and scientific principles and available materials to develop, design, create, manufacture and repair system, device and appliance. United Nations Educational, Scientific and Cultural Organization (2010) claimed technologist as those who will: exercise independent technical judgment at an appropriate level; assume responsibility, as an individual or as a member of a team, for the management of resources and / or guidance of technical staff; and design, develop, manufacture, commission, operate and maintain products, equipment, processes and services.

They help technical colleges' students during on-the-job training, internship and apprenticeship program which (Ogbuanya and Abdullahi, 2014) termed school to work transition. Thus, teachers and other workshops instructors guided technical students in acquiring knowledge and practical skills in line with approved curriculum whereas technologist introduced students on training to real world of work.

Problem of the study

Technical college is design to graduate technicians who are very competent and skillful, among others, in maintenance and repair of electrical/electronics appliances using at various home in Nigeria.

The information obtained from users of appliances affirmed that number of appliances have been wasted or dumped unjustly in an unsecured environment. This is because competent technicians who can handle and repair appliances are very scarce and limited. Electrical engineering trade students of technical colleges are taught basically how to repair radio and television. Other appliances repair and maintenance have not gain any recognition in the curriculum of technical colleges in Nigeria.

Secondly, those road side technicians who are claiming to be competent in appliances repair and maintenance are undoubtedly not. They base their operation on try and error methods which in most of the time fail and expensive. This is because they do not receive standard training on fault detection and diagnosis of electrical/electronics appliances.

To stop untimely wastage and unjust dumping of appliances technical colleges need to graduate technicians who are very competent in fault detection and diagnosis of electrical/electronics appliances. This is therefore the focus of this paper.

Purpose of the study

The general purpose of this study was to investigate the fault detection and diagnosis of electrical/ electronics appliances training requirement of technical colleges as a tool for empowering electrical/electronics trade students. Specifically, the study sought to:

Examine required skills for fault detection and diagnosis of electrical/ electronic appliances for the training of electrical/ electronic technical college students in Nigeria.

Examine required instruments for fault detection and diagnosis of electrical/ electronic appliances for the training of electrical/ electronic technical college students in Nigeria

METHODOLOGY

The study adopted descriptive survey research design. The study was conducted in Oyo and Ogun states, Nigeria. The population for the study was ninety two (92) technical college teachers and technologists. The population comprised of forty two (42) electrical/electronics teachers in technical colleges in Ogun state and twenty four (24) electrical/electronics teachers in technical colleges in Oyo states. In addition, 24 electrical/electronic technologists were sampled from the two states using purposive sampling techniques. The entire sixty six electrical/electronics teachers in technical colleges in two states and 24 electrical/electronics technologists sampled were used for the study.

The instrument used for data collection from respondents was a structured questionnaire. The questionnaire contained one hundred and fifty three (153) items which was used to obtain information from electrical/electronics teachers in technical colleges and electrical/electronics technologists in Oyo and Ogun states. The questionnaire was divided into three sections: A, B and C. Sections A was used to seek personal information from electrical/electronics technical college teachers and electrical/electronics technologists. Section B and C consisted of items relevant for answering the research questions posed for the study. Section B and C of the questionnaire was structured on six-point rating scale with value as 6, 5, 4, 3, 2, and 1 in descending order. The response options for the section B and C of the questionnaire were: Very Highly Required (VHR) – 6, Highly Required (HR) – 5, Required (R) – 4, Not Required (NR) – 3, Highly Not Required (HNR) – 2 and Very Highly Not Required (VHNR) – 1.

The questionnaire was validated by three experts. Cronbach Alpha method was used to determine the internal consistency of the questionnaire items. Thus, a reliability coefficient of 0.89 was obtained which means that the instrument was reliable for the study.

Ninety two copies of questionnaire were administered to the respondents by the researcher with the help of two research assistants through personal contact with the technical college teachers and technologists in Oyo and Ogun States.

The data collected for this study were analyzed using mean and standard deviation. The decision rule for section B and C of questionnaire were based on the mean benchmark (cut off point) of 3.50. Thus, for section B and C, any item with mean of 3.50 or above was considered required; whereas any item with a mean below 3.50 was considered not required

Result

The presentation and analysis are done in tables and arranged according to the research questions posed for the study.

Research Question 1: *What are the* required skills for fault detection and diagnosis of electrical/ electronic appliances for the training of electrical/ electronic technical college students in Nigeria*?*

Table 1:

Mean ratings and standard deviation of Responses of technical college Teachers and technologist on required skills for fault detection and diagnosis of electrical/ electronic appliances for the training of electrical/ electronic technical college students in Nigeria.

S/N	SKILLS FOR FAULT DETECTION AND DIAGNOSIS OF ELECTRICAL/ ELECTRONIC	Teacher Mean1	Technologists Mean 2	AGGREGATE mean	SD	REMARKS
1	Ability to diagnose appliances' components	4.82	4.92	4.85	0.78	Required
2	Ability to undertake fault diagnosis of entire appliances.	5.02	5.08	5.03	0.67	Required
3	Ability to detect faulty components	4.95	5.08	4.99	0.65	Required
4	Ability to isolate fault	5.03	5.12	5.05	0.67	Required
5	Ability to make proper evaluation of fault for proper estimation of cost.	5.06	5.08	5.07	0.63	Required
6	Ability to handle and work with multiple technologies	5.17	5.27	5.20	0.60	Required
7	Ability to keep up to date with new technology and performance issue	5.33	5.23	5.23	0.65	Required
8	Ability to use protective equipments that are required during fault detection and diagnosis process	5.23	5.15	5.21	0.66	Required
9	Ability to carry out first aid requirement in case of an accident during repair process	5.17	4.92	5.10	0.70	Required
10	Ability to understand the functions, features and working principles of appliances	5.24	5.00	5.17	0.66	Required
11	Ability to understand procedure for dismantling and assembling appliances under repair	5.09	5.00	5.07	0.68	Required
12	Ability to understand range of tools and testing equipment needed for fault detection and diagnosis process and their functionality	5.09	5.08	5.09	0.67	Required
13	Ability to understand standard fault finding techniques	5.08	5.19	5.11	0.69	Required
14	Ability to use basic computer knowledge to be able to run diagnostic tools and equipment	5.00	4.96	4.99	0.67	Required
15	Ability to understand the function of hardware component and software application that are required to be used during repair process	5.05	4.88	5.00	0.65	Required
16	Ability to display and use standard repairing process	4.98	4.92	4.97	0.64	Required
17	Ability to carry out operational performance test	5.03	4.96	5.01	0.65	Required
18	Ability to operate testing and measuring tools/equipment.	5.08	4.96	5.04	0.59	Required
19	Ability to connect appliance to PC/test equipment for diagnosis	5.08	4.92	5.03	0.69	Required
20	Ability to interpret test results to identify and localize faults	4.95	4.88	4.93	0.68	Required
21	Ability to use appropriate mechanisms and tools to rectify	4.91	4.77	4.87	0.63	Required

