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CONTENTS **Pages**

Guide to Authors

ZEDE is a scientific journal on engineering science and application, produced under the auspices of the Addis Ababa Institute of Technology, Addis Ababa University. The main objective of the journal is to publish research articles, findings and discussions on engineering sciences, technology and architecture thereby assisting in the dissemination of engineering knowledge and methodologies in solving engineering problems. Technical Notes of significant contribution may be considered for publication.

Original papers for publication in the journal should be submitted in triplicate to the Editor-in-Chief, P.O. Box 385, Addis Ababa, Ethiopia. All articles submitted for publication in the journal should comply with the following requirements:

1. Title of Paper: The title of the paper should be phrased to include only key words and must have a length of not exceeding *80* characters including spaces.

2. Format of Manuscript: The manuscript should be (double-spaced single column draft and single spaced double column final) in *A-4* sized paper with MS word 2007or later version. Margins of *25 mm* should be used on all sides of the paper.

3.Length of Article: The length of the article should not exceed word equivalent of 6000 words, or *20* pages, double spaced using font size *12* typed in Times New Roman.

4. Author's Affiliation: The author's full name, institutional affiliation and rank, if applicable, must appear on the paper.

5. Abstract: All articles submitted must include an abstract of length not exceeding *200* words in *italics*.

6. Keywords: All articles submitted must include Keywords not exceeding 6 in number.

7. Style of Writing: It is recommended that third person pronoun/s be used when referring to author/s.

8. Illustrations: Figures should be drawn in black, at a size with a *50%* reduction to fit in *160 mm* width of journal. Photographs should be submitted as glossy prints. Explanations and descriptions must be placed in the text and not within figures. All figures must include numbered captions. See example:

Figure 1 Typical creep strain versus time curve

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10. Equations: Equations numbers should be right-justified. See example:

$$u(x, y) = -y\theta(x) \qquad (1)$$

11. References: References in the body of the Article should be cited at the end of the paper by placing a reference number in square brackets and should be arranged sequentially as they appear in the text. Ethiopian names may be given in direct order, i.e. given name followed by father's name. All main words in titles (papers, books, reports) should be initialized by capital letters. Items in citations should be separated by commas. Page numbers should be included whenever applicable

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Examples:

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   Spillers,W.R.andLefeochilos , E., "*Geometric Optimization Using Simple Code Representation*", Journal of the Structural Division, ASCE, vol. 106, no. ST5, 1980, pp. 959-971.

2. ***References to Books and Reports***

   Korsch, H.L. and Jodl, H. –J., "*Chaos: A Program Collection for the PC*", Springer-Verlag, 1994.

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COMMUNITY INVESTMENT IN OLD URBAN QUARTERS: THE CASE OF A COMMUNITY BASED REDEVELOPMENT PROCESS IN MERKATO, ADDIS ABABA

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ABSTRACT

The history of urban development in Sub-Saharan Africa is dominated by disinvestment and weak investment. Even though that has been changing during the past decade due to improved economic performance, studies on investments in old areas of urban centers are quite scarce. A community-based process of investment in an old market district of Addis Ababa through the redevelopment approach was studied to contribute to reducing the gap.

Historically, urban redevelopment was driven by property value decline and protection of the 'public' interests of health and safety. Its major investors were professional developers and the state. It was criticized for effects such as eviction, community fights, destruction of heritage, and visual 'monotony', and the criticisms have eventually led to emergence of more responsive approaches such as rehabilitation and conservation. The focus of this paper is on why the investor role, in the case of the study redevelopment, has shifted to the community and to what extent the shift has prevented the common effects of redevelopment.

The study indicates that the *drivers of much of the blight were macro-economic and policy factors rather than property value decline; the objectives of redevelopment have not been the classic public interests of health and safety: they were mainly the 'grafted' objectives of modernization, efficient use of land, and increasing tax revenue; and that the community based investment approach was able to prevent the effects of redevelopment only partly due to inadequate support by the state. The study was made by using a case study approach of interview, document review, and observation*

***Keywords*:** blight, community investment, old areas, redevelopment, urban.

INTRODUCTION

Urban Centers and Old Quarters

With close to 70% of its population rural, urban centers are still secondary places of habitation in sub-Saharan Africa. They are, however, rapidly growing towards the role of primary places: by 2030 they are projected to house more than 50% of the population [1]. Urban centers, however, are not only demographic and social; they are also economic and spatial: while they are key factors for the economic development of a country, they also require heavy investment in buildings, infrastructure, and services so that the quality of the spatial dimension depends largely on the strength of the investment.

In a market system, the latter depends on the strength of demand (strength of 'consumer spending') which in turn may depend on the overall macro-economy. Most studies on investment in urban centers in sub-Saharan Africa are focused on new urban areas. Studies on old areas which are often place of origin of the centers and, hence, contain historical buildings and spaces are scarce. In the European context, the contents of such areas may include medieval and Victorian buildings and spaces while in the case of sub-Saharan Africa traditional, Islamic, and colonial, buildings and spaces are common. In the latter, one of the major traditional spaces is the open air market which is a major goods and services distribution facility and whose activities belong to the subsistence sector of the economy according to Lewis [2] or to the bazaar sector according to Geertz [3] and Santos [4]. Business in this sector, which dominates in less industrialized countries like Ethiopia, is characterized by small-scale, limited investment on facilities, and low-technology. As a result, it is one of the major sources of employment for vast populations in many urban centers.

The Context of Investment in Old Urban Areas

Historically, the key context for investment in old urban areas has been blight which was, again, historically defined as an urban quality that creates concerns of public health and safety [5]. The qualities are defined more comprehensively by Chapin [6] by dividing it into 'simple' and 'complex' forms of blight: simple forms of blight include such physical characteristics as structural deterioration, missing sanitation facilities, structures in disrepair or lacking in elemental maintenance, presence of trash and rubbish accumulation in yards, adverse environmental influences such as noise, odors, dust, and so on, and missing community facilities such as schools, play grounds, public water and sewerage systems and adequate street and drainage facilities.'

Chapin's simple forms of blight also include what he called 'social indicators' such as 'presence of abnormally high rates of juvenile delinquency, venereal disease, and similar results from other health and welfare indices' and 'economic indicators' such as 'concentration of tax delinquent and tax title properties, declining property values, and presence of an abnormally large number of building vacancies.'

On the other hand, complex forms of blight are said to exist: when an area contains incompatible land uses, obsolete or impractical layout of lots, blocks and streets, unsafe and unhealthful conditions existing or possible when marginal land is in use, particularly land subject to floods, mar shiness, [sic] or tidal flows' [6].

However, definition of characteristics of blight alone does not provide its sufficient understanding. Its driving factors, investment approaches that are available to remedy it, and the impacts of the approaches shall also be defined.

The Driving Factors of Blight

Various studies indicate that blight is driven, generally, by disinvestment and weak investment in urban centers and areas [7]. They also indicate that disinvestments and weak investments, in turn, are driven mainly by three types of factors: decline of demand or property value, macro-economic or structural factors, and policy and planning.

The first refers to a type of blight driven by decline of the capacity of property owners to invest on maintenance of property due to decline of value and rent. Historically, the origin of this type of blight can be traced back to the aftermath of the Industrial Revolution when the pre-industrial city core

was filled by rapid urbanization leading to crowded and unsanitary conditions, flight of business and the middle class, decline of property value, and further deterioration of the city core[8][9]. In principle, decline of rent may also result from oversupply of property and 'real estate crash' in extreme cases.

The second refers to blight driven by the overall political economy rather than by one of its segments such as the property market [10]. For example Magubane [11] argues that blight is an 'inevitable result of the capitalist economy which, in order to grow...must, besides providing employment, create a large industrial reserve army of labor', an army which is forced to reside in 'urban slums, shanty towns, and favelas' due to its weak capacity to invest or pay rent. This is a case in which blight is created mainly not because of the problem of wealth creation but partly because of its distribution.

The concept, however, appears to apply also to a political economy that has constraints of wealth creation, in the first place, such as the pre-capitalist or the agrarian macro-economy. In this case, although the level of urbanization may be low and urban centers may be small in size, the capacity of the public and private sectors to invest in buildings and infrastructure is quite weak and, as a result, urban centers are characterized by blight conditions. The difference is that, in the first case, weak investment concerns mainly the 'reserve army' while in the second case it concerns nearly the total population.

The third refers to blight driven by governments [12] [13]. Governments may drive blight in two major ways: directly, by expanding the definition of blight and, thereby, expanding the urban areas and number of buildings viewed as blighted and indirectly, through rent and investment controls. For example Gordon [5] laments the practice of 'grafting economic considerations such as underutilization of land, uneven commercial development, insufficient tax revenues and commerce and prosperity to the older health and welfare notion of urban blight' and giving more and more areas blight designation.

He gives an extensive review of how the definition has been shifting, in the US, to the extent of becoming an 'art form', based on the interest of local governments in obtaining 'federal funds', 'tax breaks' and 'prospect of capturing larger tax base' and how not only ' development officials' but also 'developers have the power to blight virtually any urban parcel' and make it available for redevelopment [5].

On the other hand, studies like Ault [14] indicate that rent control policies may contribute to decline of quantity and quality of properties. In addition, other studies and observation of urban centers in former communist countries like Ethiopia indicate that, anti-capitalist policies and ideologies that had banned private ownership of property and entrepreneurial activities and which have contributed to the weakening of public and private investments were partly responsible for much of the blight in those contexts.

Investment Approaches in Old Urban Areas

The history of investment in old urban areas indicates that redevelopment has been one of the first types of approaches. The approach is defined as a strategy that involves large scale clearance of property, re-planning, and rebuilding [15]. The definition suggests that if its scale is not large and if it does not involve a preconceived plan aimed at layout change through‘re-planning’ the strategy is not redevelopment; it is just rebuilding [15].

Originally, redevelopment’s objective was viewed as serving the ‘public’ interests of health, safety and welfare. According to this view, the public sector initiates redevelopment either when an old area is required to accommodate new public uses such as schools, parks, highways, etc. or when the qualities of its existing use threaten or affect the ‘public’ interests. Later, there were criticisms of expanding the public interest by ‘grafting’ to it other interest such as increasing efficiency of land use and tax revenue [5] or, more seriously, replacing it with the private interest. In the latter case, the use of eminent domain: taking property from one financially weaker private party to transfer it to another financially powerful private party is emphasized [1]. This is thought to be in conflict with the original understanding of the use of eminent domain which had been 'to take private property and convey it to a public body for public use' (ibid.). In addition, the fact that redevelopment involves producing built-form which is a crucial input for private' capital accumulation process' and for profit making, first as a 'physical setting for the production and sale of other commodities' and second as a 'commodity itself that can be traded in the market place for profit' is emphasized [5] [17].

In this line it is also argued that processes as diverse as urban disinvestment and decay, suburbanization, deindustrialization, urban renewal, and gentrification are part and parcel of the continuous reshaping of the built environment to create a more efficient arena for profit making' [18].

All in all, the literature indicate that, historically, redevelopment was a process generated by a sequence of factors such as rapid urbanization and filling of the pre-industrial city core, overloading and blight, ‘de-urbanization’ or flight of the middle class to suburbia, and further blight. The sequence may not explain redevelopment in cities like Addis Ababa where, although rapid urbanization has been filling the traditional core and, therefore, there has been overload and much blight, there has not been large-scale market driven de-urbanization of the core.

At a project level, the process includes activities such as designating an area for redevelopment, assessing the value of properties to be cleared, conducting voluntary or compulsory purchase of property from private owners by using the power of eminent domain, land transfer to commercial developers by the state, re-planning, clearance, and rebuilding. In this context land transfer is based on market value which is determined in the context of competition among land buyers and sellers [19]. While in the context of a specific redevelopment site the state may be the only land seller the general context is a standard market system in which, in principle, the state has to compete with land sellers in other parts of a city in order to sell the land in the redevelopment site. Rebuilding itself involves processes like building design, design review and approval and construction.

This project level process, as well, may not adequately explain the situation in cities like Addis Ababa in which the state is the sole land owner and, therefore, competition is only among buyers.

While proponents of redevelopment emphasize its benefits such as bringing back demand and economic vibrancy to old areas, others focus attention on its undesirable effects such as loss of housing and small businesses, displacement and loss of community ties, destruction of old urban fabric and heritage, monotonous and dull cityscape, and community fight [8,9,20].

It is argued that clearance leads to displacement of residents and small businesses, loss of community ties and social capital and, when there is re-housing of the displaced residents in new locations, to social segregation and visual monotony through design duplication and centralization of design process aimed at saving cost. As Adams [19] notes the 'new urban environment, consciously planned and developed across entire neighborhoods lacked interest and vitality.' For example, the infamous Pruitt-Igoe redevelopment project was based on duplication of a single building 33 times without major change in height, layout, and façade design. On the other hand, when the cleared site is redeveloped into houses and businesses that can be afforded only by middle income and wealthy residents' redevelopment leads to gentrification. Such areas may be free from the causes of visual monotony, since design duplication may not be needed, but they may not be free from the effect as a result of destruction of old structures by clearance. Clearance also, typically, leads to community fights which according to Castells [21] are 'instruments of participation' types of 'urban social movements'.

Their objectives are, typically, to stop the redevelopment, to 'shoot down' the project or to negotiate compensation for losses. Their most common actions are organization, protest, petitions, lobbying, and sometimes seeking historic designation for the redevelopment area [22].

These criticisms have eventually led to the emergence of the rehabilitation and conservation approaches. The approaches have the objective of solving the problems of old areas not by gross demolition and rebuilding but by using a variety of strategies that can maintain most of the urban fabric. Strategies have to be many because old areas commonly have many problems such as aging of heritage and other structures, structural unsoundness of some buildings, lack of social services, obsoleteness of infrastructure, and obsoleteness of uses.

The first require conservation and repair, the second and third demolition and rebuilding, the third upgrading, and the fourth change of use. While redevelopment's objective is to fight blight by any means that of rehabilitation is to fight it by means that may 'adapt the area to new needs, saves heritage, minimizes displacement of businesses and residences, and maintains the visual richness of the area.' The approach, however, is more challenging than redevelopment. It requires more complex planning and management, mobilization of political support, overcoming challenges from vested interests such as land owners, developers and even professionals, and challenges of financing [23].

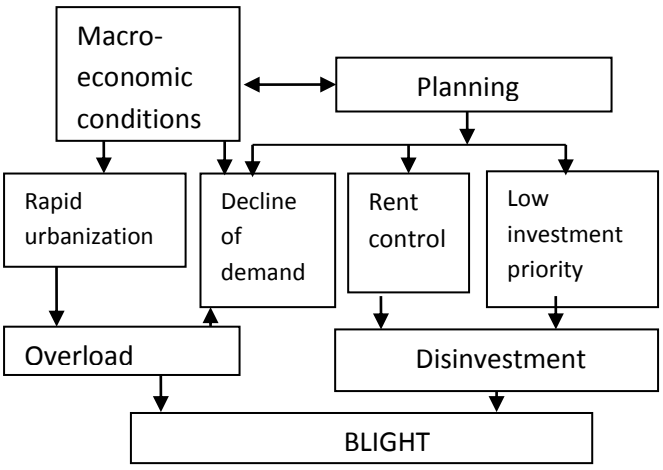

Figure 1 Conceptual framework of blight

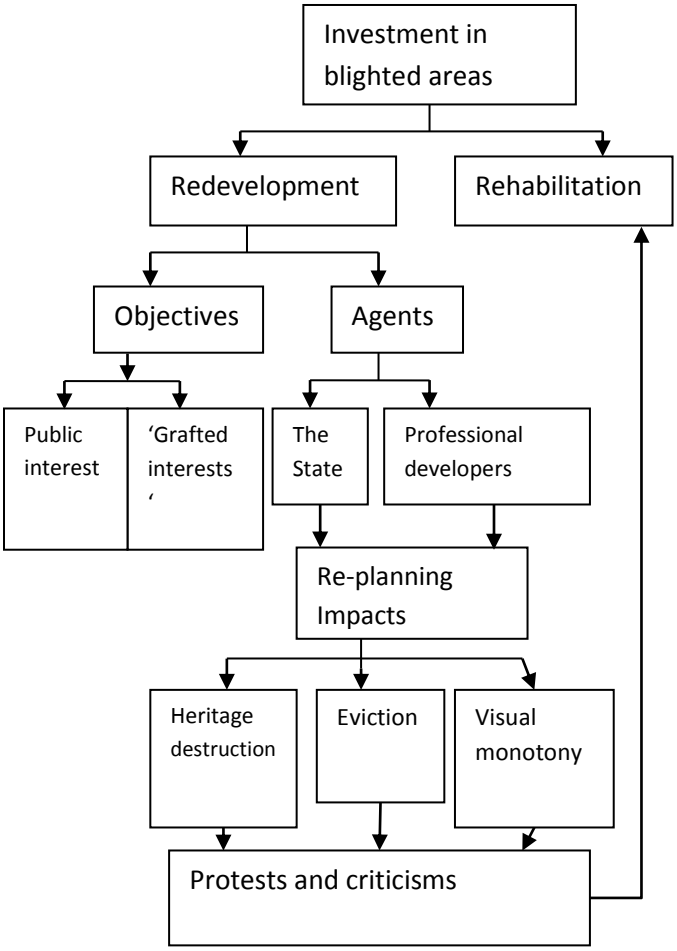

Figure 2 Conceptual Framework of investment approaches in blighted areas

Method

The objective of the research is to conduct an in-depth study of a single case within its context in which data are found in multiple sources such as people, documents, and the physical environment, and as a result, different data collection techniques such as interview, document review, and observation had to be used. A case study approach, considered as more appropriate for such studies, [24] was thus used.

The redevelopment process of the study area had two major parts:

- Designation of the area for redevelopment and selection of developer; and
- Re-planning, clearance, and rebuilding of the area.

Data on the first part and on the re-planning element of the second were collected in 2001 and 2003 for a thesis project. The major focus of the current paper is not on those parts. It is on the remaining elements of the second part and, more importantly, on whether the community based redevelopment approach has prevented the negative effects of professional developer-based redevelopment or conventional redevelopment. The first part is included only to provide a complete description of the redevelopment process of the area.

Data were collected by focusing on the main events of the parts of the process which are the focus of the study including clearance, land transfer, design, financing, construction and operation and the rebuilding output, especially, the buildings. The events were then used to generate questions for interview and checklists for document review and observation. The interview included community leaders, their employed managers, building designers, and land lease officials. Document review included land

transfer contracts, building designs, and construction and occupancy documents. Physical observation was focused on urban renewal blocks and individual buildings. The data collection process has also benefited from participant observation due to employment of the researcher as a consultant by two community associations (Dubai Tera and Tesfachin) for a period extending from design up to construction. Data were analyzed mainly by categorization under the events followed by sequencing and narration.

The Case Study

Introduction

The history of sub-Saharan African urban centers, including Addis Ababa, is dominated by weak investment. Mainly due to its macro-economic condition, many of the subcontinent's urban centers were characterized by poor quality buildings, unpaved roads, and absence of infrastructure for water supply and waste management [25].

Investment began to gain strength mainly after the continent had widened its contact with the industrialized capitalist world, first through colonialism and later through trade. In Ethiopia, the first type of contact was limited to five years of occupation while the second was interrupted from 1974-1991 after the country had joined the socialist bloc in which private investments in property and rents were controlled by policy.

Addis Ababa's founding in the 1880s was not only based on weak investment but it was, in fact, based on no investment: it was founded as a traditional military camp in which there was no need for investment since traditional Ethiopian military camps needed only tents which were mobile. Investment began only after decision was made to make the settlement permanent, following the victory over the first colonial attempt by Italy in 1896. The investment however was very weak mainly due to macro-economic conditions. As a result, buildings were limited to tukuls, roads were unpaved and infrastructures were non-existent. Investment capacity had strengthened shortly after as a result of construction of a railway line to the port city of Djibouti. Following that the city was able to import tin and steel nails and upgrade its tukul buildings to tin roof houses for the masses and to higher investment buildings named the 'Addis Ababa style' by Lindhal [26] for the chiefs in addition to investments in some public buildings and roads by government.

Investment in the city was dramatically strengthened during the brief occupation of the country by Italy even though its objective was not public interest. One of the areas which were the center of such investment was the central market place. Addis Ababa's central market (then locally known as Arada) was a large open space devoid of any investment. It had no shopping structures, infrastructure, or paved roads apart from stone and earth mounds (locally called medeb) from which thousands of small retailers selling many kinds of goods operated. Following construction of the railway line mentioned earlier, it had begun to be provided with public and private investment in roads and low investment shopping structures (Fig.3).

Figure 3 The market at its original location (Arada)

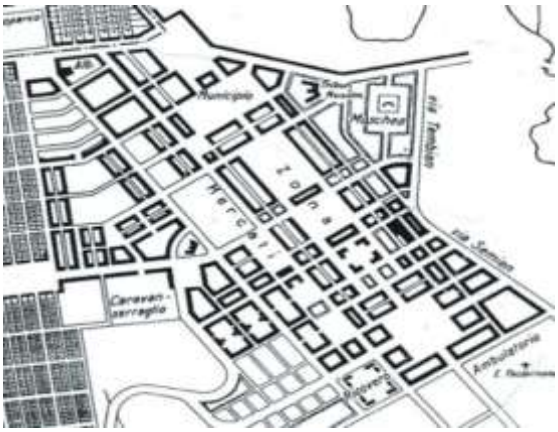

Figure 4 Italian master plan for the relocated market

Figure 5 Market Structures for the 'natives'

Figure 6 Typical Expatriate Community Shops

During the Italian occupation it was relocated to its current location and was provided with a planned layout, paved roads, shopping structures, a cinema, and a mosque (Fig.4). But, even in that relatively high investment context, local traders were able to afford only low investment spaces such as open stalls and simple shelters like tents (Fig.5) while expatriate community traders like Arabs, Greeks, Indians and Armenians were able to invest on shopping buildings organized around the perimeters of the open air markets (Fig.3,4,5,6).

During the post-occupation period the market continued to be one of the centers of public and private investments: government and business invested in several modern market, bank, and hotel buildings, and communities invested in an orthodox church. But it also continued to be dominated by disinvestment and weak investment since the occupation had not changed the country's macro-economic conditions significantly: landowners, who were the great majority of the investors, invested in typically low investment rental structures for shops in the center of the market and for residence at the periphery. The situation became even worse after the country had joined the communist bloc and the weak investment context was replaced, abruptly, by nearly two decades of disinvestment as a result of private investment bank and rent control policies. During that period rental properties together with land were nationalized and private investments in new and the nationalized rental buildings were prohibited. In addition, rent control policies which had reduced rent up to half had diminished the capacity of the property owner (government) to invest in the upkeep of the nationalized properties.

However, the policies could not effectively prohibit growth of the marketplace through informal subdivision and conversion of properties, appropriation of streets, open spaces, and the arcades. As a result, at the end of this period, and the beginning of the transition in 1991, it had grown into densely packed low-rise residential areas in its northern part, market areas for goods imported from Asian countries such as China, India, and Dubai in its central part, and markets for local products such as food, spices, handicraft and recycled products together with a large area for the recycling in its southern part all in a very severe blight condition (Fig.7). The business part of the market had developed into numerous submarkets (Teras or blocks) in which people largely from similar cultural groups traded similar types of goods.

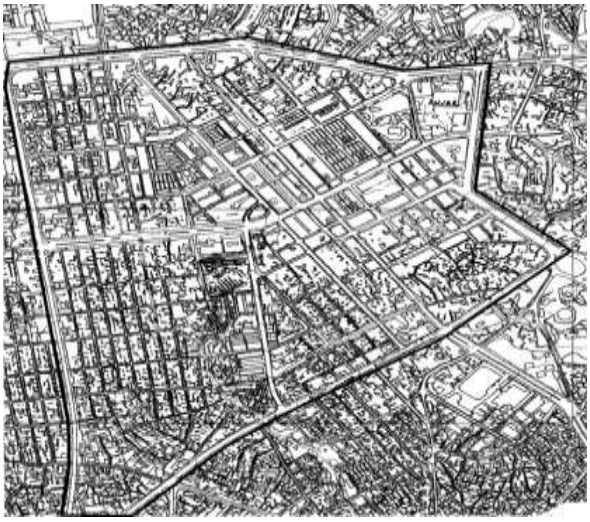

Figure 7 The market place in early 2000

This physical blight was not accompanied by loss of demand or importance. To the contrary, the market was widely viewed as an old and traditional use having heritage value, a public space and a symbol of social integration since it was accessible to all economic and cultural groups, a unique urban area having heritage value also because of its colonial buildings and planned layout, an engine and the 'heart' of the urban and even national economy because of the industriousness of its community and intensity of its activity, and an important goods and service distribution facility, especially, for the low-income majority. In addition it was a peak land value area of the city.

However, after the country had started macro-economic transition in 1991 which has led to lifting of rent control policies and the ban on private investment and strengthening of public and private investment capacities, the market place was earmarked for redevelopment regardless of its heritage value and good reputations. Data obtained from multiple sources indicate that the major factor responsible for the decision was the 'grafted' interest of increasing land use efficiency through high-rise building development which was of particular interest to the government because of its opportunity for increasing land value and tax revenues. The redevelopment was originally focused on professional developers as the subdivision plan above indicates (Fig.8).

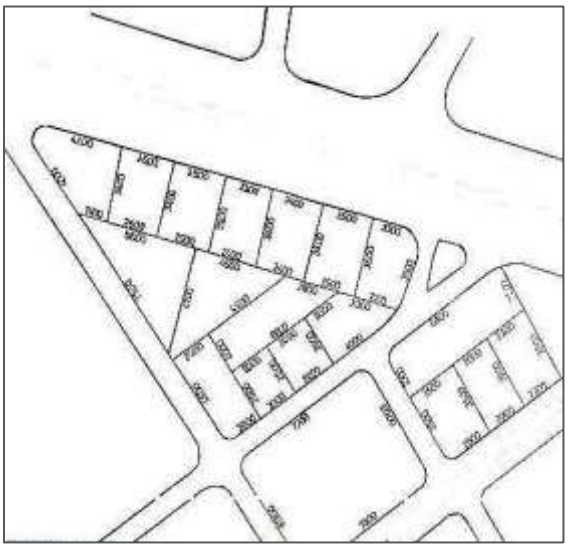

Figure 8 Redevelopment subdivision plan

The focus was even briefly shifted to an international private developer group from Malaysia which had expressed interest to redevelop the market district together with a large residential district south of it. Nonetheless, the final redevelopment agent of the market place was neither the state nor professional developers. It was rather the bazaar trade community. The focus of this paper is on why this shift of agent had occurred and whether it has prevented the common effects of redevelopment.

The Shift of the Redevelopment Agent Role to the Community

Data gathered from multiple sources indicate that the shift of redevelopment agent from the state and professional developers to the community was a result of two major factors:

First, the plan to redevelop the area had led to a threat of eviction and community organization and action consistent with historical trends. The organization was first formed by a market area (Tera) consisting of 160 traders.

Soon it was joined by 1077 traders operating from three market areas and later it was expanded to cover the entire retail and wholesale section of the market place.

The objective of the organization, however, was not to resist the investment in the market area or to maximize compensation for the impacts of eviction. It was to resist the professional redevelopment approach and to shift it to a community-based investment approach. Three factors were responsible for the choice of this form of resistance: absence of decline of property value; the land's ownership by government; and the community's ability to generate resource. At the time the area was a peak land value area despite its blighted conditions, as mentioned above [27]. 100% of the land and close to 90% of property were owned by government. The community was a bazaar trade community which had some investment capacity.

The community's desired investment approach was, however, not redevelopment. It was rehabilitation as the proposal first submitted by the community to the City Administration indicates. This proposal sought to avoid land purchase and re-planning of the area and to limit investment to rebuilding of the stall type shops without changing their scale and organization. However, when this approach was rejected by the City Administration, by insisting on the redevelopment approach, the community shifted its focus from changing the approach to changing the land purchase and re-planning aspects of the approach. In the redevelopment approach land purchase was planned to be conducted through open auctions while the community sought purchase through negotiated prices. Market areas were planned to be subdivided for private development in multi-story buildings as high as nine floors while the community desired collective ownership of the areas and thought that the planned intensity of development was unviable businesswise and beyond the community's capacity investment wise.

The community's shift of approach from rehabilitation to redevelopment led to the government's shift of focus from professional developers to the community, partly through the efforts of a partnership called the "Merkato Millennium Development Partnership" and to processes to accommodate the latter's concerns. The processes included determining land price through administrative means, discussing the prices on numerous meetings and even conferences, and determining the development intensity through a prolonged and participatory master plan preparation

and Local Development Planning process [27]. Data indicate that the community was an active participant in the processes and that the processes were able to address its major concerns stated above. Document data obtained from the Capital [28], and provided below, indicate that the participatory planning process through which development intensities were determined, in particular, was not only accommodative of the community's demands but it was also empowering.

"We, inhabitants of Merkato, for the first time were invited to say something about the future of the place. We were invited and have been participating starting from the initial stage for almost two years, and our effort can be described as successful. We discussed with them about our capacity and the unique features of Merkato. The Master Plan Revision Project is a good model for all other government institutions" [28] In short, the above is analysis of data on why and by what process the redevelopment agent had shifted to the community from professional developers. Analysis of the extent to which this shift has altered the common effects of redevelopment such as eviction, heritage destruction, visual monotony, and re-planning will be presented below.

Eviction

The marketplace's redevelopment did not involve compulsory purchase of land from private owners, state supported eviction of tenants, and transfer of land to commercial developers. As stated above all land in the entire market was owned by the state or the City Administration in addition to, close to 95% of the properties. Therefore, they did not need compulsory purchase by the state in order to be transferred to the investors. The transfer itself was made to the community share companies in which tenants were all registered members regardless of their ability to contribute to the investment. Therefore, the redevelopment did not entail direct state supported eviction of tenants because the latter were protected by the share companies.

The major cost elements of the redevelopment process were land cost and development cost. Land cost for each block was computed by multiplying the unit rate by land area and the lease period which was 50 years for business. Out of this, 25% was required to be paid as advance payment up on signing agreement while the balance and its interest were required to be settled in 15 years. Payments for land during the pre-operation period had to be effected through contributions by the share company members. The Contributions had to cover also 30% of the construction cost to fulfill the requirements of banks to qualify for loan. Banks were highly motivated to provide loans by holding the properties as collateral. They were also one of the major customers for renting space in the new buildings. For example, a total of nine banks have rented space for their branches in Dubai Tera alone. The main challenge was, thus to generate money for the contributions while the shops were cleared for redevelopment. This challenge was overcome by negotiating temporary business space on the right of way, on the perimeter of the cleared blocks. Each member was provided with a shop which could be operated or rented out during the redevelopment period. These shops were more popular than those in the new buildings because of their on-street location so much that they had delayed moving to the new buildings for months in some Teras like Dubai Tera. It was also observed that the colonial short urban blocks and grid street pattern have made provision of space for the temporary shops and storage of construction materials possible without creating serious traffic problems in the market place.

But even with these arrangements not all members were able to meet the requirements of contributions. For example, in Atkilt Tera, some 15 former vegetable trader weaker economic group tenants were reported to have sold their shares, at market prices, and exited the share companies because they could not pay contributions for land transfer payments and for starting construction. That means, although the community based redevelopment was successful in preventing direct state induced eviction, it was not in preventing the indirect one, that has resulted from requirements of paying very high land prices and investing in high investment building. The latter type of eviction was, nonetheless, relatively more preferred because its compensation, which is at market rates, was thought to be much higher than that of the former, if at all made.

Heritage Destruction

The marketplace was, in principle, a heritage in whole since it is traditional in land use, a colonial heritage in physical terms and has many good reputations. This was not acknowledged by the market's local development plan.

Fig.9 A residential building from the occupation period

Only the heritage value of some structures such as the Orthodox Church, the mosque, a post-colonial modern market hall building (Fig.9), and an occupation period large residential building later converted to a hotel (Fig 10) was acknowledged.

Fig.10 A post-occupation period market hall

The plan, however, was not implemented in full. For example, the latter heritage building was cleared with the rest of the market structures and its site was assembled with the adjoining portion of the block and transferred to the block's association.

According to Development Control and Land Lease Office officials the problem is attributed to conflict of interest on the part of the City Administration: conflict between its land seller interest and the public interest, which, in this case, was resolved by giving priority to the former.

According to the officials, although the 'religious buildings appear to be immune because they have their own strong armies' it is only a matter of time for the third heritage building to be exposed to the same practice. As long as the redevelopment is tenant based effective resistance to clearing any site, other than the religious ones, is unlikely. In fact, for most of the site's land transfer applications have been submitted by organized tenant groups and they are only awaiting decision.

Visual Monotony

The community had a centralized organization for the reaction, but once the reaction has succeeded, the design of buildings was decentralized to block level and each block was designed independently. Therefore, there was no design duplication problem. The problem, in this case, was rather lack of design coordination. There were no urban design guidelines or other instruments to coordinate the designs apart from the building height regulation. Thus, wide variation of roof design, façade design, material and color were observed. The building height regulation itself had ceased to be a regulating instrument when in reaction to rapidly increasing land value and willingness of banks to supply loans, share companies became willing to increase height as in the case of old Atkilt Tera (increased to five stories) or Mars Hotel block (increased to eight stories). However, total visual chaos was prevented by factors such as: block level centralization of design, similarity in design programs, in space organization, and in building line. The buildings, typically, consisted of one or two levels of underground car parking floors, ground and one or two upper floor commercial spaces, and cafes and restaurants on the top floors. They were, typically, organized around glass roof covered atriums provided for natural light and ventilation. Shops were organized in two rows, one facing the atrium and the other the street, and having shutters which can open them up to full public view during the day time just like the traditional stalls. Blocks were fully built-up in order to maximize number of shops and maintain their traditional close link with the street. In addition to these, block level design centralization has prevented plot level decentralization. Had the blocks been subdivided into plots and had buildings on each plot been designed independently, the effect of lack of coordination would have been increased considerably. (Fig. 11)

Figure 11 Variation of façade design among the different blocks of the market

Re-planning

Although the investment is known as redevelopment, according to Burn's definition it was more rebuilding or partial redevelopment. The investment did not involve re-planning apart from market area land assembly, widening of some roads, proposing to pedestrianize two roads, and increasing building height. Re-planning did not include change of layout, provision of infrastructure like sewerage, amenities like parks and green areas, and mixing of land use.

Increasing building height without layout and land use change has led to multiplying space supply without corresponding rate of increase in demand. This has begun to lead to decline of rent and growth of vacancy. For example Dubai Tera which is located at the heart of the market had to rent out shops at 50% of commonly expected rate. Even that had to be reduced more than two times within three years in response to threats of moving out. But still 30% of the building is vacant after three years of operation even after some floors were converted to offices. The situation is similar in many Teras.

Drainage sewer lines were not provided due to failure to re-plan the waste management system of the market area. As a result, streets are forced to accommodate storm water and market areas are forced to depend on cesspools for waste water management. It was observed that cesspools that are located under basement floors are exposed to filling during the rainy season when the ground water rises while those located at basement floors are causing air pollution.

Thus, the re-planning has two major constraints: increasing building intensity in all market areas and further investment through the redevelopment approach are likely to lead to further increase in rent decline and in vacancy rate leading to loss of capacity by the property owners to upkeep the properties. The absence of amenities and infrastructure can lead to gradual decline of demand and aggravation of this situation. When that happens, sooner or later, the market will have to deal with yet another type of blight: the demand and property value decline blight.

CONCLUSIONS

The conceptual study indicates that the main driving force for investment in old urban areas has been blight which was historically defined as an urban quality that creates concern for public health and safety, that investment in old areas were originally focused on the 'public interest' or fighting the concerns, that blight is driven mainly by disinvestment and weak investment in urban centers and areas, that these drivers are in turn driven mainly by macro-economic factors, demand or property value decline, and policy factors, and that the literature is focused on the second factor and the direct element of the third.

It also shows that, historically, the main investment approach in old urban areas has been redevelopment, that its main objective has been to return demand to the city core, that its major investors were the state and commercial developers, and that it was commonly associated with negative effects such as eviction, community reaction, heritage destruction and visual monotony, and that criticisms of these effects have gradually led to the emergence of the rehabilitation approach which attempts to solve the problems of old areas while maintaining most of the urban fabric.

On the other hand, the study generally suggests three major conclusions: much of the blight was driven by macro-economic and policy factors rather than property value

decline; the goal of redevelopment has rarely been the classic public interests of health and safety: they were mainly the 'grafted' objectives of modernization, efficient use of land, and increasing tax revenue; and although the community investment approach was redevelopment it has, however, managed to prevent some of the negative effects of commercial redevelopment in addition to empowering the community.

The unique nature of the blight has led to a unique type of community reaction: a fight to invest and stay rather than flight to the periphery. It has also led to a unique type of investor. Had the blight been property value decline-driven, the investors would very likely have been the state and commercial developers. Of course, in addition to the type of blight, types of community and property ownership have played roles. Had the community been low-income-residential a fight to become investor would have been very unlikely. Similarly, had the property ownership been private, there may not have been serious blight in the first place given that there was no property value decline. The community led redevelopment has averted the common threats of commercial redevelopment: there was no direct state sponsored eviction, heritage market use and layout were protected, and visual monotony and over-coordination were prevented although they appear to be replaced by lack of coordination because of inadequate support from the state. In addition to failing to provide sufficient coordination the state has been driving oversupply of property which has been leading to indirect eviction of lower income groups by making financial contributions for the redevelopment projects unaffordable. There are also indications that this oversupply of property is leading to rent decline and placing the market place on the path of the property value decline strand of blight.

The study also suggests the following major actions in order to improve investment in old areas of Addis Ababa and similar urban centers:

- Selection of investment approach for old urban areas shall be based on adequate study of heritage and other values of the areas through participatory processes;
- Community investment approach shall be encouraged and adequately supported and coordinated because of its empowering, wealth redistributing, and negative redevelopment impact reducing potentials;
- Redevelopment of old areas shall include re-planning to deal with lack of infrastructure and amenities and shall also include proper demand study in order to prevent over-supply of property and the threat of replacing one form of blight by another;
- Public involvement in planning shall be a proactive component of the planning process rather than a retroactive one which must be sought by communities through protest; and
- Participation in planning shall be inclusive of all stakeholders and its processes shall be accountable to the stakeholders.

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HYDRATION AND CARBONATION REACTION COMPETITION AND THE EFFECT ON THE STRENGTH OF UNDER SHED AIR DRIED AMENDED COMPRESSED EARTH BLOCKS (ACEBs)

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ABSTRACT

A research finding on amended soils for the production of blocks and mortar with lime and natural pozzolan for earthen construction was reported in the EEA Journal of 2019. The use of the amenders was to take advantage of the binding property of lime and the low reactive behavior of natural pozzolans without any further energy demanding additional treatment. In the attempt, it was learned that the existence of hydration and carbonation reactions which are the driving engines of the whole formation are competing with each other at early age of curing. The effect of this phenomenon is that it might upset the maximum/optimum stabilizing effect that could be fully achieved. Furthermore, since the proposed method was defined for air dried curing but only under shed environment; it came to mind that such a challenge needs to be addressed before embarking on an industrial scale. Thus, the main objective of this research is to investigate the effect of hydration and carbonation reaction competitions on air dried blocks in lieu of those cured under the influence of moisture to make a decision on their ultimate use. In order to understand the existence of the reactions' competition various curing mediums were experimented upon and a comparison is made to figure out the weakness of the air dried blocks and those matured at six more environments. From the finding, it is concluded that, among the contending curing conditions as for the purpose of this research, both under shed air drying and a plastic cover moist curing for 14 days and a subsequent 14 days air dry curing under the ambient lab environment (totaling 28 days) could equally be used as convenient. It is also confirmed that, the proposed curing of ACEBs under shed within an air dry condition is a well suited proposition for the practice; since the competition doesn't seem to affect its anticipated performance; per the finding.

Keywords: Amended soils, Competition, Carbonation, Earthen-construction, Hydration

BACKGROUND

The quest for affordable housing scheme is an ongoing effort and it is certainly central to UN's Sustainable Development Goal 11 (SDG 11): *"Make cities and human settlements inclusive, safe, resilient and sustainable"* [1]. In response to the ever burning issue of a global stature, innumerable researches are pursued longing for a formidable achievement. Likewise, here in Ethiopia such researches have been undertaken for a long time; though intermittent and fragmented. Quite recently, the application of lime and natural pozzolans to effectively modify/enhance natural soils for the purpose of Amended Compressed Earth Block (ACEB) and jointing mortar production was addressed in the laboratory

and field application as reported in the Journal of EEA 2019 [2]. According to many literature sources, while using such mixtures for the stated purpose there are several challenges which require effective and confidence building corroborations. Among the so many, hydration and carbonation reactions are the two competing factors which negate the possible achievement of the required total service longevity; be it in strength and/or durability of ACEBs and mortars to construct earth based buildings. Thus, the main objective of this research is to investigate the effect of hydration and carbonation reaction competitions on air dried blocks in lieu of those cured under the influence of moisture to make a decision on their ultimate use.

Pure lime hardens by carbonation; however the introduction of pozzolans alters the hardening process of the lime mortar by imparting a hydraulic set (hydration reaction). The hydration products of lime/pozzolan pastes are similar to those found in a hydraulic lime mortars and cements [3, 4]; although their formation is considerably slower than cement pastes. Lime with hydraulic properties has faster setting times, higher mechanical strength and lower permeability and flexibility along with improved resistance to salt, frost and moisture damage [5].The pozzolanic reaction depends on the chemical and mineralogical composition of the pozzolan, the type and proportion of their active phases, the particle's specific surface area, the ratio of lime to pozzolan, water content, curing time and temperature [3, 4].

In the mentioned local research, the Amended Compressed Earth Blocks (ACEBs) were conditioned only under shed without applying curing water (air dry). However, an earlier research by Cizer, et al. (2010) reported that, curing under dry conditions does not sufficiently increase the strength of hydraulic lime and lime-pozzolana mortars; because the hydration reactions are slowed down or even terminated by the full carbonation of lime in lime-pozzolana mortars. The consequence of this on the mechanical properties of the mortars is remarkable while the same impact is not observed in their porosity. Such mortars require moist conditions to ensure sufficient strength development [6]. In fact, it is this concern which triggered a revisit of the systematic formulation and synthesis of amended soils application in earthen construction. Though the earlier finding has proven the worthiness of the effort, but yet it undoubtedly needs a confirmatory verification to elevate its wider and high level of exploitation in confidence. In any scientific work, there shouldn't remain any unturned rock left aside until all facts and figures come to light.

Aspects of Hydration and Carbonation Reaction Competitions

Hydration: It is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products. According to Cizer, et al. (2010) and Diamond et al. (1965), hydration reactions are the first reaction and carbonation of lime is the complementary reaction in the strength gain. Competition between these two reactions can occur in lime-pozzolana mortars if the pozzolanic material has low reactivity with lime, leading to the consumption of lime by carbonation reaction. Fast evaporation of the water in hydraulic lime and lime-pozzolana mortars should be avoided by keeping them moist at least during 28 days to improve the hydration reactions and to assure sufficient strength development. The researcher considers what is stated by the author of the mentioned work is quite applicable in here as well; because, the research is thoroughly focusing on low reactivity lime and natural pozzolan (raw) ingredients as stabilizers [6, 7].

Carbonation

When lime is added, the silica reacts with the carbon dioxide (CO2) from the atmosphere to form weak carbonated cements. This uses part of the lime available for Pozzolanic reactions; which give rise to hardening effects [8]. Though pure lime hardens by carbonation, the introduction of pozzolans alters the hardening process of the lime mortar by imparting a hydraulic set. The hydration products of lime/pozzolan pastes are similar to those found in a hydraulic lime mortars and cements although their formation is considerably slower than cement pastes. Lime with hydraulic properties has faster setting times, higher mechanical strength and lower permeability and flexibility along with improved resistance to salt, frost and moisture damage [3, 4, 8-14].The crux of the just stated concern can be well understood by navigating through the chemical reactions initiated by the instantaneous response of a given type of ordinary soil, powdered lime and natural pozzolan in the presence of water. It's worth examining the real world of the expressions of the chemistry shown in Figures 1 and 2 below with their subsequent explanations.