	faults					
22	Ability to use appropriate communication channels to relay or report unresolved problems	4.97	4.88	4.95	0.64	Required
23	Ability to test appliances to confirm and resolve the reported fault	5.08	5.00	5.05	0.58	Required
24	Ability to undertake corrective repairing process using software porting/updates	5.06	5.19	5.09	0.63	Required
25	Ability to check appliances to confirm that the problem is resolved	5.03	4.81	4.96	0.69	Required
26	Ability to safely dismantle/assemble appliance using the right tools	5.00	4.81	4.95	0.75	Required
27	Ability to safely remove and replace components using right tools	5.00	4.96	4.99	0.69	Required
28	Ability to understand correct way of approaching a defect on appliances.	5.03	5.00	5.02	0.68	Required
29	Ability to interpret intermediate result and progress to fault rectification accordingly	4.97	4.96	4.97	0.70	Required
30	Ability to read and understand technical manuals, working order and reports	5.05	4.96	5.02	0.66	Required
31	Ability to read and understand appliance safety instruction	5.06	4.96	5.03	0.64	Required
32	Ability to fill up record sheets clearly, concisely and accurately as per company procedures	5.05	4.92	5.01	0.60	Required
33	Ability to clearly communicate relevant information to client	5.05	5.00	5.03	0,62	Required
34	Ability to make appropriate enquiry on appliance	5.08	5.00	5.05	0.62	Required
35	Ability to use information from enquiry or repair	5.06	5.08	5.07	0.64	Required
36	Ability to prioritize and execute task in a high pressure environment	5.05	5.00	5.03	0.69	Required
37	Ability to use and maintain resources efficiently and effectively	5.08	4.96	5.04	0.61	Required
38	Ability to analyze and understand manufacturing process of appliances	5.11	5.08	5.09	0.66	Required
39	Ability to interpret reports, reading and numerical data	5.15	5.08	5.13	0.62	Required
40	Ability to create and maintain affective working relationship and team environment through collaboration	5.15	4.96	5.10	0.66	Required
41	Ability to share knowledge concerning equipment with other team member and colleagues.	5.09	4.73	4.99	0.73	Required
42	Ability to apply theoretical knowledge of electrical electronic components on repairing and diagnosis.	5.12	4.81	5.03	0.78	Required
43	Ability to use soldering and de-soldering techniques	5.08	4.69	4.97	0.72	Required
44	Ability to use soldering pump	5.09	4.81	5.01	0.73	Required
45	Ability to understand soldering requirement	5.21	4.92	5.13	0.71	Required
46	Ability to use soldering iron safely and effectively	5.20	5.12	5.17	0.69	Required
47	Ability to understand installation / handling instruction of appliance	5.17	5.12	5.15	0.71	Required
48	Ability to understand and apply symbols of electrical/ electronic components	5.15	5.12	5.14	0.70	Required
49	Ability to understand various methods of testing electronics component and equipments.	5.15	5.23	5.17	0.69	Required
50	Ability to carry out fault detection and diagnosis through circuit diagram	5.09	5.27	5.14	0.70	Required
51	Ability to remove and replace faulty component	5.05	5.27	5.11	0.67	Required
52	Ability to keep/ store tools/equipments used during fault detection and diagnosis process in a good condition	5.09	5.19	5.12	0.71	Required
53	Ability to go online and search for manufacture data base as regards appliance details	5.12	5.23	5.15	0.63	Required
54	Ability to relate certain symptom to certain fault on appliance	5.14	5.19	5.15	0.59	Required
55	Ability to confirm fault before dive in to the repair	5.12	5.12	5.12	0.61	Required
56	Ability to take proper note of the position of each component of appliance when dismantling complex or high precision appliance	5.20	5.12	5.17	0.59	Required
57	Ability to keep dismantling component in a well secured area	5.23	5.12	5.20	0.63	Required
58	Ability to locate appropriate working area for the job	5.24	5.12	5.21	0.60	Required
59	Ability to work safely and complying with health and safety and other relevant regulations guidelines	5.23	5.08	5.18	0.66	Required
60	Ability to review and use relevant information on the symptoms and problem associated with the appliance	5.20	5.12	5.17	0.69	Required
61	Ability to investigate and establish the most likely causes of the faults	5.20	5.08	5.16	0.72	Required
62	Ability to select, use and apply diagnosis techniques, tools and aids to locate faults	5.21	5.12	5.18	0.68	Required

63	Ability to complete the fault diagnosis and detection within the agree time and inform the appropriate people when they cannot be achieved	5.18	5.15	5.17	0.66	Required
64	Ability to determine the implications of the faulty equipments on other work and for safety consideration	5.12	5.00	5.09	0.67	Required
65	Ability to use the evidences gained to draw valid conclusion about the nature and probable cause of the fault	5.09	5.04	5.08	0.68	Required
66	Ability to record details of the extent and location of the faults in an appropriate format	5.11	4.92	5.05	0.67	Required
67	Ability to understand specific safety precaution to be taken when working with appliance	5.08	4.85	5.01	0.64	Required
68	Ability to understand code of practice that apply to the type of appliance diagnosing and repairing.	5.11	4.81	5.02	0.74	Required
69	Ability to understand and apply customer care procedure and techniques	5.11	4.96	5.07	0.69	Required
70	Ability to understand risk of fault reoccurrences and how to minimize it.	5.05	5.04	5.04	0.69	Required
71	Ability to understand hazards associated when carrying out fault diagnosis on appliance and how they can be minimized	5.00	5.04	5.01	0.69	Required
72	Ability to understand, use and evaluate the various type of aids, reports and information available for fault detection and diagnosis	4.86	4.85	4.86	0.67	Required
73	Ability to understand procedure to be adopted to establish the background of the fault	4.92	4.96	4.93	0.68	Required
74	Ability to clear waste and restore good working area after fault detection and diagnosis process.	4.89	5.04	4.93	0.74	Required
75	Ability to reconnect and check terminals to ensure that they are electrically and mechanically sound.	4.89	4.96	4.91	0.74	Required
76	Ability to repair and replace faulty worn and damaged components effectively.	4.97	4.92	4.96	0.74	Required
77	Ability to carry out analysis of evidence and evaluate possible characteristics and causes of specific fault/problem	4.98	4.96	4.98	0.73	Required
78	Ability to relate previous report/records of similar fault conditions	4.95	4.92	4.95	0.72	Required
79	Ability to calibrate electrical testing instrument and check that they are free from damage and defects	5.02	5.00	5.01	0.69	Required
80	Ability to obtain and interpret drawings, circuit, physical layout , charts, specifications, manufacture's, history/ maintenance report, graphical electrical symbols, IEE wiring regulations and other document needed in service process	5.03	5.08	5.04	0.59	Required
81	Ability to prepare a report or take follow up action which satisfies the circuit need to ensure a good, properly bonded earth for the appliance	5.06	5.04	5.05	0.60	Required
82	Ability to understand basic principles of how the appliance functions, the operating sequence, the purpose of individual units/ components and how they interact	5.05	4.96	5.02	0.59	Required
83	Ability to understand and apply service requirement of the product	5.05	4.96	5.02	0.59	Required
84	Ability to demonstrate lab safety at all times	5.08	5.04	5.07	0.59	Required
85	Ability to source, obtain and use historical behavioral data of appliances under monitoring	5.05	4.92	5.01	0.65	Required
86	Ability to refer complicated work to other experts when one is not capable of repairing appliances.	5.06	4.92	5.02	0.66	Required