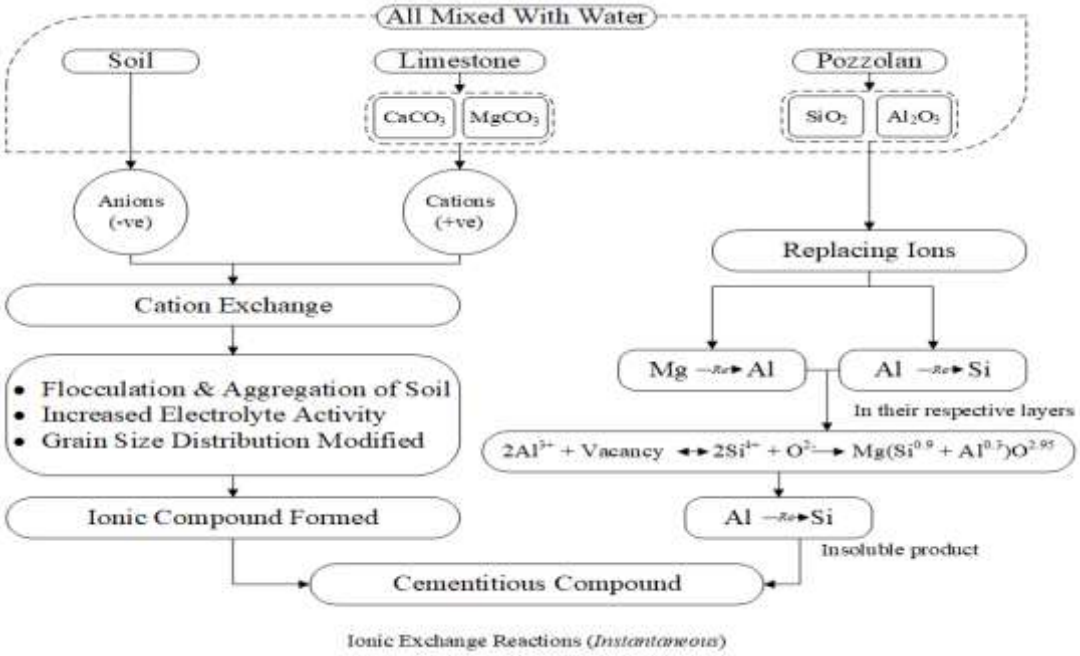

Figure 1: Schematic diagram to illustrate the reactions at ACEB production (Ionic)

(Researcher's own design)

The effects of lime on soils are such that two stages of reaction can be detected: (a) an early stage in which the properties of the plastic soil are greatly ameliorated but little permanent strength is developed, and (b) a subsequent stage marked by the slow development of strength and the accumulation of soil-lime reaction products. Among the effects observed in the first stage are large increases in the plastic limit, generally leading to a reduction in the plasticity index; a sharp reduction in the apparent content of clay size particles as they are bound into floes stable against the dispersion incident to the mechanical analysis; increase in the moisture and the compacting effort required to achieve a given density; and reduction in such parameters as swell pressure, volume change on drying, and permeability. These changes are commonly produced in periods ranging

from minutes to a few hours after the addition of lime [15, 16].

When lime is added to moistened montmorillonite or kaolinite clay, it will be flooded with calcium ions. Cation exchange then takes place (giving the clay a lower affinity for water), with Ca ions being replaced by exchangeable cations in the soil compounds, such as Mg++, Na+, K+, and H+. Thus, the resulting mix is characterized by a lower moisture movement, i.e., lower liquid limit and plasticity. The volume of this exchange depends on the quantity of the exchangeable cations present in the overall cation exchange capacity of the soil. The general order of replace ability of the common cations associated with soils is given by the lytropic series, Na+ < K+ < Ca++ < Mg++. Cations tend to replace cations to the left in the series and mono-valents are replaceable by multivalent cations [17-20].

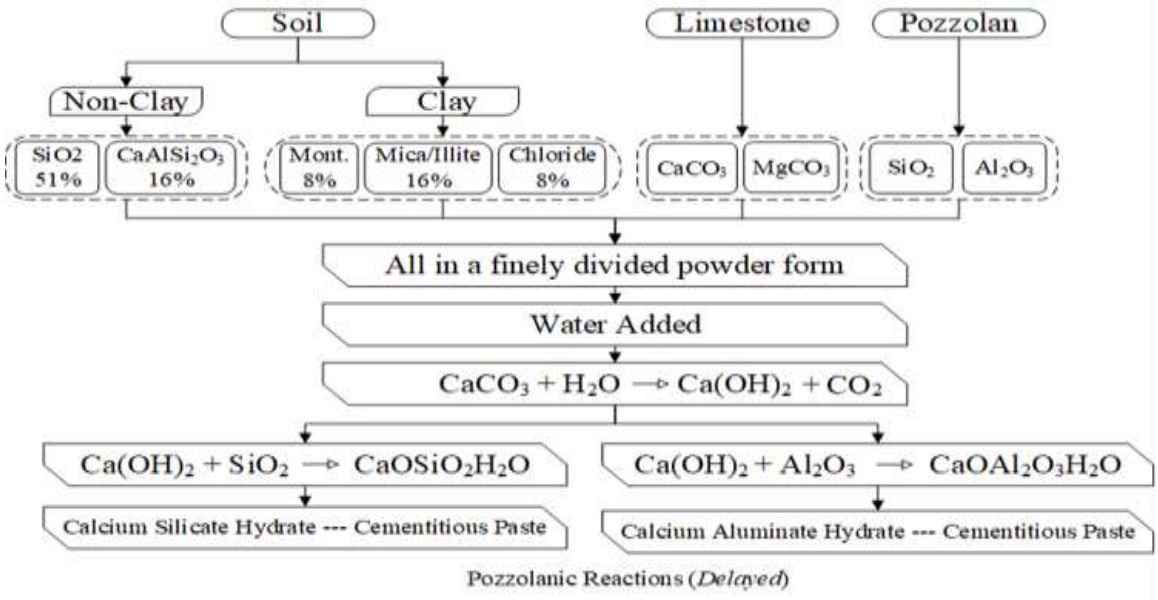

Figure 2: Schematic diagram to illustrate the reactions at ACEB production **(**Pozzolanic)

(Researcher's own design)

Mortars prepared with high reactive pozzolans have higher long term strength. This property is closely related to the extent of silicate formation resulting from reactions between $Ca(OH)_2$ and the reactive minerals (SiO_2, Al_2O_3) in the pozzolan. In previous studies of Cizer et al. (2010) and Diamond and Kinter (1965), pozzolanic reactions between calcined clay, hydrated lime and water were examined and it was observed that composites of hydrated tetra-calcium aluminate (C_4AH_{13}), hydrated tri-calcium aluminate (C_3AH_6), hydrated calcium aluminate (CAH), and gehlenite (C_2ASH_8) form and this process is facilitated by the basic state created via lime [6, 7].

In the process, both structure and grain size distributions are altered. According to Herzog and Mitchell (1963), the flocculation and agglomeration are caused by increased electrolyte content of the pore water and as a result of ion exchange [20]. Diamond and Kinter [1965], suggested that, the rapid formation of calcium aluminate hydrate is significant in the development of flocculation and agglomeration tendencies in soil-lime stabilization. The authors postulated that: Calcium ions cause a reduction in the plasticity of cohesive soil. The mechanism is either a cation exchange or crowding of additional cations onto the montmorillonite or kaolinite clay mineral.

Both processes change the electrical charge density around the clay particles [7]. Then these particles become electrically attracted to one another, causing flocculation. The crowding of additional Ca onto the clay must be the more important of the two mechanisms, since when they have tested the soil already had an excess of carbonates present (16.6%), yet the (Plastic Limit) of the soil was decreased from 40% to 18% with the addition of less than 3% lime[22]. Neville (2011), stated that, the factors that affect the activity of Pozzolana are: 1. Silica Oxide+ Alumina Oxide + Ferric Oxide content, 2.Amorphousness, 3. Fineness, 4. Quantity of reactive silica [22].

The nature of the compounds held responsible for the slow development of strength in soil-lime systems have been discussed in some detail. The exact products formed vary somewhat with the kind of clay and the reaction conditions, especially temperature. There are commonly at least two phases produced, a calcium silicate hydrate and a calcium aluminate hydrate. The former is usually tobermorite gel; the latter is a well-crystallized hexagonal compound, which is probably an impure (substituted) tetracalcium aluminate hydrate and is characterized by a $7.6A^{0}$ basal spacing; independent of drying conditions. At temperatures only slightly above normal room temperature a different calcium aluminate hydrate phase, the cubic tricalcium aluminate hexahydrate, is produced [7].

Significance of the Research Output

The launch of this research is to examine the effect of the two competing reactions of hydration and carbonation on the performance of Amended Compressed Earth Blocks (ACEBs) and mortars in their application for earthen construction. In a previous research, the author published on the subject stating that, curing of the blocks was without any additional moisture but only keeping under the lab hangar shed; till the testing date [2]. In which case, the pursued method seems susceptible to the competition phenomenon between hydration and carbonation reactions in the curing process. This exposition has to be challenged and supported with some exploratory laboratory experimentations; in order to ensure that the proposition is valid for the intended purpose; i.e., for low-cost and affordable housing scheme using lime and low reactivity pozzolans.

Hypothetical Propositions, Methods and Experimentations

Since soil is a good source of alumina, the effects of lime treatment can be enhanced to a great extent if the apparent shortage of silica can be adequately supplemented by the addition of natural pozzolana, which is high in reactive silica content. In a previous paper, Harichaneet al. (2009), presented the results of the effect of the combination of lime and natural pozzolana on the plasticity of two Algerian soft clayey soils classified as CH and CL according to the unified soil classification system (USCS) [23]. Similarly, Kassahun Admassu (2019), had successfully shown how a soil of CH or OH origin was transformed into an MH or OH type with a resulting PI reduction from 43 to 25 conforming to the mentioned USCS classification system [2].

CizerOzlem (2010) notes, a combined reaction of hydration and carbonation takes place in hydraulic lime and lime-pozzolana mortars. Hydration reactions are the first reaction and carbonation of lime is the complementary reaction in the strength gain.

Competition between these two reactions can occur in lime-pozzolana mortars if the pozzolanic material has low reactivity with lime, leading to the consumption of lime by carbonation reaction. The degree and

the order of these reactions are strongly influenced by the moisture content. Hydration reactions are enhanced under moist conditions while carbonation is delayed [6].

Moreover, five basic reactions were suggested for the theory of silica-lime reaction according to a UNIDO (1987) paper. These are: **a.** water absorption; **b.** cation exchange; **c.** flocculation and aggregation; **d.** carbonation; **e.** and silica lime-Pozzolanic reaction [17].

With all the above in the background, the current research is focusing on the various curing effects on the maturing of freshly cast Amended Compressed Earth Blocks (ACEBs) for low-cost house construction. As the understanding of these blocks in more details is gaining momentum it is essential to work into challenging specifics as to make the product a qualified alternative for construction. The obvious task at hand is to ascertain ACEBs' durability; especially, to shrug off its vulnerability to water attack; step by step, and make the product more construction worthwhile.

Thus, as a confidence building mechanism, a further detailed examination of the mechanics of these earthen blocks need unambiguous clarity from the point of view of the real chemistry of the constituent materials interaction as displayed in the stratifications of Figures 1 and 2 above. The questions are: What is going on in the real world of ACEB production as it stands now right from the dry mixing of the ingredients, addition of water, wet mixing, casting, de-molding, curing to the age of 28 days, construct walls and sustain it as a service rendering structure?

What could be the right explanation to the chemistry and the whole scenario to bring ACEB on to the accustomed building material platform as a standardized mainstream building block and mortar alternative?

Such vital and fundamental researchers' and users' queries must be unequivocally answered and supported with scientific evidence and analytical methods. Towards achieving this goal, the following are the outstanding accomplishments carried out to properly address such questions of a paramount importance.

To start with, each type of ACEB specimens were cast to conduct compressive strength tests on all those cured (under shed, plastic cover, over a water trough chicken wire bed) to their respective ages of 14, 28 and 56 days. In addition, to evaluate and assess the effect of curing at elevated temperatures, three blocks for three days (72 hrs) and another three for seven days (168 hrs) were also kept in oven under a controlled temperature of 64^{o}C, to their specified respective testing ages.

Moreover, six more block specimens were prepared. The first three specimens were initially cured in air for 14 days and the remaining 14 days under a plastic cover after being soaked in water for three minutes before starting the next stage of curing (28 days in total).

The second set was conditioned in the reverse order; i.e. first under plastic cover right after de-molding for 14 days and then taken out for air dry curing in the next cycle of 14 days (28 days in total). Finally, both sets were tested at their respective ages of 28 days.

In total, 48 ACEBs underwent compressive strength tests to solidify and strengthen the newly proposed method of air dried amended soil blocks for earthen construction; to prove that the competition reactions are not formidable challenges to refute the concept.

RESULTS AND DISCUSSIONS

The ACEB specimens casted to examine the effect of hydration and carbonation reactions competition on the performance of earthen construction under various curing conditions, including at elevated temperatures and durations were tested for compressive strength at their respective ages and the results indicated in Table 1 are obtained for further scrutiny, synthesis and analysis.

Table 1: Strength test results for different curing conditions and durations

Block Type & Curing Conditions	Testing Age (days)	Comp. Strength (MPa)	Ratios*	
			All:CEB_{air}	All:$ACEB_{air}$
1. $CEB_{air(a)}$	14	1.6	1.00	0.84
	28	1.7	1.00	0.68
	56	2.0	1.00	0.71
2. $ACEB_{air(a)}$	14	1.9	1.19	1.00
	28	2.5	1.41	1.00
	56	2.8	1.40	1.00
3. $ACEB_{plastic(p)}$	14	0.5	0.31	0.26
	28	0.5	0.29	0.20
	56	1.2	0.62	0.44
4. $ACEB_{mesh(m)}$	14	2.0	1.25	1.05
	28	2.2	1.29	0.88
	56	2.2	1.10	0.74
5. $ACEB_{(14a+14p)}$	28	0.9	0.50	0.40
6. $ACEB_{(14p+14a)}$	28	2.4	1.40	0.96
7. $ACEB_{oven(O)}$	3	3.4	1.90	1.40
	7	3.1	1.82	1.24

*Designates ratios of all strengths to CEBair & ACEBair in their respective columns

Fast evaporation of the water in hydraulic lime and lime-pozzolana mortars should be avoided by keeping them moist at least during 28 days to improve the hydration reactions and to assure sufficient strength development [9]. It was such assertive narratives which triggered the initiation of this specific research; indeed. Based on the compressive strength test results of CEB and ACEB specimens under various curing conditions including elevated temperatures and at different ages the manifestations thereof are analyzed and discussed below.

The results in Table 1 show compressive strengths of CEB and ACEB specimens cured under seven different conditions designated as: drying in air as of de-molding (air/a), under plastic cover curing as of de-molding (plastic/p), on a water trough over mesh evaporation curing (mesh/m), alternating curing of the 1st 14 days in air followed by the next 14 days in moist plastic cover and vice versa (14a+14p & 14p+14a) for all ages and 3 and 7 days in oven curing at elevated temperatures (Figure 3). Moreover, under the last column there are two sub-columns designated by All:CEBair (all strength results divided by those of the air dried soil only blocks in their respective ages). The same procedure is followed for those under the column All:ACEBair, but by only changing the denominator. In general, the ratios indicate that, there are obvious improvements though in varying degrees. However, since the focus of the study is on the competition of hydration and carbonation reactions effect on the strength development of ACEBs concentrating on ACEB(air), ACEB (14a+14p) and ACEB (14p+14a) will make the intent clear.

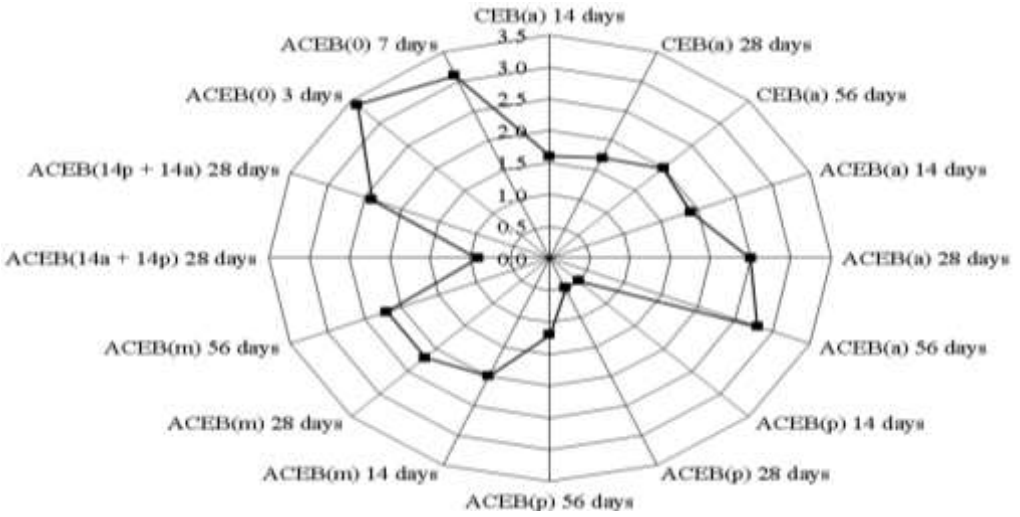

Figure 3: A chart for compressive strength at various curing conditions and ages

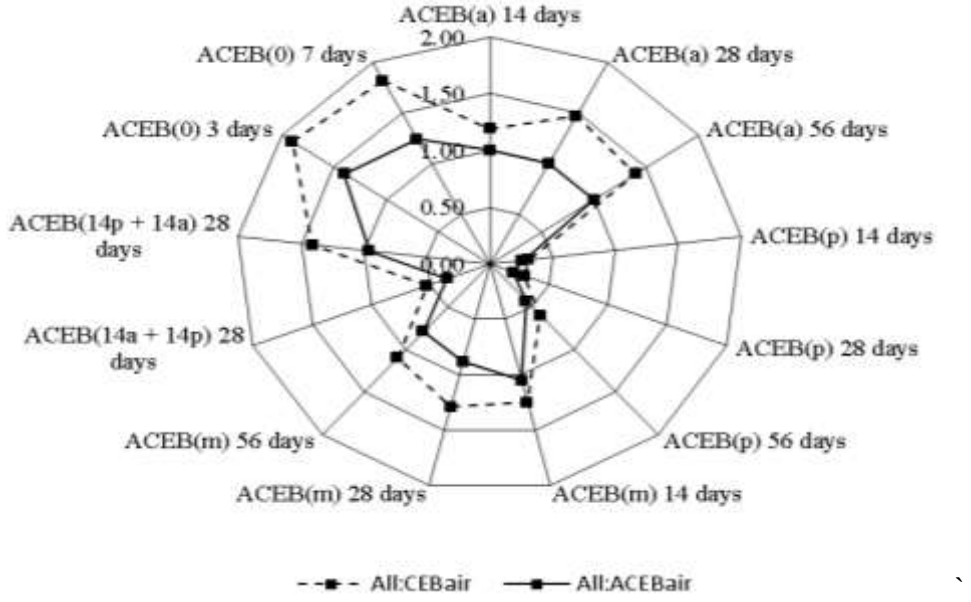

Figure 4: Compressive strength ratios to $CEB_{(a)}$ & $ACEB_{(a)}$ values to show improvements

Since the readiness of blocks for construction is after 28 days from the casting date it seems logical to construct the analysis and discussion based on those outcomes. In reference to the air dried ACEB at 28^{th} day it is only the over mesh (evaporation) cured 14^{th} day ratio which is even slightly higher than the reference. But there after it was on the decrease. This might be the ineffectiveness of that curing condition at latter ages. The ACEBs cured under plastic cover right from the time of de-molding were found to be the least performers. When it comes to the ACEBs cured in alternating, i.e., 14 days in air followed by the remaining 14 days under moist plastic cover performed less. Whereas, the one cured first under plastic cover right after de-molding for 14 days and then exposed to the room ambient temperature for the remaining 14 days scored a value nearly equal to the ACEBs cured in air for 28 days; i.e., the reference. Amongst all, the three days' in oven curing has achieved the maximum even exceeding the one cured in oven for seven days; both at a constant temperature of 64^0C.

Going back to the case of hydration and carbonation reactions competition the comparison of the test results between those cured first under plastic cover for 14 days and then kept in air for another 14 days (a total of 28 days) achieved a better result than the one first left in air for 14 days followed by a three minutes soaking in water then kept under plastic curing for 14 days (totaling 28 days). This could be accepted as an indication of the actual effect of competition because, literatures point out that, the competition is manifested in the first 14 days of curing and thus there is a need to keep the specimens moist to this age to fully exploit both reactions effectively [18]. Moreover, in the case of the blocks cured first in air for 14 days and then moved to a moist plastic cover for the remaining 14 days maturing the strength achieved at the 28^{th} day test is nearly half of its counterpart which is cured in the reverse order.

In general, it seems obvious that under all the circumstances considered the influence and the anticipated negative impact of hydration and carbonation reactions competition on the performance of ACEBs cured at ambient room temperature without any additional moisture is not observed at all. It stands high among its contenders to remain a strong alternative building material for the construction of affordable and sustainable abode for the rural segment of the society.

CONCLUSIONS

While promoting the use of under shed air dried Amended Compressed Earth Blocks (ACEBs) for earthen construction it was felt that the challenges of hydration and carbonation reactions could be a hindrance to scientifically sale the idea. Thus, assuming that such nagging issues could abort the effort eventually, this experimental investigation was launched focusing on different curing conditions and ages for maturity.

Noting that, the main objective of this research is to investigate the effect of hydration and carbonation reaction competitions on air dried blocks in lieu of those cured under the influence of moisture to make a decision on their ultimate use; six testing conditions with seven components were carried out on 48 actual size ACEBs to evaluate their performance by analyzing compressive strength test results. The findings confirmed that:

- Of all the test results the set cured under elevated temperature of $64^{\mathbf{0}}$C for 72 hrs is found as the best; even exceeding the 168 hrs oven cured set in this category.
- Among the conventional curing methods, the air dried (28 days) and those cured under moist plastic cover for 14 days and the remaining 14 days under the ambient room environment (a total of 28 days) took the lead.
- The next performer from the conventional stream is the set cured over mesh through evaporation.
- Of all the sets, the least performer is found to be the one cured under a moist plastic cover throughout all the ages.