The data represented in Table 1 revealed that the mean responses of Technical college teachers and Technologies ranged from 4.82 to 5.27 and 4.69 to 5.27 respectively. The aggregate mean responses ranged between 4.85 and 5.23 while the aggregate values of the standard deviation ranged between 0.57 and 0.78. The table indicated that all skills for fault detection and diagnosis of electrical/electronics appliances highlighted for technical colleges were required. The standard deviation range values implied that the opinion of technical college teachers and technologists were very close and similar.

Research Question 2: *What are the* required instrument for fault detection and diagnosis of electrical/ electronic appliances for the training of electrical/ electronic technical college students in Nigeria*?*

Table 2:
Mean ratings and standard deviation of Responses of technical college Teachers and technologist on required instrument for fault detection and diagnosis of electrical/ electronic appliances for the training of electrical/ electronic technical college students in Nigeria.

S/N	INSTRUMENTS (TOOLS/ EQUIPMENT) FOR FAULT DETECTION AND DIAGNOSIS	TEACHER Mean1	TECHNICIAN Mean2	AGGREGATE Mean	S.D	Remarks
	TEST, MEASURING AND DIAGNOSTIC TOOLS, DEVICE AND EQUIPMENT					
1	Microscope/ magnifying lens	5.06	4.88	5.01	0.67	Required
2	Measuring tape / Steel rule	4.95	4.57	4.85	0.78	Required
3	Signal Generator	4.94	4.81	4.90	0.74	Required
4	Wire gauge.	5.00	4.92	4.98	0.68	Required
5	personal computer	5.08	4.96	5.04	0.66	Required
6	cable length metre	5.05	4.96	5.02	0.66	Required
7	capacitance metre	5.09	4.92	5.05	0.67	Required
8	conductivity metre	5.07	4.88	5.02	0.71	Required
9	electric tester	5.15	4.80	5.03	0.73	Required
10	electrostatic metre	5.06	4.85	5.00	0.80	Required
11	Frequency metre	5.19	4.97	5.10	0.73	Required
12	insulation metre	5.82	4.18	5.05	0.76	Required
13	Neon tester	5.14	5.12	5.13	0.73	Required
14	Magnetometer	5.03	4.99	5.00	0.74	Required
15	monitoring system	5.11	5.00	5.08	0.49	Required
16	photovoltaic metre	5.22	5.02	5.12	0.71	Required
17	Resistance inductance and capacitance (RLC) metre	5.17	5.27	5.20	0.74	Required
18	logic analyzer	5.19	5.41	5.30	0.75	Required
19	Signal tracer	5.15	5.31	5.20	0.70	Required
20	Oscilloscope	5.11	5.19	5.13	0.68	Required
21	test light	5.25	5.05	5.14	0.66	Required
22	transistor tester	5.08	4.83	5.01	0.67	Required
23	watt metre	5.05	4.88	5.00	0.70	Required
	ASSEMBLING, DISMANTLING AND REPAIRING TOOLS/ EQUIPMENTS					
24	Screw drivers	4.95	4.96	4.96	0.66	Required
25	Strippers	4.94	5.08	4.98	0.68	Required
26	Hammers	5.06	5.12	5.08	0.70	Required
27	Cutters	5.02	5.18	5.11	0.73	Required
28	Hacksaws	5.06	5.04	5.05	0.73	Required
29	Mallets	5.09	4.01	5.05	0.76	Required
30	Spanners (flat, ring, socket)	5.05	4.88	5.00	0.77	Required
31	Files	4.95	4.77	4.90	0.74	Required
32	Chisels	4.91	4.92	4.92	0.77	Required
33	Taps and dies	5.05	5.12	5.07	0.78	Required
34	Drills (manual, electric)	4.97	5.12	5.01	0.76	Required
35	Reamers	4.92	5.11	4.97	0.75	Required
36	Knives	4.97	5.23	5.04	0.70	Required
37	Centre punch	4.94	5.15	5.00	0.70	Required
38	Brush	4.92	5.00	4.95	0.75	Required
39	Spirit	4.98	4.88	4.96	0.74	Required
40	Pliers	5.01	4.89	4.98	0.73	Required
41	Blowing	4.94	5.12	4.99	0.89	Required
42	Hard and flexible boards	4.94	5.04	4.97	0.69	Required
43	Adjustable dc power supply	4.97	4.96	4.97	0.65	Required
44	Soldering lead	5.00	4.96	4.99	0.64	Required
45	Insulation varnish	4.98	4.96	4.98	0.61	Required
46	Soldering iron	5.01	5.93	4.99	0.73	Required
47	Lead sucker	4.92	4.88	4.91	0.77	Required
48	Soldering Bit	4.92	4.88	4.21	0.72	Required
49	Clamp	5.06	4.92	5.02	0.75	Required
50	Work bench	5.03	5.09	5.05	0.75	Required
51	Winding Machine	5.06	5.08	5.07	0.72	Required
	SAFETY TOOLS/ EQUIPMENTS					
52	Fire extinguisher	5.05	5.27	5.11	0.70	Required
53	Sand bucket/ Flame retardant clothing/ Fire	5.05	5.19	5.09	0.67	Required

	blanket					
54	Safety posters	5.03	5.15	5.07	0.72	Required
55	Safety helmet	5.09	5.19	5.12	0.66	Required
56	Ear protection	5.05	5.07	5.05	0.65	Required
57	Nose protective equipment	4.50	5.55	5.03	0.70	Required
58	Safety boot	4.19	5.79	4.99	0.69	Required
59	Safety gloves	5.00	4.92	4.98	0.73	Required
60	Safety overall	5.09	4.84	5.02	0.73	Required
61	Face protection equipment	5.06	4.81	4.99	0.72	Required
62	First aid box	4.98	4.85	4.95	0.75	Required
63	Safety Symbols/Signs	4.93	4.92	4.93	0.72	Required
64	emergency telephones	4.39	5.47	4.96	0.71	Required
65	Safety alarm	5.01	5.04	4.02	0.70	Required
66	Hand glove	5.19	4.94	5.04	0.69	Required
67	Fire detector/ Temperature controlling equipment	5.07	5.16	5.12	0.70	Required

The data presented in Table 2 revealed that the mean responses of technical college teachers and Technologists ranged from 4.19 to 5.82 and 4.01 to 5.93 respectively. The aggregate mean responses ranged between 4.02 and 5.30 while the aggregate values of the standard deviation ranged between 0.30 and 0.89. The table indicated that all instruments (tools/equipments) for fault detection and diagnosis of electrical/electronic appliances highlighted for technical colleges required. The reason was that the mean ratings above the benchmark (cut off point) of 3.50.