Thus, it is concluded that, among the contending curing conditions as for the purpose of this research, both under shed air drying and under plastic cover moist curing for 14 days followed by another 14 days drying in air (as under bullet 2 above) could equally be used as convenient. In the final, the finding confirms that, the proposed curing of ACEBs under shed within an air dry condition is a well suited proposition for the practice; since the competition doesn't affect its anticipated performance. As a recapitulation, since this research focused on a single type of soil so far a practical application future researches are encouraged to cover a wide range of soils.

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CONSTRUCTION SITE WASTES (NON-PHYSICAL) CATEGORIZATION IN ADDIS ABABA BASED ON LEAN CONCEPT

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ABSTRACT

Waste in the construction industry has been the subject of several research projects around the world in recent years. One of the effective methods of wastage reduction is the application of lean approach to construction industry. Lean construction is a result of the introduction of a new form of production management. In general, project managers tend to conceptualize "waste" as physical construction waste only, but there are noticeable wastes in the construction processes which are named "non-value adding activities" by lean construction theory. In addition to stressing on the physical waste, lean thinking specifically pays lots of attentions to the waste produced over a construction process. Waiting time, non-value adding (NVA) works and material transportations are categorized in this group.

This article is focused on categorizing construction site activities based on lean concept on selected six construction sites. These activities include rebar work for slab, formwork for column and concrete cast for slab. Video data collection method was mainly used to conduct the study. Video data collection required to be entered into spreadsheets so that the necessary tabular results could be generated. The results of the case studies showed that, a significant portion of crew working hours was spent on NVA activities. Among the NVA activities, waiting time took the largest share, indicating interruption of flow in the work process. The results of the study further pointed out that, time spent on non-value adding but required activities (NVAR), like temporary work and supporting activities can also be minimized by using better technologies (materials and equipment).

Keywords: Construction site waste, lean construction, lean thinking, non-value adding (NVA), non-value adding but required (NVAR) and value adding (VA).

INTRODUCTION

The construction industry in Ethiopia has been developing substantially over the last two decades. Recent studies indicated that the GDP contribution of the construction industry has been raised to 5.6% and approaches to the sub-Saharan average of 6% [1]. Despite the construction industry's significant contribution to the economy of developing countries and the critical role it plays in their countries development, the performance of the industry remains generally low [2]. However, in recent years, new construction technologies and methods have emerged. The newest methods of construction are expected to improve efficiency, performance and reduce construction waste [3].

LITERATURE REVIEW

It has been understood by many that construction industry has been suffering enormously from a serious drawback, which is "waste". During the past decades many researchers tried to categorize construction sites wastes in many ways. However, almost all of the researchers follow similar approach. Excess materials, delays, rework and defects are those waste commonly mentioned by researchers [4]. Another broader definition of waste is to include not only material waste but also waste generated in a construction project

such as waiting time, transportation time, and etc. [5]. This issue of non-physical waste within construction processes is the basis of waste concept from one of the innovative approaches called "lean construction", which was introduced to construction industry in the 1990s based on a successful manufacturing theory, i.e., lean production [6].

History of lean production

The term lean production was coined by Womack et al. to define the Japanese production system developed by Toyota Production System (TPS) [7]. The foundations of lean production were developed in post–World War II Japan, when the Japanese manufacturing industry underwent a complete rebuilding [8]. The TPS was inspired by Fords mass production system, but deeply deviated from it to suit the sociopolitical and economic reality in Japan after Second World War [7]. Unlike Ford, Toyota operated in a small country that was suffering from the devastating effects of the war [7, 9]. Toyota then made the strategic decision to focus its manufacturing efforts not on massive volumes of a product but, rather, on many different products in smaller volumes since it greatly reduced the carrying costs required for huge inventories, and the cost of rework was reduced because defects showed up instantly in smaller batches [8]. Toyota also managed to reduce the amount of time required for machine setup from an entire day to three minutes, a task that enabled Toyota to increase the flexibility of its production lines as well as reduce production times. Lean production, as the TPS, aims at maximizing customer value while minimizing waste [10, 11].

The five lean principles

In 1996, Womack and Jones presented a set of five principles (value, value stream, flow, pull, and perfection) that are present in a Lean system and they set these principles as Lean Thinking [12]. These are briefly summarized as follows.

a. Value

The first principle of lean thinking starts with specifying value to a customer. This implies identifying the client's needs and expectations of a product or service. As defined by Ohno, waste is anything that consumes resources but does not add value to the product or service from the clients' point of view. The counter part of value is waste [13]. Ohno identifies seven types of waste that can be found in a production process [10]. These seven types of waste are mentioned as follows;

- Overproduction or the production of items not required and which accumulate as inventory;
- Time on hand or waiting for inputs from other activities;
- Transportation of parts, materials or equipment;
- Over processing;
- Stock on hands or inventory;
- Unnecessary movement of workers and
- Producing defective products.

b. Value stream

The second lean thinking principle is to identify the value stream. The value stream is all the specified actions that are required to bring a specific product (a good, a service, or a combination of the two) from the conceptual stage until it is delivered to the final customer [14]. Value stream analysis shows three types of actions occurring along the value stream [15]. These are;

i. Value adding activities (VA): e.g., Assembling engine, tightening a bolt
ii. Necessary but not value adding (NVAR): e.g., Inspecting welds to ensure quality
iii. Non-value adding (NVA): e.g., Products, equipment or people that must wait because of poor scheduling or unbalanced crew size and unnecessary movement of materials.

c. Flow

The third principle in lean thinking is to create continuous flow of value creating steps. This is an important step in the whole process of implementing lean.

This step requires a new way of doing things which is completely different from traditional batch thinking [15]. The goal of flow principle is based on redefining the work of functions, departments, and firms so that they can make positive contribution to value creation and to speak to the real needs of employees at every point along the stream [13].

d. Pull production

The fourth lean thinking principle is to implement pull, i.e., trigger production based on actual demand and conditions. Toyota follows pull, this means production starts only after an order is placed by customer. Traditionally, each department or company optimizes their own processes or services to produce as much as they can, as fast as they can, and pushes their products or services downstream without considering what the customer really wants at the time of production or what the actual demand is [10, 12].

e. Perfection

The last principle used to implement Lean Thinking is to seek perfection, or kaizen, the Japanese term for continuous improvement, through a Plan-Do-Check-Act (PDCA) cycle [9]. According to Womack & Jones, the most important stimulus to perfection is transparency – making entire value stream visible to everyone; subcontractors, suppliers, assemblers, distributors, customers, and employees, all of them can see everything; making value stream visible in such a way, make it easier to discover ways to create value and prevent waste [13].

Lean in construction

Lean construction has been defined in several ways as the concept continues to evolve. [16] lean construction refers to the application and adaptation of the underlying concepts and techniques of lean production as a new philosophy of production for construction. The Construction Industry Institute (CII) has defined lean construction as "the continuous process of eliminating waste, meeting or exceeding all owner requirements, focusing on the entire value stream, and pursuing perfection in the execution of a constructed project" [17]. [18] described lean construction as "a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value for the customer (both internal and external)".

Lean Construction Elements and their benefits

Lean production has several tools and techniques that have evolved since the beginning of its application in the construction industry. Lean construction has been identified as trying to develop a list of the most prominent and exhaustive tools and techniques that are being implemented in today's construction industry and that might also impact performance practices. Some of the tools related to the topic of study are: TFV theory, last planner, just-in-time and lean project delivery system.

The implementation of such lean tools and techniques had significantly reduced waste and improved performance in construction projects [15]. [19] lean construction has identified several benefits when applying lean principles in construction which include; reduce sharing of non-value adding activities, increase the output value through systematic construction of customer requirement, reduce process variability, reduce cycle times, Simplify by minimizing the number of steps parts and linkages, increase output flexibility, increase process transparency, focus on complete process, build continuous implement into the process and balance flow improvement with conversion improvement and benchmarking.

Gap Identification

In Ethiopia, limited researches were conducted on construction site wastes. However, all the researches follow similar principle by focusing on physical (material) wastes generated on construction sites only [20, 21, 22]. So far, no clear attempt was made to incorporate wastes generated on construction project sites such as waiting time, transportation time, and unnecessary movement and so on.

This issue of non-physical waste within construction processes is the basis of waste concept from lean construction approach.

METHODOLOGY

In this research, a total of six case studies were conducted at six selected construction sites. The construction sites were selected based on the years of working experience and types of technologies (material and equipment) used by the companies. Video data collection method was mainly used to conduct the study. Video data collection required to be entered into spreadsheets so that the necessary tabular results could be generated using excels for each job.

Data Collection Procedure

Table 1; bellow is an example of one of the data sheets used for rebar work. After viewing the videos several times, it was required to use a stopwatch and a data sheet.

ANALYSIS AND DISCUSSION

In this part the selected construction site activities were identified, categorized and discussed in detail based on lean concepts. Two cases focus on rebars work for slab, two cases focus on formwork for column work and the remaining two consecutive cases focus on concrete work for slab.

Case Study No.1 and No.2: (reinforcement bar work for slab)

Case Study No.1

The project was for one of Addis Ababa's sub-city G+7 office buildings. The total built up area of the building is 627 m^2. Rebar work is highly repetitive by nature; subsequently rebar work for 145.69 m^2 was only observed. Eight workers were engaged for placing 2,552.34 kg-diameter 10 mm Bar. The reinforcement bars were cu and bent on construction site and delivered to actual working site by using both tower crane and rebar workers.

Table 1:Data analyzing sheet

Name of the company, A						
Field classification sheet 1				***Case study No 1***		
Person or Equipment entire group cycle time				***Date 2/29/19 (Day One)***		
No	**Worker**	**Member classification**	**Activity**	**Time at activity**	**Activity classification**	***Waste classification***
1	Rebar worker one	Rebar for slab	Adjusting rebar position	00:00:21	NVAR	Material positioning
2	Rebar worker one	Rebar for slab	Checking rebar alignment	00:01:20	NVAR	In-process Inspection
3	Rebar worker one	Rebar for slab	Cutting and tying steel wire	00:01:49	VA	Value adding
4	Rebar worker one	Rebar for slab	Rework	00:00:59	NVA	Extra processing

Subcategories of activities based on lean concept

In general terms, inefficiencies are classified as one of three types: inefficiency due to waste (NVA activities), inefficiency due to work that does not directly contribute value to the work (NVAR activities) and inefficiency due to poorly designed work processes (ineffective VA activities) [9]. Table 2 shows inefficiencies due to VA, NVA and NVAR activities.

The reinforcement bars were stored on site; as a result, some of the rebar workers were arranging the reinforcement bars according to their size. Time spent by workers on such activities were considered as being an inventory related activity i.e., NVA. The summary of each crew member's activity along with waste classification and actual time spent on VA, NVAR and NVA activities are shown on Table 3 along with Chart 1.

Table 2: Inefficiencies due to VA, NVA and NVAR activities

Activity classification	Description	Example
Value adding (VA)	Any activity that changes the shape, form, or function of materials or information to meet customer's needs.	Assembling engine, tightening a bolt, casting concrete
Non-value adding but required (NVAR)	Activities that are required for construction operations yet have no permanent effect on the finished product.	Material positioning,
		In-process inspection,
		Temporary work and support activities (TWSA)
Non-value adding NVA (Waste)	Anything that takes time, resources or space but does not add value to the product or service delivered to the customer	Overproduction
		Waiting
		Unnecessary Transport
		Extra Processing (Rework, re-handling or defects)
		Inventory
		Motion
		Defects

Table 3: Typical result for rebar crew completing rebar work for slab section (case 1)

Activity classification	*Waste classification*	*Worker No 1*	*Worker No2*	*Worker No 3*	*Worker No4*	*Worker No 5*	*Worker No 6*	*Worker No 7*	*Worker No 8*
VA	***Value adding***	02:34:45	02:22:09	01:40:48	03:23:09	03:51:51	00:49:06	01:15:28	00:31:01
VA Total		02:34:45	02:22:09	01:40:48	03:23:09	03:51:51	00:49:06	01:15:28	00:31:01
NVAR	***In-process inspection***	01:02:11	00:10:14	00:06:18	00:57:48	00:15:51	00:27:52	00:53:58	00:06:25
	Material positioning	01:32:58	01:04:28	00:56:14	02:09:14	02:00:24	00:37:38	00:52:04	00:15:43
NVAR Total		02:35:09	01:14:42	01:02:32	03:07:02	02:16:15	01:05:30	01:46:02	00:22:08
NVA	***Waiting***	01:54:45	00:47:35	01:00:25	01:19:56	0:57:18	00:29:00	00:47:08	00:07:07
	Transport	01:36:12	00:06:18	00:40:05	01:30:57	01:22:37	00:14:28	00:26:53	00:12:10
	Extra processing	00:22:06	00:28:50	00:20:30	00:44:50	00:45:21	00:09:06	00:14:50	00:15:01
	Inventory	00:38:00	00:02:48	00:14:32	01:43:37	01:08:24	00:00:00	00:50:35	00:00:00
	Motion	00:42:33	00:17:10	00:33:24	00:25:31	01:23:53	00:13:08	00:34:22	00:18:21
	Defect	00:02:52	00:00:00	00:00:00	0:08:38	00:08:34	00:00:00	00:00:20	00:00:00
NVA Total		04:16:28	01:42:41	02:48:56	05:53:29	05:46:07	01:05:42	02:54:08	00:52:39
Grand Total		09:26:22	05:19:32	05:32:16	12:23:40	11:54:13	03:00:18	05:55:38	01:45:48

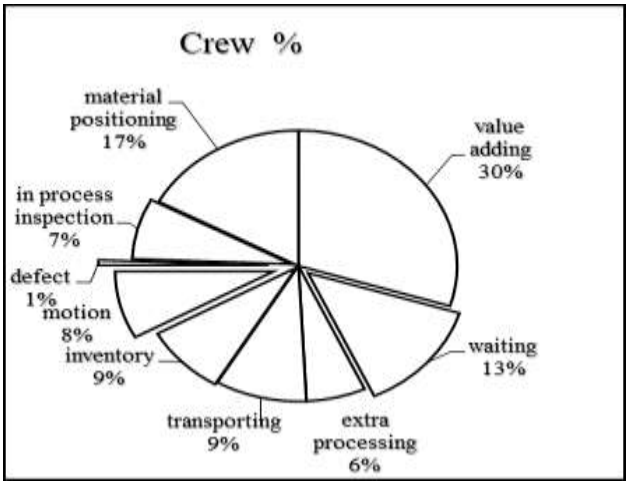

Chart 1: Typical result for rebar crew completing rebar work for slab section (case1)

The weighted average crew result shows that 30% of the working hours per slab section were spent on value adding (VA) activities, 24% of the working hours per slab section were spent on NVAR and the rest 46% was spent on NVA activities. Among the NVA activities waiting time took the largest share by holding 13%, this was due to waiting for delivery of reinforcement bar to site and waiting until inspections are performed by the resident engineer. Another 9% of the NVA was spent on unnecessary transportation of heavy weight reinforcement bars. Furthermore, 9% of the NVA was spent on sorting the reinforcement bars stored (inventory) on site

according to their respective sizes. Additional 8% of the NVA was spent on unnecessary movement of the workers due to poor site layout. Another 6% of the NVA was due to extra processing which includes rework. Among the NVAR activities 17% was spent on positioning bottom and top bars and adjusting rebar positions, while the rest 7% was spent by inspection, measuring and marking rebar.

Case Study No.2

The project was a 1B +G+8 building for office purpose. The total built up area of the building is 504 m^2. However, rebar work associated with 98.45 m^2 was only observed for this research, following repetitive nature of the work. Eight workers were involved in order to place 2,320.06 kg-diameter 10mm bars. The reinforcement bars were cut and bent on the company's workshop, which is located outside the construction site and delivered to actual working site when needed in the amount needed. After being delivered to construction site, the reinforcement bars were transported to the actual working site by using both tower crane and rebar workers. The summary of each crew member's activity along with waste classification and actual time spent on VA, NVAR and NVA activities are presented on Table 4 and Chart2.

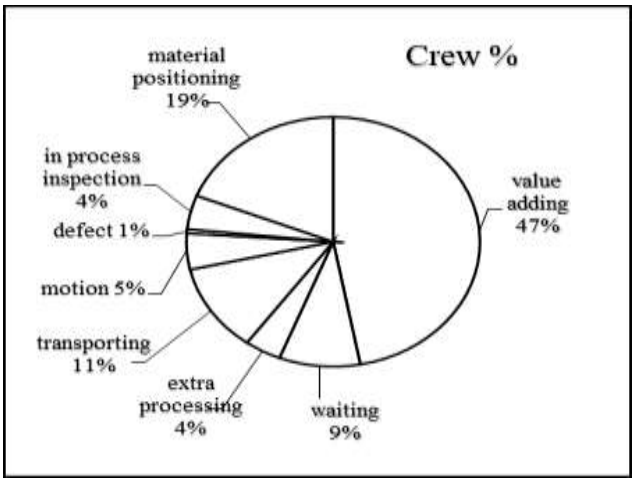

Chart 2: Typical result for rebar crew completing rebar work for slab section (case2).

The weighted average crew result shows that 47% of the working time was spent on VA activities, 23% of the working hours were spent on NVAR and the rest 30% was spent on NVA activities. Amongst the 30% of the NVA activities, 9% of the time was spent on waiting for inspection and delivery of materials; this also took a prime share among the others.

Table 4: Typical result for rebar crew completing rebar work for slab section (case 2)

Activity classification	*Waste classification*	*Worker No 1*	*Worker No2*	*Worker No 3*	*Worker No4*	*Worker No 5*	*Worker No 6*	*Worker No 7*	*Worker No 8*
VA	***Value adding***	01:32:55	01:54:18	01:40:56	01:04:15	01:20:28	01:31:15	01:35:42	01:32:27
VA Total		01:32:55	01:54:18	01:40:56	01:04:15	01:20:28	01:31:15	01:35:42	01:32:27
NVAR	***In-process inspection***	00:16:14	00:07:59	00:04:33	00:14:23	00:02:00	00:05:48	00:16:27	0:00:59
	Material positioning	00:25:25	00:21:17	00:32:19	00:46:47	00:50:45	00:43:44	00:31:53	00:43:09
NVAR Total		00:41:39	00:29:16	00:36:52	01:01:10	00:52:45	00:49:32	00:48:20	00:44:08
NVA	***Waiting***	00:14:58	00:20:01	00:17:55	00:28:59	00:12:07	00:14:08	00:14:18	00:16:27
	Transport	00:35:45	00:20:40	00:26:51	00:25:05	00:15:05	00:18:19	00:18:37	00:17:26
	Extra processing	00:11:20	00:05:53	00:03:08	00:06:35	00:13:05	00:02:49	00:03:37	00:16:21
	Inventory	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	0:00:00
	Motion	00:13:52	00:10:30	00:06:45	00:10:24	00:07:59	00:13:39	00:03:51	00:05:53
	Defect	00:00:49	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:03:36	00:04:00
NVA Total		01:16:44	00:57:04	00:54:39	01:11:03	00:48:16	00:48:55	00:43:59	01:00:07
Grand Total		03:31:18	03:20:38	03:12:27	03:16:28	03:01:29	03:09:42	03:08:01	03:16:42

Another 11% of the NVA was spent on unnecessary transportation of heavy weight reinforcement bars by the workers. In addition, 5% of the NVA was spent on unnecessary movement of the workers. The rest, 4% of NVA was spent on extra processing i.e., rework. Among NVAR activities material positioning including positioning bottom and top bars and adjusting rebar's position took 19%, while the rest 4% of NVAR was spent on in-process inspection i.e., inspection, measuring and marking bars.

Discussion on rebar work cases (case study No.1 and No.2)

Rebar crew at case study No.2 performed 17% more on VA activities as opposed to case study No.1. In addition, company at case study No.2 saved 8% of the working time spent on inventory related activities by separating the rebar bending and cutting place from the actual construction site, this as a result, also reduced waste associated with unnecessary movement of workers. On the other hand, in both companies, waiting time for inspection and delivery of materials took considerable amount of time; implying an interruption of flow in the work process.

Case study No.3 and No.4: (formwork for Column)

Case Study No.3

The project was a G+8 building for multi-use purpose. The total built up area of the building is 600 m^2. During the time of conducting the case study the building reached 2nd floor. There are a total of 30 columns in the floor, however 8 columns with a size of (600mm × 600mm) were only observed for this study. The company used plywood for formwork preparation. Eight carpenters were observed, during preparing the formworks. The summary of each crew members' activity along with waste classification and actual time spent on VA, NVAR and NVA activities are shown on Table 5 and on Chart 3.

Table 5: Typical result for carpenter crew each completing formwork for column(case3)

Activity classification	*Waste classification*	*Carp No.1*	*Carp No.2*	*Carp No.3*	*Carp No.4*	*Carp No.5*	*Carp No.6*	*Carp No.7*	*Carp No. 8*
NVAR	***In-process inspection***	00:07:08	00:11:26	00:20:07	00:05:25	00:08:40	00:31:03	00:17:10	00:12:59
	Material positioning	00:50:55	00:51:28	00:35:54	00:50:43	00:36:05	00:48:13	00:55:56	00:50:11
	TWSA	01:15:17	01:27:25	00:59:51	01:06:12	01:08:34	01:00:40	01:09:00	01:05:15
NVAR Total		02:13:20	02:30:19	01:55:52	02:02:20	01:53:19	02:19:56	02:22:06	02:08:25
NVA	***Waiting***	01:03:38	00:46:32	01:05:55	01:07:50	00:42:03	00:27:40	01:01:25	01:07:03
	Transport	00:00:00	00:00:00	00:06:36	00:02:16	00:00:00	00:04:52	00:05:00	00:00:00
	Extra processing	00:07:41	00:13:43	00:17:08	00:09:03	00:02:18	00:00:50	00:15:32	00:17:59
	Motion	00:00:00	00:00:00	00:00:00	00:00:00	00:14:41	00:00:00	00:12:47	00:18:13
	Defect	00:01:10	00:00:13	00:02:07	00:04:48	00:01:34	00:00:00	00:07:01	00:11:13
NVA Total		01:12:29	01:00:28	01:31:46	01:23:57	01:00:36	00:33:22	01:41:45	01:54:28
Grand Total		03:25:49	03:30:47	03:27:38	03:25:28	02:53:55	02:53:18	04:03:51	04:02:53

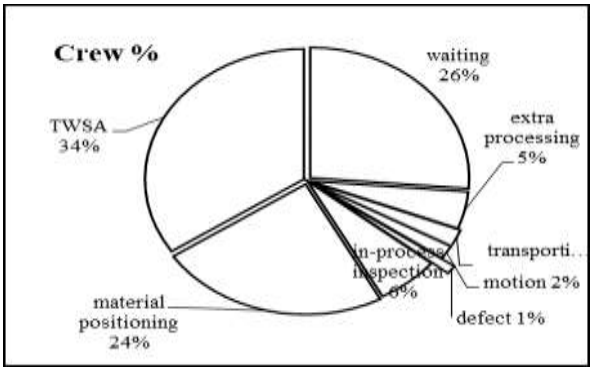

Chart 3: Typical result for carpenter crew each completing formwork for column (case 3).

According to the carpenters' crew result, 64% of the working hours per column were spent on NVAR activities. Among this temporary work and supporting activities (TWSA) took 34%, these activities include; erecting formwork and nailing horizontal and diagonal support. The other 24% of the NVAR was spent on material positioning i.e., positioning horizontal, vertical and diagonal support. The rest 6% of the NVAR was spent on in-process inspection i.e., plumbing and leveling, checking rebar alignment and by measuring and marking. On the other hand, NVA activities took 36% while waiting time consumed 26% of the working time; this was due to waiting for delivery of materials on site and waiting until the rebar crew complete their work. The fact that the plywood formworks were re-used several times, the carpenter crew was fixing defective formworks, this activity took 5%.

There were 38 columns on the floor, however 8 columns of (600mm×600mm) size were only observed for this study. The formworks used for the columns were modular type delivered from

Italy and are assembled on site. The summary of each crew's activity along with waste classification and actual time spent on VA, NVAR and NVA activities are shown on Table 6 and on chart 4.

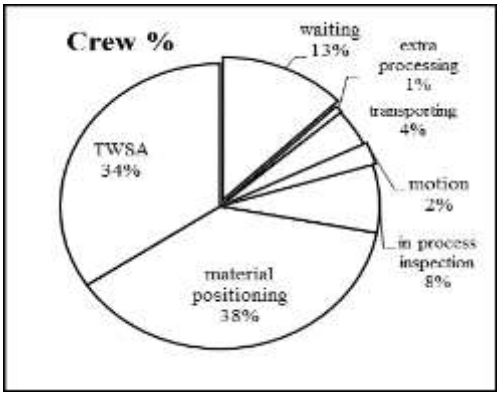

Chart 4: Typical result for carpenter crew completing formwork for column (case 4).

Table 6: Typical result for carpenter crew each completing formwork for column (case 4)

Activity classification	*Waste classification*	*Carp No.1*	*Carp No.2*	*Carp No.3*	*Carp No.4*	*Carp No.5*	*Carp No.6*	*Carp No.7*	*Carp No. 8*
NVAR	***In-process inspection***	00:10:40	00:06:21	00:03:58	00:03:25	00:12:38	00:11:36	00:13:22	00:16:29
	Material positioning	00:48:56	00:38:44	01:01:50	01:04:41	00:44:18	00:42:30	00:49:12	00:33:23
	TWSA	00:39:01	00:37:15	00:42:07	00:37:58	00:55:11	00:50:43	00:47:48	00:39:37
NVAR Total		01:38:37	01:22:20	01:47:55	01:46:04	01:52:07	01:44:49	01:50:22	01:29:29
NVA	***Waiting***	00:14:48	00:18:53	00:11:32	00:15:24	00:13:28	00:17:13	00:17:29	00:21:47
	Transport	00:00:00	0:14:32	00:03:45	00:07:14	00:00:00	00:01:29	00:11:50	00:03:45
	Extra processing	00:00:00	00:00:00	00:18:19	00:02:22	00:00:00	00:00:00	00:02:22	00:00:25
	Motion	00:02:15	00:00:43	00:00:00	00:02:33	00:06:43	00:08:03	00:02:47	00:02:33
	Defect	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00
NVA Total		00:17:03	00:34:08	00:18:19	00:27:33	00:20:11	00:26:45	00:34:18	00:28:30
Grand Total		01:55:40	01:56:28	02:06:14	02:13:37	02:12:18	02:11:34	02:24:40	01:57:59

Case study No.4

The project was a 2B+G+8 building for apartment use. The total built up area of the building is 1070 m^2. There were two sections in the building, the case study focused on one of the sections. The selected section has a total area of 507 m^2. The building reached 4th floor when the study was conducted.

The weighted average crew results show that 80% of the carpenters working hour per column was spent on NVAR activities while the rest 20% was spent on NVA activities. Among NVAR activities, material poisoning took 38%, these activities comprise of positioning the pins, wedge, zinc-coated distancing steel bars and props and adjusting

formwork position. The other 34% of the NVAR was spent on TWSA, which includes; erecting formwork, locking formwork with pins and wedges, locking formwork with head arresters and tying timber support with wire.

The rest 8% of NVAR activities was spent on in-process inspection including checking for formwork alignment. Among NVA activities 13% was spent by transporting formworks to working site and waiting for confirmation order. While the rest 4% and 2% respectively were spent by unnecessary transportation and movement of workers. Due to the use of good quality of formwork (segmental formworks), defective work and rework was only 1%.

Discussion on formwork for column cases (case 3 and case 4)

The different mechanisms and materials used by the two companies showed an insight on how working hours spent on temporarily built and supporting activities (NVAR) can be shortened. Due to modular type of formwork used on case study No.4, working hours spent by the carpenter crew was less compared to case study No.3. Waiting time of carpenter crew at case study No. 4 was also 12% less, due to the same reason.

Furthermore, on case study No. 4, the probability of making defective works and reworks were almost none, owing to segmental formworks used, while on case study No.3, due to the regular reuse of plywood formworks, the probability of making defective work was 4% more.

Case study No.5 and No.6 :(Concrete work for slab)

Case study No.5

The project was in one of the renowned universities in Addis Ababa.

The project has five ongoing buildings for different uses. The case study focused on one of the buildings being constructed for students' laboratory purpose. It's a 3B+G+5 building with a total built up area of 457. 15m^2. Nevertheless, concrete work for slab work associated with 106.06 m^2 was only observed for this study. The company used ready mix concrete, delivered to site by mixing trucks, after then the concrete was placed through trailer pumps (small general pumps). There were 29 workers involved for placing concrete. Among the 29 workers, 9 of them were carrying concrete pipes hoses attached to the end and were placing concrete. Two crew each having 8 and 6 workers were placing concrete using shovel, the rest 6 masons were vibrating and finishing concrete. The summary of each crew member's activity along with waste classification are shown on Table 7.

Table 7: Typical result for entire crew completing concrete work for slab section in % (case 5)

Activity classification	*Waste classification*	*Concrete transporting crew*	*Concrete placing crew 1*	*Concrete placing crew2*	*Concrete vibrating and finishing (mason crew)*
VA	*Value adding*	0.00%	27.35%	37.48%	26.94%
VA Total		**0.00%**	**27.35%**	**37.48%**	**26.94%**
NVAR	*In- process inspection*	0.00%	0.00%	0.00%	4.11%
	Material positioning	17.57%	0.00%	0.00%	0.00%
NVAR Total		**17.57%**	**0.00%**	**0.00%**	**4.11%**
NVA (waste)	*Waiting*	27.94%	65.83%	59.14%	55.37%
	Transport	54.49%	0.00%	0.00%	0.00%
	Extra processing	0.00%	0.00%	0.00%	3.88%
	Motion	0.00%	6.82%	3.38%	9.70%
	Defect	0.00%	0.00%	0.00%	0.00%
NVA Total		**82.43%**	**72.65%**	**62.52%**	**68.95%**
Grand Total		100%	100%	100%	100%

The transporting crew spent 54.49% of the working hours per slab section on unnecessary transportation of concrete by carrying heavy weight concrete pipe hoses attached to the end. Another 17.57% was spent on adjusting concrete placing pipe's position, while the rest

27.94 % was spent on waiting until an empty concrete mixing truck was replaced by another loaded mixing trucks. Concrete placing crew No.1 spent only 27.35% on value adding activities i.e., by placing concrete using shovels while 72.65% was spent on NVA i.e., waiting until concrete was transported to site and until concrete pipe's position was adjusted.

hose attached to the boom ends with the aid of the remote-control guy, while 2 workers were placing concrete using shovels, and the rest 5 masons were vibrating and finishing concrete. The summary of the entire crews' activities along waste classification are shown on Table 8.

Table 8: Typical result for entire crew completing concrete work for slab section (case 6)

Activity classification	**Waste classification**	**Concrete placing crew No. 1**	**Concrete placing crew No.2**	**Concrete vibrating and finishing (mason crew)**
VA	**Value adding**	64.12%	67.69%	58.10%
VA Total		**64.12%**	**67.69%**	58.10%
NVAR	**In process inspection**	0.00%	0.00%	0.00%
	Material positioning	0.00%	0.00%	0.00%
NVAR Total		**0.00%**	**0.00%**	**0.00%**
NVA (waste)	**Waiting**	35.88%	32.31%	41.90%
NVA Total		**35.88%**	**32.31%**	**41.90%**
Grand Total		**100%**	**100%**	**100%**

The rest 6.82% was spent on unnecessary movement of the workers. On the other hand, the concrete placing crew No.2 spent 37.48% by VA i.e., placing concrete using shovels, while the rest 62.52% was spent on NVA activities such as waiting until concrete was transported to site and until concrete pipe's position was adjusted. The rest 3.38% was spent on unnecessary movement of the workers. The mason crew spent only 26.94% on VA activities i.e., vibrating and finishing concrete, while 55.37% was spent NVA activities such as waiting until concrete was placed by concrete placing crew, and the rest 9.70% was spent on unnecessary movement of the masons.

Case study No.6

The project was a B +G+10 office building for one of the construction companies in Addis Ababa. The total built up area of the building is 552.15 m^2. However, concrete work for a slab associated with 134.52 m^2 was only observed for this study. The company used ready mix concrete and the concrete was placed by a means of power boom (remote pedestal booms). Only 9 workers were involved for placing concrete. Among the 9 workers, 2 of them were placing concrete by adjusting the

Concrete placing crew No.1 spent 64.12% of the working time on VA activities while the rest 35.88% was spent on waiting until the pedestal boom change position and until the empty trucks are replaced by loaded trucks. Concrete placing crew No.2 on the other hand spent 67.69% on VA activities while the rest 32.31% was spent on waiting until the crew1 finish placing concrete. The mason crew spent 58.55% on VA activities by vibrating and finishing concrete while the rest 41.25% was spent on waiting until the concrete placing crew finish placing concrete.

Discussion on concrete work for slab cases (case 5 and case 6)

Concrete work case studies result showed that, methodologies used by case study No.6 acquired less time and number of workers than on case study No.5. On case study No.6 all the 9 workers were adding value to the work process while on case study No.5, among 29 workers only 20 workers were adding value to the work process. On case study No.5 waiting time of the concrete placing crew was twice more than it was on case study No.6, this was due to an interruption of flow in the work

process due to various reasons i.e., waiting until vibrators are fixed, waiting until empty mixing trucks are replaced by loaded trucks and waiting until concrete pipes' positions are adjusted. Furthermore, on case study No. 5 significant amount of time was spent by workers, by pointlessly transporting concrete by means of carrying the heavy weight hose attached to concrete pipe ends of the trailer pump. However, on case study No.6, no time was spent on unnecessary transportation (NVA) of concrete by workers, due remote pedestal booms used for placing concrete.

Summary of the discussion

The result of this study pointed out that, the observed construction companies viewed construction site wastes in physical terms only and paid a lot of attention to material wastes generated on site. On the contrary, non-physical wastes which were generated on the construction sites such as waiting time, unnecessary transportation, unnecessary movement and defective works, which are named non-value adding activities by lean construction theory, were not given attention. Among these non-physical wastes, waiting time took significant portion of time; this is due to lack of organization in the work process, late delivery of materials and unnecessary allocation of laborers. Furthermore, in almost all of the case studies conducted, unnecessary transportation of construction materials to site by workers was also very common. Unnecessary movement of the workers like smoking, drinking and chatting with colleagues was also considerably observed in all of the case studies.

CONCLUSIONS

Based on the discussions made earlier, the following conclusions are drawn;

1. In all case studies conducted, working times spent on NVA activities took considerable amount of time. In addition, among the NVA activities, waiting time took the top share; indicating an interruption of flow in work process.
2. On the rebar work cases, the company at case study No.2 saved 8% of the working hours spent on arranging and categorizing reinforcement bars on site, by separating the rebar bending and cutting place from the actual construction site.
3. Waiting time of carpenter crew at case study No. 4 was 12% less as compared to case study No.3, due to readily available modular formworks. In addition, on case study No 4, the probability of making defective works and reworks were almost none, while on case study No. 3 due to continuous reuse of plywood formworks, time spent on rework reached 5%.
4. On the concrete work for slab cases, due to well -planned and organized crew on case study No.6, there was less waiting time and less interruption of flow in the work process. In addition, the company avoided unnecessary transportation (NVA) of concrete, by using remote pedestal booms for placing concrete. This in addition, reduced unnecessary movement of workers. NVAR activates like adjusting and changing concrete pipes position were also avoided due to the same reason.

RECOMMENDATIONS

1. The study strongly believes that, construction companies should take the first steps in understanding non- physical wastes; (overproduction, waiting time, transportation, over-processing, inventories, movement and making defective products) existing on construction sites, in order to maximize value to customers and minimize cost.

2. In order to avoid waiting time in the work process, the flow should carefully be planned starting from inception to completion and any interruption of flow in the work process should be avoided as much as possible.

3. Site layouts and working spaces should as well be planned to reduce wastes arising out of unnecessary transportation and movements of the workers. In addition, unnecessary transportation (NVA) of heavy weight materials like

reinforcement bar and formworks by workers should be reduced as much as possible, by using the available machineries and equipment efficiently.

4. Time spent on NVAR activities like temporary work and supporting activities (formwork) should be minimized by using better technologies (materials and equipment), in addition associated NVA activities like waiting time, defective works and re-works can also be minimized.

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DEVELOPING A MATHEMATICAL TOOL TO ANALYZE PUBLIC TRANSPORT CAPACITY OF ADDIS ABABA CITY

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ABSTRACT

Transportation is a crucial aspect for people living at different life standards in different areas at different times. The necessity for transportation usually is for satisfying one's life targets. The way of moving from place to place varies from rural areas to urban areas. Transportation in urban areas is too complex to that of rural once.

This study aims at developing a mathematical tool to analyze public transport capacity of Addis Ababa, the capital city of Ethiopia. Understanding the approach how to estimate the public transport capacity of the city is of great importance in planning the public transport for the future. There exist many case reports reflecting different cities suffering from insufficient transport for the habitants and visitors. Having clear understanding of existing public transport capacity, hence, is helpful to allocate options to improve its performance. There exist a variety of urban public transport service providers in Addis Ababa, such as the Light Rail of the city, Anbessa city Bus, Sheger Bus, Higer bus, Taxis, and different types of midi buses.

Keywords: Mathematical tool, Public transport, Transport capacity, Transportation.

INTRODUCTION

The probability of the public to get means of transport depends on many factors such as the population size, the number or amount of available vehicles and their capacity [1]. The capacity and efficiency of public transport differs from country to country and also city to city having better standards at developed countries and low standards at developing ones. This generally is because of the direct relation between quantity & quality of transport facilities with level of economy [2].

In developing countries, increased population growth and urbanization have led to several transport problems [5]. Mass transport in these countries is essential especially for the urban poor who have to rely on walking, cycling, and road-based public transport to meet most of their travel needs. Mainly buses provide urban mass transport and competition of service providers assures the efficient supply of mass transport services [5]. In the last decades, urban areas have experienced an increasing expansion resulting in several socio-economic problems.

These include unequal spatial urban development, a high pressure on non-refundable infrastructure, land and housing shortages, and, to high degree, lack of urban services.

These problems, in addition to low income and unemployment, eject poorer people to urban peripheries where housing costs are lower. But these peripheries are diploid of public services and increase the cost of providing urban infrastructure. Public transport, in particular, planned to operate in more density populated areas, offer a lower frequency and quality service, due in part to larger distances and unstable road system [1].

Unorganized urban expansion leads to an unorganized and irrational transport system in which superimposition of routes is one of its characteristics. In addition, municipal system if not centrally coordinated results in superimposition and low coordination of routes and irrationality of the whole system Urban expansion bring planning difficulties. But people require in each area an adequate public transport that allows easy moves to work, shopping, educational, health, and cultural centers [1].

Thus, an urban public transport system needs to assure mobility and accessibility through a fast, secure, regular, and trustable transport at a reasonable cost. Unfortunately it is not easy to assure all these characteristics due to complex institutional arrangements between state and several municipalities. Thus, a first step consists of working an agreement among all political institutions involved [1].

Transport is a catalytic force, both as an agent vital for economic growth and as an agent for economic decline where economic resources and conditions, as well as human endeavor, are insufficient. In this vein, efficient transportation should be seen as a factor that unifies the entire economy, which facilitates development [2]. A well-functioning transport system helps to maximize economic growth (progress) of cities [3]. Urban mass transport continues to be a high priority social obligation of governments throughout the world and, in some jurisdictions, it is the prime responsibility of national governments, while in other localities, it is a state or local government responsibility [4].

Mass transport in developing countries is essential for the urban poor who have to rely on walking, cycling, and road-based public transport to meet most of their travel needs. Mainly buses provide urban mass transport and competition guarantees the efficient supply of mass transport services [5].

Transport capacity deals with the movement of both people and vehicles. It is defined as the number of people that can be carried in a given time period under specified operating conditions without unreasonable delay or hazard and with reasonable certainty [6]. Capacity is a technical concept that is of considerable interest to operators, planners and service designers.

There are two useful capacity concepts stationary capacity and flow capacity. Scheduled transport services are characterized by customer waiting at boarding areas and traveling in discrete vehicles along determined paths. The waiting area and the vehicle itself each have a stationary capacity measured in persons per unit of area. Transportation services also have a flow capacity which is the number of passengers that can be transported across a point of the transportation system per unit of time. While this is usually thought of as the number of total customers per transit line per direction per hour, flow capacity can be measured for other elements of the system including corridors, fare turnstiles, stairs, elevators and escalators [7].

The key factors which influence capacity include the type of right-of-way, the number of movement channels available, the minimum possible headway or time spacing between successive transportation vehicles, obstacles to movement along the transport line such as complex street intersections and "flat" rail junctions, the maximum number of vehicles per transport unit, operating practices of the transport agency pertaining to service frequencies and passenger loading standards, and long dwell times at busy stops resulting from concentrated passenger boarding and alighting, on-vehicle fare collection and limited door space on vehicles [7].

One of the most important capacity considerations is to distinguish between maximum theoretical or crush capacity and practical operating capacity, also called schedule design capacity). A transit vehicle may have an absolute "maximum" capacity usually referred to as the crush load. This commonly is the capacity cited by vehicle manufacturers. The absolute capacity assumes that all space within the vehicle is loaded uniformly at a specified passenger density and that occupancy is uniform across all vehicles throughout the peak period, a condition that rarely happens in practice.

Similarly a rail line or a bus system operating in an exclusive right of way may have a theoretical minimum headway (time between two successive vehicles) based on station dwell times, vehicle propulsion characteristics and safety margins. From these characteristics, the theoretical maximum capacity measured as vehicles per hour per direction can be determined. However, random variations in dwell times caused by such things as diminished boarding and alighting flow rates on crowded trains, reduces the maximum or theoretical line capacity [7].

Operation at maximum capacity strains the system and should be avoided. They result in serious overcrowding and poor reliability. Therefore, scheduled design capacities should be used. This capacity metric takes into consideration spatial and temporal variation and still results in some but not all transit vehicles operating at crush capacity [7].

Further, the arriving patterns of passengers and vehicles at transit stops during peak periods may result in some vehicles having lower than capacity loads particularly if there is irregularity in the gap between successive arriving vehicles. Finally, there can be a "diversity of loading" for parts of individual

vehicles (e.g., in partial low-floor LRT vehicles or buses with internal steps) and among vehicles in multi-vehicle consists such as heavy rail trains [7].

BACKGROUND

In Ethiopia, the need of public transport is highly increasing both in rural and urban areas. Many are losing their valuable time and business due to shortage of transport to jobs. This time, looking peoples making lines waiting for busses or taxis becomes somewhat familiar, especially in the capital city Addis Ababa.

The city covers total area of around 540 square kilometers. Its current population is above 4.5 million. Public transport in the city mainly consists of conventional bus services provided by the publicly owned Anbessa City Bus and Public Service Employees Transport Service Enterprises, Alliance Transport Service Share Company, Midi-buses and Taxis operated by the private sector. [8].The leading purposes of trip in the city are Work and education. The road network of Addis Ababa is limited in extent and right of way. Its capacity is low, on-street parking is prevalent, and the pavement condition is deteriorating. Despite a large volume of pedestrians, there are no walkways over a large length (63%) of the roadway network.

This is a major concern because it contributes to the increased pedestrian involvement in traffic accidents (10,189 accidents occurred in 2004 E.C. [9].

Research Questions

At the end this research paper answers the following basic questions.

1. What are the main factors on which capacity of public transportation in Addis Ababa depends?
2. How can the capacity be calculated depending on these factors?

Research Objective

Having clear knowledge about the approach how to determine the public transport capacity will help the concerned government officials and transportation professionals to apply strategies for maximizing the existing capacity and improve the service so that it will fit to the daily demand. The main goals behind this paper are:

1. To identify the different factors on which the public transport capacity of Addis Ababa depends.
2. To develop a mathematical tool that can be used to determine the operating public transport capacity for Addis Ababa.

LITERATURE REVIEW

Public Transport Generals

The basic purpose of any urban public transit system is to carry people as efficiently and effectively as possible. However, defining the aims of a transit system in more detail is not easy [11].

A public transport system has two basic objectives that it is expected to achieve simultaneously to serve the public interest and to be profitable. However, the two objectives can sometimes be in conflict.

In such cases, the policy must focus either on the public interest or on profitability [11].

The general worldwide trend has been for urban public transit systems to take the public interest approach. This has helped maintain public transit systems that offer relatively low fares and generate large networks [11]. The public transport operators always work hard to improve the status of their service in order to maximize the satisfaction of their public while satisfaction of the public depends on different factors such as: the population size, service efficiency, service quality, the number and type of available vehicles and their capacity.