Discussion of the findings

The findings of the study revealed that eighty six skills for fault detection and diagnosis of electrical/electronic appliances are required for training Technical college students in Nigeria. These required skills according to technical colleges teachers and technologists include: ability to detect faulty components, ability to diagnose appliances components, ability to work with multiple technologies and keep up to date with new technologies, ability to understand various ways of testing appliances component, ability to interpret reports, readings and numerical data among others are required for the training of electrical/electronics students in technical colleges. The findings are in line with the findings of Ibezim, Ohanu and Shodeinde (2014) who claimed that the skill required in identifying audio faults in mobile phones is ability to identify either the earpiece is working or not or there is distorted sound from the earpiece. The findings are also in support of Samson and Anthony (2015) work who remarked that technical college students required ability to test capacitors, diode, transistor with millimeter; assembling and disassembling home theatre player.

The result of the finding also revealed that all the sixty seven instruments (into test, measuring and diagnostic tools and equipment; assembly dismantling and repairing tools and equipment and safety tools and equipment) for fault detection and diagnosis of electrical/electronics appliances are required for the training of technical college students in Nigeria. The tools and equipments include: magnifying lens, oscilloscope, personal computer, screwdrivers, drills soldering iron, fire extinguishers, and first aid box among others. The findings correspond with Samson and Anthony (2015) work who revealed that soldering iron, drilling, Allen key, signal generator, hand glove and oscilloscope among others are the necessary tools and equipments for the corrective maintenance of DVD home theatre sound system. The findings are also in line with Nwachukwu, Bakare and Jika (2011) work who reported that wearing of hand gloves while working in laboratory and make use of recommended extinguisher in the laboratory are safety practice skills required by electrical/electronic students in working in the laboratories of Technical colleges in Ekiti state.

Conclusion

Nigeria is rated among the country where issue of unemployment is reoccurring. The reason according to series of report is lack of adequate skills required by youths to gain employment or to be self dependent or self employed. To resolve unemployment issues in Nigeria, youths need to undergo training which will equip them with necessary skills that will enable them to gain entry to and progress in a selected occupation or which will enable them to be self employed. However, the study identified required skills for the training of technical college students in Nigeria. The study also identifies required instruments for the training of technical college students in Nigeria.

Recommendation

In line with the findings of the study, the following recommendations were made:

Necessary effort should be made by stakeholders of education and curriculum development to integrate the relevant skills on fault detection and diagnosis of electrical/electronic appliances into the curriculum of electrical/electronic students of technical colleges of Nigeria.

Necessary attempt should be made by government to equip electrical/electronics workshop in technical colleges with adequate tools and equipment which are necessary to train students on fault detection and diagnosis of electrical/electronics appliances.

Competent workshop technologists should be employed into electrical/electronics workshop of technical colleges in Nigeria.

Teachers in technical colleges should also be given training regarding teaching of appliances repairs.

Adequate supervision and monitoring should always be planned and implemented by teachers and technologists of electrical/electronics anytime students are in practical section of their training.

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Market Chain Analysis of High Value Fruits in Bench Maji Zone, Southwest Ethiopia

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Abstract
This research aimed at assessing the market chain of banana, avocado and mango fruits in Bench Maji zone. Both primary and secondary data were collected from 2 purposively selected fruits producing districts namely North Bench and South Bench districts. Primary data were collected through semi-structured questionnaire and focus group discussion. A total of 150 households were selected by using systematic random sampling technique. In addition, 40 traders were selected by using simple random sampling technique. Market structure-conduct-performance analysis model was used to assess the performance of the fruits market. The result revealed that the participants in the fruits markets were identified as primary actors and secondary actors. Primary actors in the fruits market chain were producers, brokers/agents/, farmer traders, collectors, and wholesalers. Whereas, local tax authority, local police, transporters, and district Trade and Industry office were identified as secondary actors. Fruits market in the area was characterized by non-competitive nature with concentration ratio ranging from 42 to 91.10% indicating the existence of oligopoly market structure. Entrance and exit in the fruits market was blocked by licensing and access to channel. A channel that links producers to local wholesalers through brokers was more efficient in terms of large volumes of sales. However, performance of the fruits market was affected by seasonality, the existence of few big traders, limited access to information, absence of organized market center and brokers' interference. Therefore, attention has to be given to alleviate the problems so as to improve the performance of the fruits market.
Keywords: Market chain, oligopoly, market concentration ratio and market performance

1. INTRODUCTION

1.1 Background and Justification

Trade in fruit and vegetable products in Ethiopia has been attractive in the face of highly volatile or declining long-term trends in prices for many traditional export products (NBE, 2013). Particularly, given the declining export earnings from traditional exports of coffee, horticulture products like fruits and vegetables are one of the main possible sources of foreign exchange for the country (World Bank, 2004). There is good opportunity for small scale growers to increase the exports of fresh fruits and vegetables to the neighboring countries such as Djibouti, Sudan and Somalia (NBE, 2013). Fruits and vegetables also have a large domestic market (EIA, 2012). Thus, fruit and vegetables are a priority sector for the government of Ethiopia, which aims to increase production by 47% between 2015 and 2020 (GTP II, 2015).

The production of horticultural crops, however, is much less developed than the production of food grains in the country (EIA, 2012). Lack of concerted public support, scanty information, poor understanding of how the market chain works, and lack of systematic documented knowledge are main threats that hampered the benefit of the sector (World Bank Group, 2006). Now a day, the demand for local fruits with higher quality like mango, papaya, apple and avocado are emerging (Humble and Reneby, 2014). Though there is a growing demand for fruits in recent years because of growing population and changing dietary habits (ILRI, 2011), the contribution of fruits both to the diet and income of Ethiopian is insignificant (Simegnew, 2012). Consequently, the growing demand for fruits can only be satisfied if there is an efficient market that can create better incentive for the producers. Without having efficient and well-functioning market, the possible increment in output, incomes, and foreign exchange earnings could not be realized.

Marketing is the most significant energetic force of economic development and contains a guiding and simulating impact on production and distribution of agricultural products. The agricultural marketing system needs to bring an improvement in income and livelihood of agrarian societies. According to FAO (2005), in developing countries, most permanent crops produced by smallholder farmers and their product were marketed by the non-public entrepreneurs who operates as marketing chain, and distribute the products to terminal markets. Although the marketing chain is well known, smallholder farmers specifically face high cost in accessing markets and market information.