The capacity and efficiency of public transport differs from country to country and also city to city having better standards at developed countries and low standards at developing ones. This generally is because of the direct relationship between quantity & quality of transport facilities and level of economy. In developing countries, increased population growth and urbanization have led to several transport problems. Mass transport in these countries is essential especially for the urban poor who have to rely on walking, cycling, and road-based public transport to meet most of their travel need. In these countries buses are the main urban mass transport providers and competition guarantees the efficient supply of mass transport services.

Public Transport Capacity

Transport capacity is different than highway capacity: it deals with the movement of both people and vehicles; depends on the size of the transport vehicles and how often they operate; and reflects the interaction between passenger traffic concentrations and vehicle flow [6].

Capacity is a technical concept that is of considerable interest to operators, planners and service designers. There are two useful capacity concepts – stationary capacity and flow capacity [7]. Scheduled transit services are characterized by customer waiting at boarding areas and traveling in discrete vehicles along predetermined paths. The waiting area and the vehicle itself each have a stationary capacity measured in persons per unit of area. Transit services also have a flow capacity which is the number of passengers that can be transported across a point of the transportation system per unit of time. While this is usually thought of as the number of total customers per transit line per direction per hour, flow capacity can be measured for other elements of the system including corridors, fare turnstiles, stairs, elevators and escalators [7].

PERSON CAPACITY

At the simplest level, transport capacity is determined by the product of transport vehicle capacity and the maximum frequency with which transit vehicles can pass a given location [6]. The person capacity or passenger-carrying capability for any given transit route can be defined as “the maximum number of people that can be carried past a given location during a given time period under specified operating conditions without unreasonable delay, hazard, or restriction, and with reasonable certainty [6].

More specifically, person capacity depends on the mix of vehicles in the traffic stream, including the number and occupancy of each type of vehicle that can reasonably be expected to pass a point on a transit route. It is a function of vehicle size, type, occupancy, and headway. The number of transit vehicles along a route reflects the degree of scheduled service [6].

TRANSPORT LINE CAPACITY

The passenger capacity of a transport line is the product of the number of vehicles per hour (usually past the busiest stop) and the number of passengers that each vehicle can carry [6].The following four basic factors determines the maximum passenger capacity [6]: Maximum number of vehicles per transport unit (bus, car, train);
Passenger capacity of individual vehicles; the minimum possible headway or time spacing between individual vehicles; and, The number of lanes or passenger loading positions available.

Factors that affect Transport Capacity

The key factors which determine transport capacity are the following [7]:

- ✓ The type of right-of-way (interrupted flows vs. uninterrupted flows),
- ✓ The number of movement channels available (lanes, tracks, loading positions, etc.),
- ✓ The minimum possible headway or time spacing between successive vehicles,
- ✓ Impediments to movement along the transport line such as complex street intersections and "flat" rail junctions,
- ✓ The maximum number of vehicles per transport unit (buses or rail cars),
- ✓ Operating practices of the transport agency pertaining to service frequencies and passenger loading standards, and
- ✓ Long dwell times at busy stops resulting from concentrated passenger boarding and alighting, on-vehicle fare collection and limited door space on vehicles.

Here under are factors determining transport capacity [6]:

Vehicle Characteristics

Right-of-Way Characteristics

Stop Characteristics

Operating Characteristics

Passenger Traffic Characteristics

Street Traffic Characteristics

Method of Headway Control

Procedures to Determine Transport Capacity

Procedures to determine capacity of an existing and operating bus transport system [7]:
Step 1: Data Collection for Critical Stop
Step 2: Data Collection for Critical Intersection
Step 3: Data Analysis
Step 4: Estimate Future Volumes
Step 5: Capacity Expansion Estimate
Step 6: Assess Capacity Expansion Alternatives for Stops
Step 7: Assess Capacity Alternatives for Intersections (curbside bus lane)
Step 8: Assess Capacity Alternative for Running Ways

Factors about Addis Ababa City Transport

Buses provide 40 percent of the public transport in the city; taxis account for 60 percent [9]. The city is currently experiencing horizontal growth, but the bus service has not exhibited growth proportionate enough to accommodate this increase. Analysis results of the transit availability indices show that only the city center is being served by the existing

bus networks while urban expansion areas have low transit availability [10].

Taxis experience many operating constraints, including bad driver behavior, excessive fares, and high accident rates. This study examines the existing situation as an input for future public transport development and improvement programs [10]. The absence of an up-to-date structure in the bus company, shortage of finance, and reduction of the subsidy from the government are the biggest challenges for the service [10]. The lack of well-defined performance parameters to evaluate the operational efficiency of the bus company is also a constraint for development.

The prospects are the year-to-year increase in the number of bus users [10]. Among the 14,083 taxis operating in Addis Ababa in 2005, 12,283 had 12 seats and 1800 were small taxis with 4 seats. Of the total number of taxis, only 11,806 were inspected and registered by the Addis Ababa Transport Authority through March 005. Public transport service is highly dependent on taxis as a mode despite high fares (taxis are an expensive means of transportation when compared to buses), which are not affordable, particularly for the low-income group (i.e., the urban poor). Taxis, which are operated by the private sector, usually run on fixed routes even if they are not highly enforced by the government (unlike that of the bus).Taxi speeds are affected by frequent stopping for loading and unloading [10]. In the city of Addis Ababa, the dominant public transportation modes are city buses and taxis. Although buses have 30 seats each, they have a carrying capacity of 100 people in a crowded situation. Taxis have a carrying capacity from four (small taxis) to 12 persons (large taxis).

Car ownership among residents is very low, so the majority depends on buses and taxis for their day-to-day mobility. Walking is the main means of transportation for a number of residents. Unlike other cities in the country, bicycle use is insignificant because of topographic inconveniences. [10].

Anbessa City Bus Service, Sheger mass transport, the light rail transit, mini bus taxis, midi buses and other buses like Public Service Employees Transport Service Enterprise (PSETSE) are operating in the city currently.

The companies are mandated to provide public transport services to the city and the surrounding areas. They provide scheduled services along different routes. The basic bus service has a system of flat fares for the route with a range varying according to distance.

METHODOLOGY

The passenger capacity of a transport line is the product of the number of vehicles per hour (usually past the busiest stop) and the number of passengers that each vehicle can carry [6]. Since the aim of the paper is to develop a mathematical tool for determining the daily capacity of the operating transport system in the city, all factors will be used in their daily basis.

The daily capacity of a single service provider can be determined as a multiple of number of vehicles, capacity of a vehicle and number of trips made per day.

$$C_i = (N_V * C_V * N_t)_i \quad (3.1)$$

Where: C_i = Average daily capacity of service provider i.

N_V = Average daily operating number of vehicles of service provider i.

C_V = Average Operating capacity of a vehicle of service provider i.

N_t = Average number of trips travelled by a vehicle of service provider i per day.

After determining the individual capacities of each serving company, the total capacity can be given as the sum of all.

$$C_d = \sum_{i=1}^{n} C_i \quad (3.2)$$

Where:

C_d = Total daily capacity of the public transport.

To do so, value of Nt for all providers must be determined. It can be determined by using the following equality. The average total distance covered by a vehicle in a day is the multiple of the average length of routes and number of trips made. This in other ways is equal to the multiple of the average speed of the vehicle and effective time of the vehicle in a day.

$$(S_t)_i = (l_t * N_t)_i = (V_V * t_e)_i \quad (3.3)$$

Where:

$\boldsymbol{S_t}$ = total distance covered by a vehicle of service provider i in a day (km)

$\boldsymbol{l_t}$ = Average length of trip for service provider i, (km)

$\boldsymbol{N_t}$ = Total number of trips travelled by a vehicle of service provider i.

$\boldsymbol{V_V}$ = Average speed of vehicles of service provider i, (km/hr)

$\boldsymbol{t_e}$ = Effective time of a vehicle of service provider i in a day (hrs) .

The effective time of a vehicle in turn is calculated as a difference between the total working time in a day and the sum of all times spent at origins, stations, and destinations, time of brake for drivers and daily down times.

$$(t_e)_i = (t_d - T_S * (N_s * N_t) - t_b - d_t)_i \quad (3.4)$$

Where:

$\boldsymbol{t_e}$ = Average effective time of a vehicle of service provider i in a day (hrs)

$\boldsymbol{t_d}$ = Average total working time of a vehicle of service provider i per day, (hrs)

$\boldsymbol{T_s}$ = Average loading/unloading time at stations for a vehicle of service provider i, (hrs)

$\boldsymbol{N_s}$ = Average number of stations on a route of service provider i.

$\boldsymbol{N_t}$ = Total number of trips travelled by a vehicle of service provider I per day.

$\boldsymbol{T_b}$ = sum of all average breaking times for a vehicle of service provider I per day, (hr)

= lunch **b**reak + sum of **s**toppages at **o**rigin and **d**estination + **T**ea **b**reak.

$$= l_b + N_t * T_{od} + T_b \quad (3.5)$$

Where**:**

$\boldsymbol{l_b}$ = Lunch break per day per vehicle.

$\boldsymbol{T_{od}}$ = Average time spent at origins and destinations per day

$\boldsymbol{T_b}$ = Tea break per day per vehicle (hrs)

$\boldsymbol{d_t}$ = Average down time per day for a vehicle of service provider i, (hr)

From the above two equations, equation 3.3 and 3.4, **Nt** can be given as below.

$$N_t = \frac{V_V(t_d - t_b - d_t)}{l_t + T_s V_v N_s} \qquad (3.6)$$

Substituting equation 3.4 for $\boldsymbol{t_b}$ will give us:

$$\boldsymbol{N_t = \frac{V_v(t_d - l_b - T_b - d_t)}{l_t + V_v(T_s N_s + T_{od})}} \qquad (3.7)$$

The total of all daily passenger trips that can be served by all set of the public transport providers in the city can, hence, be determined by summing up the total daily passenger trip capacity of each service provider (look at equation 3.2.). It can also be expressed as under.

$$\boldsymbol{(TDPT)_{city} = \sum_{i=1}^{n} (TDPT)_i} \qquad (3.8)$$

Where:

(TDPT) $_{\text{city}}$ = Total daily passenger trip capacity of all public transport providers in the city

(TDPT)$_i$ = Total daily passenger trip capacity of public transport provider i.

The total daily passenger trip capacity of each service provider, on the other hand, can be determined by multiplying its total daily trips, ***Nt***, with the capacity of its vehicle (look at equation 3.1.). It can also be given as hereunder.

$$\boldsymbol{(TDPT)_i = (Nt)_i * (Nv)_i * C_i} \qquad (3.9)$$

Where:

(TDPT)$_i$ = Total daily passenger trip capacity of public transport provider i.

$\boldsymbol{N_t}$ = Average number of trips travelled by a vehicle of service provider i per day.

$\boldsymbol{N_v}$ = Average daily operating number of vehicles of service provider i.

$\boldsymbol{C_i}$ = Average Operating capacity of a vehicle of service provider i.

Substituting equation (3.7) for (***Nt)*** results in the following form.

$$(TDPT)_i = \left[\frac{V_v * (t_d - l_b - T_b - d_t)}{l_t + V_v * (T_s N_s + T_{od})}\right]_i * (N_v)_i * C_i \qquad (3.10)$$

Now, equation 3.10 can be substituted for $(\boldsymbol{TDPT})$i in equation 3.8. Doing so, the total daily passenger trip capacity in the city can be estimated using this formula.

$$(TDPT)_{city} = \sum_{i=1}^{n} \left[\frac{V_v * (t_d - l_b - T_b - d_t)}{l_t + V_v * (T_s N_s + T_{od})}\right]_i * (N_v)_i * C_i \qquad (3.11)$$

CONCLUSIONS

1. Public transport capacity of Addis Ababa City can be determined by using this equation.

$$(TDPT)_{city} = \sum_{i=1}^{n} \left[\frac{V_v * (t_d - l_b - T_b - d_t)}{l_t + V_v * (T_s N_s + T_{od})}\right]_i * (N_v)_i * C_i$$

2. Public transport capacity is dependent on a range of factors such as road geometry, transport planning, driver behavior, vehicular characteristics and traffic stream characteristics. As shown in the last formula this paper comes up with, there is no variable representing the road geometry. This can be justified as since the speed of the vehicles is counted, the effect of the geometry can be well revealed through the operating speed. Because as the geometry gets somewhat

inadequacy, it usually causes traffic congestion which in turn reduces the operating speed in the traffic stream and the vice versa holds true.

3. Different consequences of transport system planning affect the public transport capacity. In Addis Ababa almost all public transport providers have fixed routes to which they are assigned. At some routes and terminals a number of vehicles may spend more time until they will get their turn to load. On the other hand, peoples may be obliged to make lines looking for a means of transport on other routes. So, to maximize the daily capacity of existing public transport, it is a mandatory to have an efficient citywide transport planning.

4. Drivers' behavior affects the public transport capacity in many ways. Some drivers may prefer to start working early and get back home late so that serving the community for longer time while some others favor the opposite. A number of drivers devote long period of time when taking tea breaks and lunch breaks while some others prefer to use their time wisely so that they will have maximum working hours.

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TOWARDS SSL BASED LED LUMINAIRES: POLICY FRAMEWORKS AND GLOBAL BEST BENCHMARK PRACTICES ETHIOPIA NEEDS TO EXPLORE AND ADOPT

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ABSTRACT

Lighting, which solely accounts for about 20% of world energy consumption, is one of the major sources of greenhouse gas emission and environmental degradation. In the 21st century where factors like, environmental pollution, global warming, climate change and resource depletion are threatening earth, energy efficient lighting control strategies and systems are increasingly becoming an obligation. Solid State Lighting (SSL) evolution with the parallel miniaturization and advances in sensing, electronics and computing technologies in the last few decades, has brought a very robust, precise and energy-efficient Light Emitting Diode (LED) based luminaire systems. Hence, many countries in the European union, America and Asia took the leading initiatives and responsibility in setting frameworks and policies in their lighting sector of the economy and also incentivizing and implementing projects in the transformation process towards LED based luminaire systems with promising outcomes. Ethiopia, as a country with a great ambition to become a power house in East Africa in the coming few years, it needs to explore, craft and or adopt clear lighting standards, policies and strategies, to shift towards SSL based LED luminaire, benchmarking global best practices.

Keywords: Lighting Luminaire LED, Policy and Framework. SSL,

INTRODUCTION

As global warming, environmental pollution and resource depletions are becoming major concerns of the present world, efficient energy production and consumption goals are one of the major challenges worldwide [1]-[3]. At present, environmental protection and energy savings are critical for the planet's future and its residents more than ever before. Hence, energy saving is becoming one of the basic requirements and necessities in all economic sectors including lighting.

Globally, lighting solely accounts for almost a fifth of overall energy consumptions which in turn is accountable for about 6% of global Greenhouse Gases (GHG) emissions and environmental pollution[3-11]. Therefore, beginning the past few decades', studies on maximizing energy efficiency, monitoring and control in the lighting domain has been one of the major research focal points [12]. Several studies presented that energy consumption in lighting can be significantly reduced if different appropriate lighting systems were put in place [5], [6]. Of the many recommended findings and suggested solutions, energy efficient artificial lightings based on Solid-State Lighting (SSL) devices and building designs, which maximize natural daylight benefits, are more frequently investigated and premeditated compared to other practices [13].

SSL technologies, like LEDs, offer a dramatic energy saving of 50-60% with higher durability, limited maintenance cost, environmental friendliness and longer life span [14]. LEDs have radically transformed the lighting industry with brand new valuable characteristics and also possibilities of smart electronics control integration [4]. They offer improved brightness, tunable light spectrums (good color property), compact size, high luminous efficacy, durability, longevity and tremendous energy efficiency [3,15]. Further, automatic control of illumination and color temperature of lighting sources is possible in LED luminaires resulting in improved quality of life, experience and comfort [14]. These lighting systems are the future of the lighting industry and can be applied in a wide range of specialized lighting systems including industrial, commercial and residential applications.

Currently, LED based lighting systems are becoming increasingly popular in the lighting industry and are aggressively controlling the market [3], [4], [10], [14], [16]-[18]. They are widely used in many applications including in automotive, industrial, domestic, digital signage and televisions, backlight units (BLUs), and in public lightings [17], [18]. They are also extensively used in consumer electronic products, televisions displays, mobile phones, domestic lighting and vehicle industry [3]. Supplementary, with the continuous advancement & evolution of electronics, sensing, communication and actuation technologies, further reliable and robust advanced smart lighting systems with better power efficiency, users' comfort and safety are expected to be better accomplished in the near future [19].

Smart lighting systems are automatic smart lighting systems that deliver visually comfortable lighting illumination and color temperature with an efficient energy savings depending on users-response, wellbeing, activities and comforts [14]. Smart lighting control systems achieve automatic lighting control via integrating different sensors, actuators, electronics and communication schemes with a closed-loop control system [9]. Such systems can be designed not to only reduce lighting energy consumption significantly but also boosting users experience and comfort.

Smart lighting systems provide different proper illumination levels and color temperatures depending on activities and visual well-being [14]. Hence, smart lighting control plays a vital role in boosting users experience and energy efficiency. It helps in tailoring lighting conditions to tasks and users' preferences and requirements and possible amendments in buildings configuration and purposes [2]. They are typically capable of arbitrary spectra, brightness, color temperatures, intensity reproductions for better user experience with greater, faster and better responses [20]. With smart and advanced LED luminaires it is possible to achieve as high as 80% energy consumption cut [21].

Studies showed that by 2050 cities are expected to be populated by almost two thirds of the total global population, i.e. more than seven billion people, and anticipated to account for about 70% of greenhouse gas emissions and energy consumptions [4]. Therefore, cities all over the world are expected to be significantly affected by environmental pollution, resource depletion, climate change and their practice of lighting designs [2].

Therefore, taking this into consideration, optimizing lighting systems to save energy is a vital requirement and responsibility [7], [10], [11]. Thus, as the global population is rapidly increasing and if the effects of this scenario on the environment and quality of living are deemed to be minimized, the right lighting systems and policies should be in place way before it is too late. Many studies and researches underway currently in the world target addressing energy conservation and optimization of lighting sector via introducing different flexible lighting systems and techniques [7]. Hence, detailed analysis, studies and researches for improved luminaire systems and setting the right polices and strategies in advance is a necessity for a better future.

ETHIOPIA'S CONTEXT

To the authors' knowledge and the date of this paper writing, Ethiopia does not have any officially reported policy, guideline, rules and expectations in the lighting sector of its economy to shift towards SSL based luminaires. The country's very few and infant LED assembling companies only have the capability of assembling LED luminaries, lacking the ability to meet the market demand and compete with imported products. The country's pioneer lighting industry, daylight engineering, has stopped working on lightings and shifted its operation to glass manufacturing some years back. Even though there is no officially conducted research or study to analyze the country's human capacity in the lighting industry sector, it is clear that the country lacks the expected skilled man power and technology.

Energy efficiency and conservation aspects in Ethiopia is monitored, regulated and controlled by "Ethiopian Energy Authority (EEA)", which is mandated via proclamation [22]. The EEA is authorized for formulating directives and guidelines for energy consumption conservation and efficiency in all economic sectors including lighting, manufacturing, domestic appliances, transportation, agriculture, building and industry. Although most of the activities under progress and draft formulations underway by the agency need some time to be implemented country wide, most of the activities target reducing and regulating the energy sector in terms of safety, conservation, efficiency, quality, source diversification and the like based on standards, directives and regulations in different economic sector of the country including households. However, by far it has mainly focused on, substitution of fuel wood with improved stoves and biofuel sources to narrow the gap between energy demand and supply in the country to improve environmental degradation.

In addition, conferring to the "Second Growth and Transformation Plan (GTP II)" of the country, it positions the need to elevate the country's energy source management, efficiency, diversification, conservation and extenuation of energy losses to international standards [23]. The Government of Ethiopia (GoE) targets to reduce energy losses in the country by the end of GTP II to internationally acceptable average from its present staggering 20%. In order to comprehend that, it states the need for upgrading the existing distribution systems in the country to internationally tolerable energy loss emblematic standards.

However, the document lacks clarity and lucidity in setting any clear and explicit economic sector targets for energy consumption reductions for any economic sector in the country, including lighting. Further, residential target of distributing low power consuming compact fluorescent lamps that was being carried out by the

Ethiopian Electric Power corporation (EEP) some years back at a national level to make energy usage more efficient seems not to be comprehending as planned and is now being halted due to some unspecified official reasons. Further, the recent study on the awareness of lighting efficiency and LED, which was done in AAiT with ALTO University showed that there is a serious awareness gap and lack of preparedness to shift to SSL based luminaires in the country.

Although there are no officially reported or clearly stated national lighting energy consumption standards, guidelines or regulation mechanisms set in the country, there are several huge urban and rural electrification projects planned and underway to boost electricity coverage. Further, there are also numerous planned and already operational projects set to connect Ethiopia to its neighbors and far through a sub-regional power interconnection to export electric energy to generate income. To comprehend this, it is clear that the country needs to focus on the future of lighting, like SSL based energy efficient systems, to save energy. Thus, there is no doubt that the country needs to formulate and follow a national policy/roadmap towards realizing energy efficient lighting systems in the country like other countries in the world.

GLOBAL BEST PRACTICES AND POLICIES

Countries that can and do mobilize all the necessary finance, formulate policies & standards and rationalize private investment in LED luminaire manufacturing capacity are expected to rule the lighting industry and claim the jobs and market it will create globally. Nations like China, that have a good balance of well-coordinated polices, standards, market aggression initiatives and subsidies in LED based SSL luminaires are capitalizing the global LED luminaire markets being leaders of SSL based LED revolutions [21], [24]. Such systematic and structured bold moves are being taken as a role model by many other countries in adapting and adopting valuable polices, experiences, practices, challenges and successes in realizing energy efficiency in lighting.

In recent years many countries and multi-national organizations globally have actively promoted political and economic campaigns towards LED based luminaire system transformation for improved energy efficiency [12]. Hence, in order to supplement, assist, promote, accelerate and realize this ambitious global march, many countries crafted tidy policies & standards and instigated exemplary projects initiating and supplementing LED based luminaire initiatives and movements. Today, China, Taiwan, Japan, Europe, USA, South Korea, Russia and India are major world LED manufacturers, consumers and beneficiaries [21]. The following subsections highlight on selected global best benchmark practices and policies.