In a country like Ethiopia, which is frequently stricken by drought and famine, producing and marketing of fruit products generates income which can act as an economic buffer and seasonal safety net for poor farm households (Takele, 2014). This is because marketing enables the agricultural producer to move from semi-subsistence to growing produce regularly for sale. However, if market performance is inefficient, the sustainability of the production becomes questionable and as a result a continuous supply of the commodity for the market becomes difficult (Nega, Teshale, Zebene, 2015). In the study area, though fruits are among the

commercially important agricultural commodities for increasing income and improving livelihood of smallholder farmers, the marketing and market chain aspects of the fruits sub-sector have not yet been studied. This paper, therefore, intends to analyze the current chain of market for commercially high value fruits such as Banana, Mango, and Avocado in Bench Maji zone.

2. MATERIALS AND METHODS

2.1 Description of the study area

The present study was carried out in Bench Maji zone of South Nations Nationalities and Peoples Regions (SNPPR) which is located 561 km southwest of the capital city Addis Ababa. The zone has 10 districts. The altitude of the zone varies between 700-2500 meters above sea level. The mean annual rainfall and temperature varies between 400-2000 mm and 15-27 ℃ respectively. According to land utilization date of the region, 7.65% is cultivated land, 6.37% grazing land, 8.29% forest, bushes and shrub land, 69.88% cultivatable and 7.89% is covered by others (SNNP Investment Office, 2007).

2.2 Sources of Data

In order to address the objectives of the study, both primary and secondary data were used. The primary data were collected through semi-structured questionnaires and focus group discussion. Two types of interview schedules were prepared (one for farmers and the other for traders). Two types of focus group discussion were held with a member of 5 producers and 5 traders in a group whom are selected based on their knowledge and experience about fruits production and marketing.

2.3 Method of Sampling and Sample Size

Multistage-stage sampling techniques ware used to select sample fruit producer farmers. In the first stage, North Bench and South Bench districts were selected purposively based on the level of fruit production and access to marketing. In the second stage, 2 kebeles from North Bench district (Yali and Gacheb) and 3 kebeles (Fanika, Janchu, and Kite) from South Bench district were selected purposively. During the selection process, the kebeles potential for fruit production and the accessibility to market were taken into consideration. In the third stage, three villages from each kebeles were selected by using stratified random sampling techniques. In the fourth stage, since there was no document about the number of fruits producers in the kebeles and homogeneity of fruit producers, 30 producers from each kebeles were selected. Thus, a total of 150 households were selected using systematic random sampling technique. Finally, 18 wholesalers, 5 agents/brokers, 2 collector cooperatives and 15 farmer traders were selected randomly. Overall, a total of 190 respondents were selected.

2.4 Data Analysis

Two types of analysis techniques, namely descriptive statistics tools (like mean, standard deviation, percentage, and table) and Market structure, conduct and performance analysis were used. Data were analyzed by using SPSS version 21 and Microsoft Excel 2007.

2.4.1 Market structure, conduct and performance analysis (S-C-P)

Efficiency factors can be evaluated by examining marketing enterprises for structure, conduct and performance (Abbott and Makeham, 1981). The structure-conduct-performance (SCP) analysis involves the collection of both primary and secondary data (WFP, 2011).

(a) Market Structure

It refers to a set of market characteristics that determine the economic environment in which a firm operates (Thomas and Maurice, 2011). The structure of the market is determined by computing the market concentration of firms in the market.

Market concentration

According to Tomek and Robinson (1990), concentration ratio refers to the number, and relative size of buyers in the market. The structure performance hypothesis states that the degree of market concentration is inversely related to the degree of competition (Edwards *et al.,* 2005).

The concentration ratio is given as:

$$C = \sum_{i=1}^{r} Si \quad i = 1, 2, 3, 4 \ldots . r$$

Where, C= concentration ratio

Si= the percentage market shares of the i^{th} firm

r= the number of relatively larger firms for which the ratio is going to be calculated

Concentration ratio of 50% or more is an indication of a strongly oligopolistic industry, 33-50 % a weak oligopoly and less than that a competitive industry (Uhl and Kohi, 1985).

(b) Market conduct

It is a systematic way to detect indication of unfair price setting practices and the conditions under which

practices are likely to prevail. Meijer (1994) said that, "conduct is pattern of behavior which enterprises follow in adopting or adjusting to the market in which they sell or buy", in other words the strategies of the actors operating in the market.

(c) Market performance (Marketing margin)

Market performance is concerned with the benefits an industry generates for its different stakeholders (Stead et al., 1996). Measures of market performance reveal whether there is market power in an industry (Perloff, 2007). To evaluate market performance marketing margins analysis and sales volumes were analyzed. The total marketing margin is given by the formula shown below:

$$TGMM = \frac{Consumer\ price - Farmers\ price}{Consumer\ price} \times 100$$

Where TGMM-Total gross marketing margin

Computing the total gross marketing margin (TGMM) is always related to the final price paid by the end buyer and is expressed as a percentage (Mendoza and Rosegant, 1995). Wider marketing margin indicates high price to consumers and low price to producers and it is an indicator of the existence of imperfect markets (Cramer and Jenson, 1982).

The producers' margin (which is the portion of the price paid by the consumer that goes to the producer) is calculated as:

$GMMp = 1 - TGMM$

Where *GMMp* is producers' share in consumer price.

The above equation tells us that a higher marketing margin diminishes producers' share and vice versa. It also provides an indication of welfare distribution among production and marketing agents.

3. RESULT AND DISCUSSION

3.1 Socio-economic Characteristics of the Respondents

Out of the total respondents, 95.97 percent of them were male and 4.03 percent of them were female. This implies that fruit production in the area is highly dominated by male headed households. Regarding marital status of the respondents, 4.70 percent of them were single, 91.95 percent of them were married, and the remaining 3.35 percent of them were widow. Having more than 90% of married respondents implies that fruit production plays greater contribution for household income and livelihood in the area. Regarding educational attainment of the respondents, 21.48 percent of them were unable to read and write, 69.80 percent of them were attended from grade 1 up to 6, and the remaining 8.72 percent of them were attended from grade 7 up to 10. This implies that the majority of the respondents attended basic education.

Table 8: Demographic information of the Respondents

Description		Number	Percentage
Sex	Male	143	95.97
	Female	6	4.03
Marital status	Single	7	4.70
	Married	137	91.95
	Widow	5	3.35
Educational Attainment	Unable to read and write	32	21.48
	1-6	104	69.80
	7-10	13	8.72

Source: Own Survey (2016)

Regarding age of respondents, the mean age of the respondents (Table 2) was 35.27 years old. Out of the total respondents, 40.27 percent of them lied in the age range of 20-30 years old, 32.21 percent of were lied in the age range of 31-40 years old, 22.82 percent of them lied in the age range of 41-50 years old, and the remaining 4.70 percent of them lied in the age range of above 50 years old. The average family size in the area was 6.12. Regarding the experience of the respondents in fruit production, the mean work experience was 8 years. The mean landholding in the area was 1.18 ha per head. Out of the total respondents, 83.89 percent of them have a holding of less than 2 hectares per head and the remaining 16.11 percent of them have a holding of more than 2 hectares per head. This implies that the majority of the respondents are smallholder farmers.