EUROPEAN UNION (EU)

The EU set policy to reduce its carbon emission by a fifth from its amount in 1990's by 2020 and realized that successfully in 2019 [25], [26]. In order to realize this goal, it has set up a wide range of legislative measures and policies in SSL lightings researches and deployments [27]. There are many mandatory and voluntary guidelines and policies put in place to support deployment of LED based luminaires across the European Union member countries.

The EU has also achieved complete incandescent light phase out by September 2012 through its well-crafted environmental policies and guidelines [21]. EU through the Competitiveness and Innovation Framework Programme (CIP) assists and supports SSL based lighting innovations to further their

efficiencies and provide financial access. Further, EU introduced "EU public procurement for a better environment" in 2008 and "EU Green public procurement" by the end of 2011 for traffic signals and street lightings. It also supported different lighting projects. Cities like, Amsterdam, Eindhoven and Tilburg in Netherland, Mechelen in Belgium, Lyon in France, Copenhagen in Denmark, Hódmezővásárhely in Hungary and Birmingham in the UK are some of the best implemented success project examples [21], [28].

CHINA

China developed policies identifying the need for SSL technologies and their unique benefits for the country economy and draws clear national guidelines and principles in how to innovate, develop, deploy and safeguard SSL based luminaires in the country [29]. It introduced incentives for promotion of SSL including via reducing taxations in order to save significant amount of energy [21]. Financial institutions in china provided financial support for SSL based lighting plans in line with the national polices set in the country to boost and penetrate more economic sectors in the country. The targeted economic sectors included street lighting, offices, agriculture, transportation and high technologies. Different organs of the government further provided financial subsidy promotion programs towards shifting to the more energy efficient SSL systems.

China set a national roadmap in phasing out incandescent lighting systems in the country and supported the process through policy incentives and providing financial supports [30]. China formulated an ambitious lighting electricity consumption of an annual 5% reduction and planned to make urban lighting based on SSL to 85%. It also set government procurements to be using energy efficient lighting products since 2007. Another best practice from china is the economic development area of Tianjin, a city which is solely build from LED lighting under the international initiatives of boosting LED lighting consumption for a better future and efficient energy consumption [31]. Tianjin Economic Development Area (TEDA) was the first municipal in china to join the rapidly expanding international consortium of promoting, deploying and accessing LED lighting technologies across its municipals. The Chinese government also took the initiative to successfully implement '21 cities of 10,000 lights program' targeting to save 220 kWh annually through 1 million indoor and outdoor LED luminaire installation in 10 cities [32].

USA

USA is one of the countries in the world that formulated and benefited from lighting policy strategies and implementations [25]. U.S. department of environment is the leading and responsible organ of US government for setting national polices for SSL programs [33]. The department, supported by the government industry linkage programs, targets to financially support and assist low cost energy efficient advanced semiconductor-based technologies for the lighting industry [34]. It also carved 'next generation lighting initiatives' to support and develop more efficient long-lasting lighting systems with minimized energy consumptions.

The US department of energy and its supporting partners in SSL developed a multi-year R&D plan to assist SSL funding of new products from the stage of development to the test and deployment in the laboratories and the market. The plans and policies set frameworks in how to R&D, manufacture and deploy SSL lighting

systems for domestic, commercial, industrial and street luminaires [21], [35]. It also plays crucial role in introducing and creating awareness and giving support in the country. It also introduced incentive measures for SSL based lightings innovation researches and deployments. The US government also forced governmental procurements and deployments in the lighting arena to be energy efficient lighting systems based on SSL. Los Angeles world's first largest, New York, Las Vegas and Seattle LED street light retrofit wok projects are examples of the successful implementation of the polices, frameworks and besieged goals [36].

The government forced government procurements to be energy efficient lighting system deployment after President Bush ratified the 'Energy Independence and Security Act (EISA)' in 2007. The EISA further forced roughly 25% greater efficiency for light bulbs in lighting energy efficiency, phased in from 2012 through 2014 forcing phasing out of incandescent lamps since 2012 [37]. The US department of energy forecasted that the LED penetration is projected to reach 84% of all lighting installation in all over USA by 2035. The US realized a combined LED installed in commercial, residential, industrial and outdoor of 19% in 2017, 35% in 2020 and is forecasted to reach 60% by 2025, 76% by 2030 and 84% by 2035 [38].

JAPAN

In Japan, "Ministry of Economy, Trade and Industry (METI)", is responsible for setting national polices and regulations. It has established exemplary policies and roadmaps to replace lightings in Japan by an energy efficient luminaire by 2020 and formulated new energy conservation standards for lighting equipment and light bulbs by 2027 [39]. Japan expects all new luminaire shipments to be based on SSL technology from 2020 onwards and all building and outdoor luminaires to be replaced via SSL based technologies by 2030 [37]. SSL based luminaires penetration reached 18% in 2010 and is thriving in recent years. METI introduced tax incentive measures to foster LED luminaire deployments for small and medium sized enterprises. It also introduced economic stimulus package to foster energy efficient air conditioners, lightings, refrigerators, and televisions [29]. This program was crafted to minimize greenhouse-gas emissions and energy consumption across Japan.

After Fukushima disaster in 2011, power shortage and public pressure forced Japan government to seek better ways for reducing energy consumption and realized 50% LED lighting deployment [40]. Further, under the Green purchasing law, the Japanese government encouraged eco-friendly lighting deployments to reduce environmental impact and pollutions. The polices and law set by the government forces green purchasing by the government, public organizations, local governments, business and citizens of Japan. The government further supports Light for the 21st Century lighting, medical equipment, and therapeutic techniques projects, which are based on LED's.

KOREA REPUBLIC

The republic of Korea formulated "Low Carbon, Green growth" strategy on 2009 which mainly focuses on SSL luminaires [41]. It invested significantly on new LED lamp installation and retrofit works in the country. It also set LED lighting expansion and distribution polices making them mandatory in commercial and public buildings. The government of Korea continuously revised and updated its policies and regulations according to the LED technology development and market reality. It has also introduced lucrative incentive measures and set ambitious goals in its light

and lighting to be based on LED systems. One good indicator is, its plan to equip Seoul city government office to be 100% LED based lighting by the end of 2018 and accomplished it successfully [42]. The government of Korea has also significantly expanded LED lighting of the country through boosting government procurements.

Furthermore, through the 'LED 2060' plan the government targets to reach LED lighting penetration of 100% in public institution and 60% countrywide by 2020 and is aggressively working on it [43]. It puts a way forward and determined to realize the ambitious targets via financial funding and supporting different projects. It is providing low-interest loans and tax initiatives all over the country for efficient SSL lighting research, development and deployment. It has also launched a major 'The Photonics Industry Project' project, which deals with the lighting and photonic industry of the country.

SOUTH AFRICA

South Africa is the first African country who banned incandescent lighting products and set a national policy to identify and support efficient lighting system in key areas of its economy. It has set a target to phase out its incandescent lighting products completely by 2016 [44]. However, a policy and a framework which specifically focuses on LED lighting is yet to be formulated and effected.

BRAZIL

Brazil also sets exemplary polices and laws including 'Law No.10295 – Energy Efficiency Law, which set out minimum energy performance standards for equipment and buildings', 'Law No. 9991 – Energy Efficiency Programs of Distribution Utilities' and 'PBE – Brazilian Labeling Program, which focus on energy conservation through informative labels about energy efficiency of equipment sold in the country' to reduce its energy consumption in different sectors including in its lighting [45]. The government also introduced government procurement directions towards energy efficient systems in public investments. Through its 'Brazilian Energy Efficient Lighting Program' it has also drafted a framework to step by step transit towards less energy consuming lighting systems countrywide [46].

INDONESIA

Indonesia also laid national policies including 'The Energy Law (Law No. 30/2007)' and 'National Energy Policy (Presidential Regulation No.5/2006)' [47]. It has also standards for minimum energy performances in different electrical appliances including the lighting sector. The government further introduces fiscal and tax exemptions for investments and imports of low energy electrical utensils to meet its energy conservation plan. It also set mandatory requirements for energy efficient lighting systems in its regional governments, agencies and departments and commanded their monthly energy usage reports.

INDIA

India also realized the importance of SSL lighting transition and set its first ever policy framework in 2010 [29]. The frame works are primarily set to overcome the barriers and obstacles that the transition could pose including, technological, incentive, standard and policy barriers. Indian ministry of commerce drafted a law that is advisory for all medium & small cities and municipalities street lighting with LED based systems via funding to more than 180 bodies. The government introduced incentive measures via subsidizing and forming LED test facilities for LED lighting across the

country. It also set roadmap for government procurement in its major investments of the future [48].

BOEING.VSMPO-AVISMA, BRITISH PETROL AND SHELL

Multinational companies like Boeing, VSMPO-AVISMA, Shell and British Petrol have also joined the march in introducing and deploying LED based lighting across the globe supplementing the effort of governments. These proved that not only government organs and bodies but also companies can play their crucial role in LED lighting deployment and energy conservations. Shell and British Petrol (BP) are retrofitting their gas stations with LED based luminaires to assist the march moving towards to energy efficient eco-friendly lighting systems in the world [21]. These retrofit works are expected to cut lighting energy consumption by 50% with an increased safety and comfort to users.

Further, Boeing Manufacturing plant located in Ural (UBM), and VSMPO-AVISMA Corporation, one of the largest metallurgy industries in the world, also replaced their lightings to LED based systems in the support of energy efficient manufacturing. Consequently, the LED retrofit work both resulted in 60% lighting intensity increase and safer working environment on top of the energy consumption reduction [49]. Further, Boeings Utah Recycler hanger was also retrofitted with the state-of-art LED based smart lighting which was also designed to boost its sunlight help for artificial lighting [50]. Further, Boeing has set a framework for its future new buildings to use only energy efficient LED based lighting technologies whenever possible, in support of eco-friendliness.

ROADMAP FOR SSL MANUFACTURING

Production of SSL products are tough for developing countries, like Ethiopia, as patents, Intellectual property (IP) rights, and confidentiality issues, makes it hard [51], [52]. Further, manufacturing of LED electronic drivers has diverse manufacturing steps and processes and electronic circuit integrations. Generally, SSL manufacturing involves two stages. The first stage comprises component collection, package production and LED chip manufacturing. The second stage encompasses assembling of the LED luminaires. LED chip manufacturing is the most complicated and capital intensive of all [53]. However, experiences from nations like India, China, Koreas and USA showed that by formulating the necessary policies, standards, and mobilizing incentives, investments and starting from SSL assembling leads in to becoming a leading SSL manufacturer [29].

Korea supports public investment in SSL industries and offers tax incentives. It has also funded numerous SSL based R&D and market roadmap development works. USA has financed several innovation competitions, awards and recognitions accelerating and inspiring SSL innovations. India has significantly invested in SSL assemblies first and later worked extensively in empowering SSL based production and skilled manpower capacity building. It has policies promoting SSL based luminaire systems and subsidization of SSL establishments. China has heavily invested in the SSL industry via crafting policies and strategies that support the steadily development level of SSL industry, implement incentive policies, support SSL technology innovations, conducted SSL introduction, education and training boosting its skilled manpower in the sector.

Hence, developing nations can start from SSL assembling via promoting SSL luminaires with incentives and supporting domestic assembling. In the long run, by significantly investing on education,

awareness, capacity building, and attracting major corporation in the SSL industry, they can steadily grow to SSL manufacturing. Further, the fact that SSL manufacturing cost is dropping exponentially since 2000, paves the way and presents an opportunity to put their finger prints in the area [29].

CONCLUSIONS

Indoor and outdoor lighting matters in energy conservation marches as it solely accounts for about 1.9 billion tons of carbon dioxide emission worldwide and almost a fifth of electric energy consumptions. On average 40% reduction in energy usage in this sector is possible via adopting LED based lighting systems. It is equivalent to reducing carbon dioxide emission by staggering 760 million tons globally. With smart and advanced LED luminaires it is even possible to achieve as high as 80% energy consumption cut.

Given its capacity to accomplish significant energy consumption cut, boost users' safety and comfort, minimize environmental impact, LED luminaires are crucial and one of the cutting age technologies of the 21st century with huge potential of carbon dioxide emission cuts and environmental pollution. Among the many stakeholders in the lighting arena, governments have the highest responsibility for the transformative scale-up and overcoming the primary obstacles of deploying LED lightings. This will bring immense economic and environmental benefits and also improved quality of living.

Cities all over the world are expected to adopt and follow economic policies and frameworks that help them transit their lighting systems from the traditional lamps to the LED based systems in the near future. Today, politicians, policy makers and leaders all over the world have the perfect opportunity to shape the future of our planet with a huge visionary step of promoting and enforcing LED lighting with long lasting positive impacts, more than ever before. Governments and multi-national corporations are expected to be the main propellers and prime movers of the LED market demand.

It is a must that governments, including GoE, and corporations all over the world be committed to make LED lighting as an essential part of their energy efficiency policies and frameworks as it offers many positive impacts. LEDs market barriers should be cleared and supported via different organs of a government in order to accelerate their market share and penetration for a better economic and environmental returns. Some of the schemes can be;

- Government procurement: as different government organs are one of the main consumers of artificial lightings, they should set a policy in which they could become the prime adopters, procurers and deployers of LED lighting systems.

- Incentive measure: to scale-up LED lighting adoption and deployment, nations administrations and states in the world should craft different incentive measures to overcome economic and financial barrier.

- Education and capacity building: nations should enlighten their citizens regarding the advantages of LED luminaires in comparison to the traditional lighting system and create strong man power in the lighting sector research and development.

- Setting lighting standards: different agencies and institutions in any country responsible for lighting should set relevant lighting standards that favors LED technologies to speed up their deployments.

Therefore, the government of Ethiopia and its branches responsible for energy efficiency and conservation should look into and thoroughly investigate policy frameworks and global best benchmark practices in order to benefit and explore SSL based LED luminaire scheme benefits. Furthermore, it should also benchmark these global prolific practices in order to formulate, adapt and/or adopt policy frameworks and roadmaps in to its national policies and plans.

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ETHIOPIC AND LATIN MULTILINGUAL TEXT DETECTION FROM IMAGES USING HYBRID TECHNIQUES

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ABSTRACT

Caption and scene texts found in images contain valuable information. These texts can be used for many applications to answer questions like what, when, where, and by who to give context to the images. So, automatic text detection enhances the user's understanding of the media content. In Ethiopia, most street posts and promotional boards are written in multilingual characters such as Latin (English, Afaan Oromo etc.) and Ethiopic (Amharic, Tigrigna etc.). In this work, we have studied Ethiopic and Latin multilingual text detection from images for both caption and scene texts. After the images are pre-processed, maximally stable extremal region (MSER) algorithm, aspect ratio and stroke width transform (SWT) algorithm are used to extract text regions, respectively. Then texture features are computed using local binary patterns (LBP) from the extracted regions. Finally, the support vector machine (SVM) is used to classify text region vs non-text using the computed LBP features. We prepared a new multilingual Ethiopic and Latin script image dataset to evaluate our method.

Keywords*:* Images, LBP, SWT, MSER, SVM classifier

INTRODUCTION

The text embedded in an image provides clear and more obvious information about the content of specific media. It is necessary to detect and extract the text information from these images automatically for potential applications such as image retrieval and processing, in robotics, computer vision and intelligent transport systems. However, developing a robust system for extraction of texts from captured scenes is a great challenge due to several factors such as variations of style, colour, spacing, distribution, layout, light, background complexity, presence of multilingual scripts and fonts. In this modern era where we live today, multimedia technologies play an important role in transforming row data into digitally encoded information. Automatic detection of the region of a text area in images is an active research issue in the design of computer vision systems. Image text can broadly be classified into two categories: artificial or caption text and scene text.

Artificial text refers to those characters generated by graphic titling machines superimposed on video images, such as video captions, while scene text occurs naturally as a part of scene, such as text in images information boards/signs, nameplates, food containers, etc. The goal of this work is to develop a system which will efficiently detect

image regions that contain Ethiopic and Latin texts from images. The paper is organized as follows. The first part of the paper provides an overview of the general background and reviews of different works which helps to understand multilingual text detection techniques from images.

The next part basically included the design and development parts of the paper. Here the proposed model and algorithms used in the model are discussed. Then the results and the experiments conducted are discussed. Finally, the conclusion and the recommendation of a future work which are forwarded by the researchers are put together.

RELATED WORKS

Current text detection from images approaches can be broadly categorized into four groups: texture-based approach, region-based approach, hybrid approach of texture and region-based Methods and Morphological based text detection.

A. Texture Based Approach

These methods are based on the fact that texts in images have distinct textural properties which distinguish them from the background [1]. Wenge, et al, Proposed wavelet transform of an image is done to characterize the local energy variations (LEV) of pixels in the successive scale levels. In each scale level, the corresponding local energy variations are computed. The resulting binary map image in each scale level is subsequently analysed by connected component analysis (CCA) technique to label different objects and backgrounds. Finally, all text regions in the consecutive scale levels are fused into the original image and text regions are detected.

Kim Kwang suggested a technique that uses a combination of (Continuously Adaptive Mean Shift) CAMSHIFT and SVM for detection and extraction of text is proposed. They use a small window to scan the input image, classifies the pixel located at the centre of the window into text or non-text by analysing its textural properties using a SVM. Then the CAMSHIFT algorithm is used to verify text regions which are the result of the texture analysis. Ye, Qixiang, et al [4] applied coarse-to-fine detection framework by using different text properties in different detection stages. In the coarse detection, candidate text regions are firstly obtained using properties of dense intensity variety and contrast between text and its background. In the fine detection step, Texture property is used to discriminate text with other non-text patterns. Texture features such as wavelet moment features, wavelet histogram features, wavelet co-occurrence features and crossing count histogram features are used to identify text lines from the candidate ones. A forward search feature selection algorithm is used to find effective features and an SVM classifier is used to perform text/non-text classification tasks.

One system developed by Vinod, H. C., et al in [5] for detection of text makes use of Laplacian method based on wavelet and colour features. The Maximum Gradient Difference (MGD) map is obtained by moving the window over the image. Text regions typically have larger MGD values than non-text regions because they have many positive and negative peaks. Therefore, they convert the input frame into a binary frame and then Fuzzy C-means is applied to classify the feature into two clusters: background and text candidates.

B. Region Based Approach

Region-based approaches done by Zhang, Jing, and Rangachar Kasturi in [1] attempts to use similarity standard of text, such as colour, size, stroke width, edge and gradient information. These approaches usually have lower computation cost and the outputs can closely cover text regions. In paper [6] Liu, Xiaoqing, and Jagath Samarabandu proposed a method which has three stages: Candidate text region detection, text region localization and character extraction.

In its first stage, they used the magnitude of the second derivative of intensity as a measurement of edge strength, and this allowed a better detection of intensity peaks that normally characterizes text in the images. Edge detector is carried out by using a multiscale strategy in which the multiscale images are mainly produced by Gaussian pyramids after successively applying a low pass filter and down sample the original image reducing the image in both vertical and horizontal directions.

In the second stage, they assume texts are found in clusters arranged compactly. So, this characteristic of clustering is used to localize text regions. In the third stage, the existing OCR engines were used. For text detection mainly from video images, Anthimopoulos, Marios, et al [7] applied a two-stage methodology. In its first stage, the text lines are detected based on the canny edge map of the image. In the next stage, the result is refined using the sliding window and a SVM classifier. Feature vectors of the candidate regions are obtained usingLBP which describes the local edge distribution.

In research work [8], Chen, Huizhong, et al proposed Connected Component based (CC-based) text detection algorithm, which employs MSER as basic letter candidates. To improve the weakness of MSER they deploy the complimentary properties of canny edges and MSER is combined in edge-enhanced MSER. Further they propose to generate the SWT image of these regions using the distance transform to efficiently obtain more reliable results. Then they apply the geometric as well as stroke width information to perform filtering and pairing of CCs. Finally, letters are clustered into lines. In other work which uses a connected component-based approach for text extraction [9] is based on colour reduction technique. The Colour images are converted to gray scale images and edge image is generated using a contrast segmentation algorithm. Luminance value thresholding is applied to increase the contrast between the possibly interesting regions and the rest of the image. Then they applied the horizontal projection of the edge image in order to localize the possible text areas.

In the works of Zhang, Xin, et al [10], the Colour-Edge combined algorithm consisting of two stages is proposed for text detection and extraction. In the first stage, they detect the text area by applying the Colour-Edge combined algorithm.

In the second stage, the text background is removed and the left part is binarized for text location. The Transition Map method is used to filter the text from the background. The model makes use of the exponential changes of colour between the edge of text and background to detect the text area, and then the background is removed. To improve the efficiency of the method, canny edge detection and some morphology operation is performed

C. Hybrid Approach of Texture and Region Based Methods

Hybrid approaches [1] seek to introduce the textural property of text regions into region-based approach. In a research work done in [11] they try to combine texture and CC-based information to detect text. They propose first and second order statistical texture features to detect and localize the text in the image. CC extraction is used to segment candidate text components from the localized text region. Finally, morphological operations and heuristic filters are used to filter out non-text components. The other literature in this regard is the one mentioned in [12]. The authors created a text confidence map for a series of different scaling of gray scale images to represent the possibility of text on an area using the wald boost classifier trained by histogram of gradient (HOG) features. They adopted Niblack's algorithm to convert gray scale image into binary image, and uses the conditional random field to determine whether the candidate area contains text or not.

Finally, they applied a minimum spanning tree to connect the same line of text.

D. Morphological Based Approach

In work [13] by Thilagavathy, A., et al, the researchers go through the following steps to detect texts. They split the video into frames. Key frame is selected from the frames by edge comparison with the help of the Sobel edge detector.

Text candidate regions are generated again using Sobel edge detector. They assume texts in video frames found closer to each other. Thus, morphological dilation operation is performed to remove pixels that are far away from the candidate region.

PROPOSED METHODOLOGY

Among the many published region-based methods, we observe an increasing use of the MSER algorithm for character candidate's detection. Based on the review of previous methods, we identify the following text characteristics that are frequently used in text detection, localization, and extraction: contrast, colour, stroke density and aspect ratio. After pre-processing the target image, since text characters usually have consistent colour, we begin by finding regions of similar intensities in the image using the MSER region detector which is applied for character candidate extraction. Although the MSER algorithm picks out most of the text regions, it also detects many other stable regions in the image that do not contain text. For text detection either rule based or machine learning approach can be used.