Table 9: Household and Farm Characteristics of the Respondents

Items	Mean	Standard Deviation
Age (years)	35.27	8.74
Family size	6.12	2.25
Experience (years)	8	5.21
Landholding (ha)	1.18	1.01

Source: Own Survey (2016)

3.2 Structures, Conduct and Performance (S-C-P) of fruits market chains

3.2.1 Market Structure

Market structure analysis covers other market actors outside of farming households such as importers/exporters, wholesalers, retailers, assembler/collectors, transporters and laborers (WFP, 2011).

1. Major actors in the fruit market chain

The actors in the fruit market chain in the area were classified in to two categories as primary actors and secondary actors. Primary actors in this research included those that have direct influence from production to final consumption, whereas, secondary actors were those individuals and organizations which indirectly influence the fruit market chain.

The primary actors and their role are specified as follows:

a) Producers: - they are the first actors in the fruits market chain who are engaged in producing and supplying fruit products.
b) Farmer traders: - these are generally seasonal traders who actively participate in times of high supply of fruits products. The main objective of farmer traders is to handle certain volumes of fruits products for supplying to local consumers. The excess supply of fruits in the area in certain seasons is the triggering factor for them to be engaged in the fruits markets. Farmer traders do not possess a license to participate in the fruits markets. They distribute very small volumes of fruits products to the local market in peak seasons. They will return to farming as soon as the supply of fruits vanishes.
c) Agents/brokers: - these are individuals whose role in the fruits market chain is to purchase fruits from producers on behalf of wholesalers. They are given full delegation by licensed wholesalers to participate in fruits marketing process.
d) Collector cooperatives: - these are an association of unemployed rural youths formed with the entitlement of collecting fruit products from producers and supply it to local wholesalers. They are not entitled to distribute fruits products out of the locality.
e) Local wholesalers: - these are individuals who are licensed to purchase fruits from producers, brokers, or collector cooperatives and supply it to big cities in Ethiopia.
f) Local consumers: - these are considered as one of the actors in the local fruits market chain. They buy fruits products from farmer traders to satisfy their consumption demand.

Other primary actors identified situated in terminal markets were big wholesalers, retailers, processors and consumers.

The secondary actors in the fruits market chain are local tax authority, local police, transporters and trade and industry office at district level.

g) Local tax authority- it is a government organization responsible for collecting tax from licensed traders. Dispatch tax and annual income tax are collected. Without paying dispatch tax, smuggling of fruits products out of the locality is an illegal act.
h) Local police- police play a role of inspecting the type of products that local wholesalers are transporting to big cities. Without policy approval it is impossible for traders to distribute fruits products to regional and national markets.
i) Trade and industry office- it's a government body which is responsible for giving trade license for those who wants to enter the fruits industries.
j) Transporters – they are car owners facilitating the distribution of fruits products to big cities. Without the provision of car, distribution of fruit products to big cities in remote areas is unreliable.

(b) Major Channels for fruit products

Based on the direction of flow and volume of fruits transacted, different marketing channels were identified. Most of the channels started from producers and end up in terminal markets of big cities through wholesalers.

i. Market channels for banana

Channel I: Producer ⟹ farmer traders ⟹ local consumers

This channel was the oldest and informal channel in the banana market chain. This channel linked producers to local consumers through farmer traders. Out of the total respondents, 22.70 percent of them took part in this channel. This channel was considered as informal because farmer traders do not have a license. Rather, they

engaged in trading in seasons of excess production.

Channel II: Producers ⟹ Agents/Brokers ⟹ Local Wholesalers

This channel linked producers to local wholesalers through agents/brokers. This channel was also identified as one of the oldest channels in the area. More than 40 percent of the respondents took part in this channel. Local wholesalers were in high preference of using brokers to purchase banana from producers. The good knowledge of brokers of their locality played an important role in saving wholesalers' time which would have been spent in search of marketable products.

Channel III: Producers ⟹ Collectors' cooperatives ⟹ Local Wholesalers

This channel was a newly introduced market channel in the area. This channel linked producers to local wholesalers through collector cooperatives. The proportion of sampled banana producers using this channel accounted for 16.82%.

Channel IV: Producers ⟹ local wholesalers

This was a usual channel in the banana market chain. In this channel, producers directly sell their products to local wholesalers. The proportion of sampled banana producers using this direct channel accounted for 20.17%.

ii. Market channel for Avocado

Channel I: Producers ⟹ farmer traders ⟹ local consumers

This channel linked producers to local consumers through farmer traders. This was considered as the oldest and informal channel that prevails in the area. Out of the sampled avocado producers, 45.54% of them took part in this channel to distribute avocado products to the local market.

Channel II: Producers ⟹ Agents/ Brokers ⟹ local wholesalers

In this channel producers linked to local wholesalers through agents/brokers. This channel was practiced by 40.66% sampled producers.

Channel III: Producers ⟹ Collectors

It was an informal market channel in the avocado market chain. In peak seasons, collectors collect avocado products from producers and transport it to big cities to look for market opportunities for the harvested products. The biggest challenge in this channel was any marketing loss is borne by the producers. This implies this channel was the riskiest channel for the producers. This channel was practiced by 13.8% of sampled producers.

iii. Market channel for mango

Channel I: Producers ⟹ farmer traders ⟹ local Consumers

This was the oldest and the most active market channel for mango in the area which was experienced by more than 65% of mango producers. Due to excess production and poor product quality traders were not interested to be engaged in mango trading.

Channel II: Producers ⟹ Agents/ Brokers ⟹ local wholesalers

This was also the oldest channel practiced by 35% of the producers. This channel linked producers and local wholesalers through brokers.

(c) Market Concentration Measure

In this research, the concentration ration of the biggest four firms were considered to determine the structure of the market. 40 traders in each specific fruit type were interviewed to understand the structure in the market.

Table 3: Concentration ratio

Fruit type	CR_4	Market Structure
Banana	86.76	Strong oligopoly
Avocado	91.67	Strong oligopoly
Mango	42.63	Weak oligopoly

Source: own survey (2016)

The table (table 3) shows that the market structure in the area shows different distinct feature for different fruit types. CR_4 for banana was 86.76% which indicated that the market structure for banana was strong oligopoly. With regard to the structure of the avocado market, since the concentration ratio was 91.67% the structure was strong oligopoly. According to Severova, Kopecka, Svoboda, and Brcak (2011), oligopoly can be defined as a market model of the imperfect competition type, assuming the existence of only a few companies in a sector or industry, from which at least some have a significant market share and can therefore affect the production prices in the market. Therefore, a strong oligopoly market structure for banana and avocado implies that the concentration of market power on few big wholesalers in the locality. On the contrary, a less than 42.63% concentration ratio for mango indicated a weak oligopoly which, in turn, indicated a concentration of market power on few traders. Contrary to this finding, Nega et al (2015) reported that the markets for Banana, Avocado, and Mango in Tembaro District were characterized by the prevalence of unconcentrated suppliers/traders/sellers.

(d) Barriers to Entry and Exit in the fruits market

The ability of firms to enter an industry is an important structural factor that determines market performance

(Perloff, 2007). The major causes of barriers to entry in the area were licensing and access to channels.

1. Licensing

A license is a permit given by the local government's trade and industry office for those who want to be engaged in fruits industries. Technically, the trader should have a warehouse and a weighing balance to get license. Institutionally, the trader should have a tax paying ID card (tin number). In addition, the licensee should have a dispatch letter from the local tax authority while distributing fruit products out of the locality. Without a dispatch letter from tax authority, any attempt to distribute fruits products out of the locality is illegal. Even agents should have an official delegation letter from the wholesaler to purchase fruit products from producers. Consistent with this finding, Desalegn and Solomon (2014) reported that licensing was an entry barrier in a sense that licensed traders were strictly forbidden to perform other than the activity for which they were licensed.

2. Access to channel

Few established local wholesalers control the access to channels of distribution in big cities of Ethiopia through long-standing relationships. This also has given the established local wholesalers an opportunity to distribute larger volumes of fruits products in big cities. This implies that in order to get access to a new market, finding a trusted partner to work with is highly important. Therefore, access to channel in new markets is highly determined by established social relationship.

(e) Market catchments (Market Points)

Market catchments refer to the informal boundaries where market forces naturally limit the movement of a commodity (WFP, 2011). These areas are often functions of transaction costs, roads and infrastructure, international or sub-national borders and trade restrictions, trader networks, agricultural calendars, population density, language, etc (Ibid). According to the result of focus group discussion with traders, the common market catchments for traders were big cities like Jimma, Wolkite, Addis Ababa, Adama, Harar, Bahirdar, and Mekele. The participation of local traders in the aforementioned market catchments was highly influenced by the network they created in those cities. Since fruit products are highly perishable products, having a trusted trade partner in big cities is the most important criteria to do business. In this regard, the most reliable market point for the local traders was Jimma town. Most of FGD participants (traders) stated that they experienced defraud while trying to enter into a new market.

3.2.2 Market Conduct

Market conduct investigates the behaviors and rules that regulate the relationships between actors or how they engage with one another (WFP, 2011). Market conduct in this research indicated components like level of competition, the accepted standards in the market, transparency of transactions and terms of payment.

(a) Price Setting Mechanisms

Fruit products are easily perishable by their very nature. Once the status of the fruit products reached maturity level, the producer's power to influence price is insignificant. In the study area, due to the existence of too many producers and few numbers of traders, producers were price takers. Consistent with this finding, Ayelech (2011) reported that farmers don't negotiate on price to sell their produce; indicating this large amount of producers are price takers.

(b) Standard setting in the market

The existence of few numbers of traders in the market also gave a significant power for traders to set the standards of the fruit products. The FGD result revealed that good quality fruit products ware determined by visual observation. After harvesting, the trader can reject the offer by the trader if the trader believes that it's a low quality product; or low price will be offered to the producer for low product quality. The lack of additional premium for good quality fruit products discouraged farmers from performing activities which can enhance product quality. Furthermore, constant price offered for fruit products irrespective of quality made farmers subservient to the needs of traders and agents.

(c) Sources and Transparency of Information

Clear market information was highly crucial to create transparency and efficiency in the fruits markets. Out of the total respondents, 64.43% of them stated limited access to information as one of the bottlenecks in fruits marketing. This implies imperfect information was one of the causes for imperfect market. There was no formal source of information for producers regarding pricing and overall market situation. Most producers relied on informal sources of information obtained from neighbors, brokers and traders. Regarding information transparency, there was no perfect exchange of information between producers and traders about product price in terminal markets. Therefore, in the absence of timely and reliable market information, market fails to bring economic efficiency. Consistent with this finding, Nega *et al* (2015) reported that the majority of fruit producers lack adequate, timely and reliable market information in the study area.

(d) Terms of trade

There was no formalized or regulated system in which effective exchange could take place between producers and traders. Regarding terms of payment, there was irregularity. Most of the time an exchange was being made on cash basis, but there were some room for post payment. More than 90% of producers practiced cash in hand

system. On the contrary, all local traders stated that they received post payment. This implies that a deferral payment method was practiced between local traders and big city traders. The lack of formal and regulated trading system between actors in the chain typifies traditional marketing system where exchange took place based on trust and good social relationship. Since there is no legally binding agreement between actors in the chain, experiencing defraud is very common while entering in to a new market. Consistent with this finding, Adugna (2009) and Nega *et al* (2015) found that large proportion of the fruit producers practiced cash in hand system and take the price as soon as they sell the fruits.

3.2.3 Market performance

Market performance refers to the impact of structure and conduct as measured in terms of variables such as prices, marketing margins, and volume of output. The gross & net marketing margins and producer's share in the final price for different marketing channels in banana, avocado and mango marketing are presented in Tables 4, 5 and 6.

3.2.3.1 Performance of Banana market chain

The performance of banana market chain was calculated by taking Jimma town as a common market catchment for all traders. This happened because of its accessibility to all local traders as compared to other catchment areas. In terms of TGMM, total gross marketing margin in channel II and channel IV were 83.33% for each respective channel. TGMM in channel III was 85.33%. Channel I accounted for 60% of TGMM. According to Cramer and Jenson (1982), wider marketing margins in all channels were good indicators of the existence of imperfect markets for banana in the study area.

In the final price for the different channels of the banana marketing system, producers captured 16.67% of the final price in channel 2 linking producers and wholesalers through brokers; followed by 16.67% in channel 4 linking producers directly to wholesalers. 14.67% of the final price was captured in channel-3 where producers and wholesalers linked through collectors. The highest producers' share was 40% in channel-1 where banana flows from producers to local consumers through farmer traders. High TGMM diminished the share of producer's in final price.

In terms of carrying large volumes of banana, 89.48% sales volumes accounted for channel II, followed by 8.21% for channel IV, 2.31% for channel III, and the remaining 0.001% of sales volumes accounted for farmer traders. This implies that channel II is more efficient in terms of distributing large volumes of sales. The FGD result revealed that wholesalers preferred to be linked with producers through brokers (channel II). Brokers' knowledge of the locality made this channel highly preferable for wholesalers in providing information about marketable products which in turn saves wholesalers' time.

Table 4: Performance of the banana market chain

Marketing channel	Items	Market actors							
		Producers	Brokers	Farmer traders	Collectors	Wholesalers	Big wholesalers	Retailers	Consumers
Channel 1	Selling price/bunch	20		50					
	TGMM			60%					
	GMMp			40%					
	Sales volume			.001%					
Channel 2	Selling price/bunch	25	28			50	80	150	150
	TGMM		10.71%			50%	68.75%	83.33%	83.33%
	GMMp		89.29%			50%	31.25%	16.67%	16.67%
	Sales volume								2.31%
Channel 3	Selling price/bunch	22			30	50	80	150	150
	TGMM				26.67%	56%	72.50%	85.33%	85.33%
	GMMp				73.33%	44%	27.50%	14.67%	14.67%
	Sales volume								89.48%
Channel 4	Selling price/bunch	25				50	80	150	150
	TGMM					50%	68.75%	83.33%	83.33%
	GMMp					50%	31.25%	16.67%	16.67%
	Sales volume								8.21%

Source: Own Computation (2016)

3.2.3.2 Performance of avocado market chain

In analyzing market chain for avocado, the common market catchment taken for the sake of this analysis was Addis Ababa city. All traders highly participated in avocado trading at a market in Addis Ababa. Hence, price information at Addis Ababa was used to calculate TGMM.

In terms of total gross marketing margin, TGMM was highest in channel II and III (90%). Channel I captured the lowest TGMM which accounted for 66.67%. According to Cramer and Jenson (1982), the wider marketing margins in all of the three channels were good indicators of the existence of imperfect markets for avocado in the study area.

Regarding share of producers of final price for avocado market chain, producers captured 10% of the final price in channel II and channel III, followed by 66.67% in channel I. In terms of volume, channel II, which linked producers to wholesalers through brokers, covered 82.84% of total sales volumes, followed by 14.71% of sales volumes in channel II, and the remaining 0.02% of sales volumes in channel I. This implies channel II was more efficient in terms of distributing large volumes of quantities to terminal markets in big cities. According to FGD result with collectors and producers, a relatively higher GMMp in channel I was not supported by high volumes of sales. In addition, in channel III all costs incurred (post harvesting- losses) were born by producers which made this channel inefficient in terms of distributing large volumes of sales. Like the banana market chain, channel II which linked producers to local wholesalers through brokers was preferable channel in terms of ease access to information through brokers to local wholesalers.

Table 5: Performance of the avocado market chain

Marketing channel	Items	Market actors for Avocado							
		Producers	Brokers	Farmer traders	Collectors	local wholesalers	Big wholesalers	Retailers	Consumers
Channel 1	Selling price/qt	200		300					
	GMMp			66.67%					
	TGMM			33.33%					
	Sales volume			.02%					
Channel 2	Selling price/qt	200	250			600	1000	2000	2000
	GMMp		80%			33.33%	20%	10%	10%
	TGMM		20%			66.67%	80%	90%	90%
	Sales volume					82.84%			
Channel 3	Selling price/qt	200			500		1000	2000	2000
	GMMp				40%		20%	10%	10%
	TGMM				60%		80%	90%	90%
	Sales volume				14.71%				

Source: own survey (2016)

3.2.3.3 Performance of mango market chain

In the mango marketing system, the common market catchment used for this analysis was Addis Ababa city.

Table 6: Performance of the mango market chain

Marketing channel	Items	Market actors for Mango						
		Producers	Brokers	Farmer traders	wholesalers	Big wholesalers	Retailers	Consumers
Channel I	Selling price/qt	120		200				
	GMMp			60%				
	TGMM			40%				
	Sales volumes			3.11				
Channel II	Selling price/qt	150	200		500	1000	2000	2000
	GMMp		75%		30%	15%	7.5%	7.5%
	TGMM		25%		70%	85%	92.5%	92.5%
	Sales volumes				96.89			

Source: Own Survey (2016)

In terms of TGMM, channel II captured more than 92% of TGMM and the remaining 7.5% of TGMM was captured in channel I. Regarding the final price for the two channels of mango marketing system, producers captured 60% of the final price in channel I linking producers and consumers through farmer traders and 7.5% of the final price share in channel II linking producers to wholesalers through brokers. However, in channel I, small volumes (3.11%) of mango were distributed to the market as compared to channel II which covered 96.89% of

sales volumes. This clearly indicates that a link created through brokers was highly preferred in terms of absorbing large volumes of products. However, the TGMM in channel II pointed out that the market was imperfect.

3.3 Challenges of fruits marketing

1. Seasonality

Seasonality is another factor affecting fruits marketing in the area. More than 89.93% of the respondents stated that seasonal price fluctuation was the major problem in fruits marketing. During peak supply period, price declined. In peak seasons, the perishability of the products does not give enough time for producers to look for alternative market opportunities. Thus, producers accept low price offered in peak seasons to avoid massive loss of profits. The FGD result revealed that price declined by more than 15 percent in peak seasons. This implies that when there is excess supply of fruits, price declines. Therefore, seasonal price fluctuation was common in the study area implying that supply and price moves in opposite direction.

2. Few number of big traders

There were many producers but very few big traders in the area. The large volumes of outputs produced in the area must be absorbed by high demand in big cities. More than 66.77% of the respondents stated that limited access to market was among the challenges of fruits marketing in the area. The participation of big traders in the fruits industries is highly important in bringing better opportunity for producers. However, the existence of few big traders in the fruits industries limited producers' access to more efficient market channel.

3. Lack of organized market center

In the FGD, it was revealed that lack of organized market center was one of the basic problems for the existence of imperfect competition in the area. Getting better incentives in terminal markets depend on the quality of the produce to be offered in those markets. However, due to absence of market center in which good product quality is inspected and standardized, producers and traders failed to receive their fair share from the market in big cities.

4. Brokers' interference

The main role of brokers/agents in the fruits markets was providing information about price and output both for producers and traders. As a result, they were considered as the most reliable partners for traders in making deals with producers. Brokers created collusion in the fruits markets in terms of geographic dispersion to avoid unnecessary competition. This collusion helped them to monopolize a certain geographic area. So, without brokers, it is hardly possible to create direct link between producers and traders in the study area. More than 52.35% percent of total respondents stated that broker's unwelcome interference was one of the major problems in fruit marketing.

4. CONCLUSION AND RECOMMENDATION

The result of this study revealed that different market actors were involved in the fruits market chain. The actors were classified as primary actors and secondary actors based on the role they play in the markets. Producers, farmer traders, agents/brokers, collector cooperatives, and wholesalers were identified as primary actors. Whereas, local tax authority, local police, transporters and district Trade Industry office were identified as secondary actors because of their indirect influence in facilitating the fruits market. The market structures of fruits show non-competitive nature characterized by barriers to entry and exit. The market concentration ratios ranging from 42% up to 91.67% were indicators of oligopoly market structure. The existence of few big-traders in the market gave market power for traders in deciding output price and setting product quality standard. The TGMM indicated that the markets for banana, avocado, and mango were imperfect markets. However, the most efficient fruits market channel in the area was the one that links producers to wholesalers through brokers. Brokers' good knowledge of the locality made this channel a preferable channel to distribute large volumes of fruits products to terminal markets in big cities. However, seasonal price fluctuation, the existence of few big traders, limited access to information, lack of organized market center, and brokers' interference mainly affected the performance of fruits market in the study area. Consequently, the fruits marketing in the study area were found imperfect. Therefore, attention has to be given to alleviate the problems so as to improve the performance of the fruits market.

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