We apply the combination of the rule-based methods and a machine learning approach to produce better results. False regions, which are detected as text regions by MSER, are minimized using the geometric property of texts which is the aspect ratio. Then SWT Algorithm is used to refine the false positives. Even after the SWT filtering is performed regions which are not a text are also detected as text region candidates. To eliminate those candidate regions which are not text, each candidate text regions are verified using a machine learning technique.

A. Pre-processing

Noise can seriously affect the quality of digital images. Different factors may be responsible for introduction of noise in the image. In this phase of the system, we apply three different filters used for smoothing, sharpening and denoising to pre-process images in order to obtain a picture with more stable text regions. Eliminating the noise without blurring the details too much and enhancing edges without amplifying noise is very difficult. So, when using more than one filter, special care should be taken in order to make sure their effect is important.

To get information which can describe images, we use these filters in the following order.

a) Bilateral filter: To smooth images.
b) High-pass filter: To sharpen images
c) Median filter: To filter out noise from images.

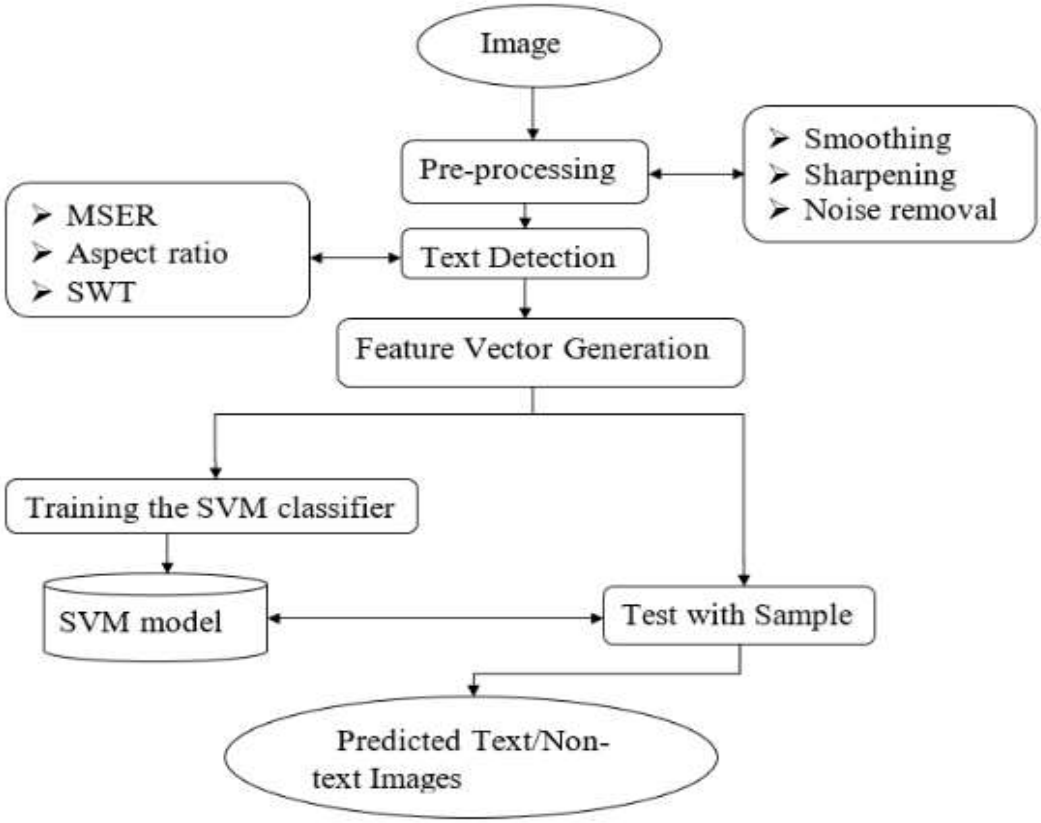

Fig. 1: System architecture for text detection

B. Extracting Character Candidates

In order to refine the character candidate information in images, we use MSER to retrieve the edges and local features of characters. The word extremal refers to the property that all pixels inside the MSER have either higher (bright extremal regions) or lower (dark extremal regions) intensity than all the pixels on its outer boundary. The MSER works fine for finding text regions. Since the consistent colour and high contrast of text regions with the background leads to stable intensity profiles.

C. Constructing Text Candidates

We choose the character candidates according to structural features called aspect ratio as given in equation 1. Aspect ratio: the shapes of characters are found to be roughly rectangular connected components. But in English" i"," I"," l"," j"," J" are comparatively thin texts, with arrangements similar to cable in an image. The below threshold is used to remove the background noises while it preserves the thin text at the same time.

$$Aspect\ Ratio = \frac{Max(Width,Height)}{Min(Width,Height)} \quad (1)$$

The biggest threshold is used to eliminate big candidate regions while the small threshold is used to discard non-text regions like wires and leaves.

D. Stroke Width Transform

Stroke width of a text remaining is almost the same as in a single character; however, there is significant change in stroke width in non-text regions as a result of their irregularity. The initial step of stroke width extraction is to get skeletons of the remaining MSERs. On every foreground pixel on the skeleton, distance transform is applied to compute the Euclidean distance from this pixel to the nearest boundary of the corresponding MSER.

Then we obtain a skeleton-distance map. If the standard deviation of the stroke width of the character candidates is large, it is less likely to be a true character. A value of 0.5 is chosen as a threshold for removal of non-text regions using equation 2.

$$Thresh. = \frac{Standard\ deviation_{stroke\ width}}{Mean_{Stroke\ width}} \quad (2)$$

Even after the stroke width filtering is performed, regions which are not text are also detected as text region candidates.

We first merge the individual characters into a single connected component using a small bounding box threshold which is 0.02. To eliminate those candidate regions which are not text, for each of the candidate text regions within the bounding box, their respective feature vector is computed with LBP which is the input for SVM. Finally depending on the feature vector, the SVM classifier classified each region as text and non-text. Those regions which are classified as text will be the output of the system.

E. Feature Extraction

LBP which is a feature extraction algorithm is chosen because one of the aspects of text is that it has a unique pattern for each character. These can be used for constructing a feature descriptor for a window. The LBP operator assigns a decimal number for each pixel of an image, called LBP codes. This pattern is used to encode the local structure around each pixel. Each pixel is compared with its eight neighbours in a 3 x 3 neighbourhood by subtracting the centre pixel value. The results which are less than the centre pixel value is encoded with 0 and others with 1. A binary number is obtained by concatenating all these binary codes in a clockwise direction starting from the top left one and its corresponding decimal value is used for labelling.

Table 1 LBP Computation

1	2	2		0	0	0	Binary:
9	5	6	-	1	1	1	00010011
5	3	1	>	1	0	0	Decimal:19

F. Classification

The preliminary aim of the classification phase of our system is to distinguish candidate text regions which come from as output from rule-based filtering as text or non-text. Finally, it is determined if the text candidates actually contain a text string using a SVM classifier.After text candidate combination; we use SVM to classify potential text regions into text and non-text using the extracted feature vectors. Those text regions which are classified as text will be the output of the system.

RESULTS AND DISCUSSIONS

As far as we know, there is no work done in detection of Ethiopic text from images. Due to this there is no available Ethiopic text image database used for conducting an experiment. So, we prepare a multilingual scene and caption text dataset. The dataset contains 400 images, which contains 50 caption images and 350 scene images.

The second dataset used is the International Conference on Document Analysis and Recognition (ICDAR) 2003 dataset which evolves from a series of robust reading competitions held by ICDAR. The dataset consists of 462 images including 229 for training and 233 for testing. For each word within each image, the ground truth is fully annotated. We set two types of evaluation units in the dataset; objective and subjective evaluations.

Objective evaluation, the word level as shown in Figure 2.1(a), is used in the ICDAR dataset. However sometimes, it is hard to partition text regions within an image into individual words based on their spacing; it is almost impossible and non-trivial to perform word partition. Therefore, we consider subjective evaluation, the evaluation metric to use regions which contain the text rather than a word as shown in Figure 2.1(b).

(a) Sample ground truth for objective evaluation

(b) Sample dataset for subjective evaluation

Fig 2: A multilingual scene text example.

The performance of our approach was evaluated by measuring its detection rate, based on precision, recall, and F-Measure. The three evaluation values were computed by using equations 3-5, respectively. Precision is defined as the number of true positives (TP) over the number of true positives plus the number of false positives (FP).

$$Precision = \frac{TP}{TP+FP} \quad (3)$$

Recall is defined as the number of true positives (TP) over the number of true positives plus the number of false negatives (FN).

$$Recall = \frac{TP}{TP+FN} \quad (4)$$

These quantities are also related to the (F-Measure) score, which is defined as the harmonic mean of precision and recall.

$$F - Measure = 2 * \left(\frac{(Precision*Recall)}{(Precision+Recall)}\right) \quad (5)$$

1) ***Objective Evaluation***: This evaluation unit is based on the ICDAR word level evaluation mechanism. DetEval software is used for evaluation. The first experiment is conducted on our prepared dataset. For both the training and testing 400-word blocks are extracted using our system. All the dataset is fully annotated. Finally, DetEval software is used for objective evaluation and the following results in Table II are obtained.

Table 2: Text detection result

Precision	Recall	F-Measure
81%	74%	77.5%

As far as we know there is no work to compare our method with it by conducting an experiment with the same dataset. So, to compare with other methods we conduct an experiment on the publicly accessible ICDAR 2003 dataset. We compare our approach with existing methods which conduct experiments on ICDAR 2003 dataset. The comparison is made with the state-of-the-art method developed by Boris Epshtein.

Table 3: Text detection result in ICDAR dataset

	Criteria for Assessment			
Method		Precision	Recall	F-Measure
	Ours	78%	70%	74%
	Method[14s]	73%	60%	66%

The experimental results in Table 3 demonstrate the effectiveness of the proposed method. Our method performs better than the results obtained by the state-of-the-art method given in [14]. We believe the improvement in the performance comes from the usage of the pre-processing stage, MSER and classification stage of our system.

2) Subjective Evaluation: For most images as shown in Figure 2.1(b), it is hard to partition and prepare a ground truth for a word text in images.

As a result, even if the detector successfully identified the text in the image, the match scores between a bounding box for an entire block of text and bounding box for a single word tended to be very low. In this evaluation mechanism there are no ground truths consisting of bounding boxes for individual words, while our detection system outputs bounding boxes for the entire group of text regions.

We consider the evaluation metric to use regions which contain the text rather than a word level objective evaluation mechanism. The performance measure in the subjective evaluation is its detection rate, defined as the ratio between the number of detected text images and all the given images containing text. The experiment is conducted using our prepared dataset.

Table 4: Text detection result

Precision	Recall	F-Measure
97.28%	84.12%	90.7%

(a) MSER detection result

(b) After removing non-text regions based on aspect ratio

(c) After removing non-text regions based on stroke width transform

(d) Candidate text regions

(e) Final detection result

Fig. 3: Sample step by step text detection.

CONCLUSIONS

Text detection in images is a difficult problem. The difficulty is due to wide dissimilarity in fonts, sizes colour and textures of text regions embedded in scenes. The location of the text in the image also follows a random behaviour presence of repeating patterns and complex backgrounds in unconstrained images increase the difficulty for detecting text from images. Encoding all these variabilities in a rule-based approach is extremely challenging. So, in this work, we combine rule-based approach with machine learning methods to generate a model to discriminate between text and non-text regions from images. In order to minimize the effect of noise in images, pre-processing techniques have been applied in input images.

Then since text characters usually have consistent colour, we begin by finding regions of similar intensities in the image using the MSER region detector. Although the MSER algorithm picks out most of the text, it also detects many other stable regions in the image that are not text. Geometric properties of a text character which is aspect ratio followed by SWT are used to filter out non-text regions. After the geometric filtering and SWT is performed, regions which are not a text may be detected as text region candidates.

To eliminate these candidate regions which are not text, the respective feature vector of each candidate text region is computed by LBP. The feature vector is then used as input for the SVM classifier which decides whether the candidate regions are text or not.

FUTURE WORKS

1. Script identification can be done since the output of the system which is the localized text regions may contain multiple lines of text with different scripts which can be applied as input for script identifier.
2. Multilingual OCR can be developed using this work as a pre-processing step.

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LIMITATIONS OF PROOF OF STAKE ALGORITHM IN BLOCKCHAIN: A REVIEW

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ABSTRACT

Blockchain is a new technology that has emerged to provide solutions to various sectors including health, insurance, advertising and many more. Despite the benefits, the technology has its own challenges with respect to the architecture and the consensus protocols involved. Proof of stake (PoS) is one type of consensus protocol by which a decision is made in order to handle transactions inside the blockchain technology. PoS concept states that a person can mine or validate block transactions according to how many coins the person holds. This work is aimed at studying the pros and cons of PoS and its proposed variations, and come up with recommendations to handle the drawbacks that currently exist in these algorithms. A detailed exploration has been carried out to understand the issues behind proof of stake protocol and the consensus algorithms that tried to address those issues. Consequently, four research gaps were identified. These gaps are less decentralized blockchain, vulnerable to 51% attack, not tested for security and performance, and problem of another issue being raised when trying to solve one. Most of the previously developed algorithms are based on proposing variation to the PoS working principle and trying to handle a particular limitation of PoS. Through careful analysis, specific and assumed best options on how to go about in addressing each of the four research gaps are laid down as future directions. This includes bringing hybrid implementation of different capability based consensus algorithms; generating, maintaining and testing traceability links on the system frequently; implementing merged mining of capability based consensus algorithm on a blockchain with a higher hash rate and through bringing more participants to the platform and making the committee of participant's mobility dynamic.

Keywords: block chain, consensus algorithms, proof of stake

INTRODUCTION

A blockchain is a growing list of records, called blocks that are linked using cryptography. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data [1]. The process of creating new block on the chain is called mining and the nodes which create the new blocks are called miners. These miners are in turn rewarded for their efforts to create new blocks. There are three critical concepts behind the technology [2]. Digital assets are distributed instead of transferred, the asset is decentralized, allowing full real-time access and a transparent ledger (record) of changes preserves integrity of the document, which creates trust in the asset. Though blockchain has evolved to many levels since inception, there are broad categories in which blockchains can be classified majorly [3]. These are public, private and consortium blockchains. Public

block chain is a permission less ledger and can be used by anyone who has access to the internet and who is eligible to download it. Private block chain is the one which is shared only among the trusted participants. The rules of a private blockchain can be changed according to different levels of permissions, exposure, number of members, authorization etc. Consortium blockchain can be considered as a sub category of private blockchain. The main difference between consortium and private blockchain is that consortium blockchains are governed by a group rather than a single entity.

A key aspect of blockchain technology is determining which user publishes the next block. This is solved through implementing one of many possible consensus mechanisms [4]. The general category being compute-intensive, capability and voting based mechanisms. Compute-intensive based consensus protocols are energy-hungry mining algorithms. The miner needs to invest in huge amount of power in order to generate blocks. Capability based consensus protocols select a miner based on various factors such as the amount of cryptocurrency owned by that miner, the contribution of the miner to the community, the trust the network has on the miner, or the amount of storage owned by the miner. Voting based consensus protocols use a voting system to elect a miner for generating a block, eliminating the issue of high energy consumption and wealth dominance. All in all, due to the enormous benefits of the technology, today many sectors are looking for ways to integrate blockchain into their infrastructures. However the focus of this work is on proof of stake (PoS) which is the pioneer from capability based consensus mechanisms [4]. This is because PoS is more affordable for less developed countries and can further be applied for supply chain traceability, property ownership or digital payments. But before applying it for such sensitive purposes, the limitations of the mechanism and how they have been addressed before should be studied. The reason being, incorrect implementations can cause significant security issues. Consequently, the gaps involved in those solutions should be identified so that better alternatives can be suggested as future directions.

In light of this, we conducted a detailed exploration to understand the issues behind PoS protocol and the consensus algorithms that tried to address those issues. Accordingly, four research gaps were identified. These gaps are generating less decentralized blockchain, vulnerability to 51% attack, not being tested for security and performance, and problem with another issue being raised when trying to solve one.

The previously developed mechanisms base their concept on PoS by adding some other factors besides the stake in order to select the specific miners. Therefore the mechanisms tried to handle one particular limitation of the PoS. In this work, through careful analysis, recommendations on how to go about in addressing each of the four research gaps are laid down as future directions. These include bringing hybrid implementation of different capability based consensus algorithms; generating, maintaining and testing traceability links on the system frequently; implementing merged mining of capability based consensus algorithm on a blockchain with a higher hashrate and through bringing more participants to the platform and making the participant's mobility dynamic. The main contributions of this work are:

- Provide substantial information on proof of stake and its limitations
- Propose way forward for further improvement on the proof of stake mechanism

- Details alternatives and opportunities to apply PoS locally on record handling and supply chain systems

The rest of the paper is organized as follows. Sections 'Proof of Stake (PoS)' and 'Limitations of PoS' discuss PoS in detail highlighting the variants of PoS and their limitations. The efforts made in the state of the art to address the limitations of PoS are presented in Section 'Addressing the Issues of Proof of Stake', while the gaps in the state of the art are discussed in Section 'Research gaps in the State of the Art'. Section 'Future direction' outlines the future directions that could be used to address the gaps identified in the state of the art. Finally, Section 'Conclusions' concludes the paper.

PROOF OF STAKE (PoS)

PoS was proposed in 2011, as an alternate consensus protocol, which was later used by the crypto currency Peer coin (also known as PPcoin) in 2012 [5] in order to eliminate the competitive approach of Proof of Work (PoW) consensus protocol consuming a high amount of energy. PoS is designed for permissioned public distributed ledger and works on economically bonded puzzle solutions. In PoS, as there are no new coins generated, there is no block reward and the miner, which adds a new block of transactions to the blockchain, only takes the transaction fee. In addition, the miner for a particular block is chosen in a way that depends on its economic stake in the network with other factors combined [6].

Forger/Miner selection methods

The miners in PoS are called forgers and the mining process is referred to as forging. At the beginning of a forging round, each forger deposits a certain amount of owned crypto currency coins in the network as stake. The deposit is used by the protocol to select the next forger in the network.

There are two forger selection methods [4]:

1) Coin-age selection based on the number of days the coins are held at stake; and,

2) Randomized block selection based on the calculation of a hit value 25 using the forger's private key.

Coin age selection method

In the coin age selection method [5], a forger having the maximum value of coin age is selected to forge the block. Coin age is calculated by multiplying the total number of coins that are being staked by a forger and the total number of days the stake is held as shown in Equation 1. For example, 30 coins held for 10 days will have coin age of 300 coin days. In order to participate in the process of forging, the coins must be staked for minimum of 30 days. The stake holding duration is involved in order to avoid repetitive selection of a forger having more number of coins and to make the process semi-random. However, it may occur that a malicious user increases the probability of forging a block by holding the stake for a long period of time. To prevent this situation the stake holding period is capped at the maximum of 90 days by the protocol. Once a block is created by a forger, the coin-age value of the coins staked by that forger becomes zero.

$$Coinage = coinsstaked * Numberofdaysstakeheld \quad (1)$$

Peer coin uses a coin age parameter as part of its mining probability algorithm. In the peer coin system, the longer your peer coins have been stationary in your account (to a maximum of 90 days), the more power (coin age) they have to mint a block. The act of minting a block requires the consumption of

coin age value, and the network determines consensus by selecting the chain with the largest total consumed coin age.

There's a time lag in accepting a newly created block after it has been produced. This time lag may lead to another miner solving for the same exact block. This leads to a temporary mix-up on the blockchain network, as the nodes try to decide which block of the two newly identified blocks it wants to accept. In such a situation, the block with the larger stake gets accepted into the blockchain. The other block, with a smaller stake, is discarded from getting added to the blockchain and is termed as an orphan block.

When peercoin blocks are orphaned, the consumed coin age is released back to the blocks originating account [5]. As a result, the cost to attack the peercoin network is low, since attackers can keep attempting to generate blocks (referred to as grinding stake) until they succeed. Peercoin minimizes these and other risks by centrally broadcasting blockchain checkpoints several times a day, to freeze the blockchain and lock in transactions.

When blockchain checkpoints are broadcasted as many times as possible during the day, the nodes in the network will always have up to date information on the status of the blockchain. This will make it harder for attackers and malicious users to generate invalid blocks and add them to the chain. In addition, the transactions are not moved and are locked until they are verified and known by the nodes existing in the network.

Randomized block selection method

In the randomized block selection method [7], a forger having a specific hit value is selected for forging the next block. In order to calculate the hit value, each forger encrypts the hash of the previous block using its private key. The encrypted value is hashed and the first 8-bytes of the hashed output are stored as hit value. The use of a private key in the calculation generates a unique hit value for each forger in the network. The forger having the hit value below a target value is selected for the process of forging. The target value (T) is calculated using Equation 2. To make the selection based on the capability of the miner, the calculation of the target value involves the amount of coins staked by the miner. Consequently, the target value of each forger in the network is different and the value is higher for a forger having more coins at stake. When a forger holds more coins, the target value becomes high which provides an opportunity for the hit value to be less and the forger to be selected. Moreover, to make the target value non-deterministic, the calculation involves the time elapsed from the last block forged changing the target value every second.

$$T = T_b - S - B_e \quad (2)$$

Where T_b is the base target value calculated by multiplying the previous block's target value and the amount of time that was required to forge that block, S is the time elapsed since the last block forged and B_e are the coins at stake.

In scenarios, where more than one forger is having the same hit value below the target value, additional criteria which is based on the cumulative block difficulty D_{cb} value is used to discriminate and select a forger.

The cumulative difficulty mentioned is calculated using Equation 3. The forger who forges the block receives the transactions' fees of all the transactions in the block. There is no mining fee in PoS. If any forger tries to generate a malicious attack, the coins

at stake are lost as a way of discouraging the forgers to not perform such action.

$$D_{cb} = D_{pb} + \frac{2^{64}}{T_b} \quad (3)$$

Where D_{cb} is the cumulative difficulty, D_{pb} is the previous block's difficulty (the level of effort to create the previous block) and T_b is the base target value.

The PoS cryptocurrency known as Nxt uses a system where each coin in an account can be thought of as a tiny mining rig. The more tokens that are held in the account, the greater the chance that account will earn the right to generate a block. The total reward received as a result of block generation is the sum of the transaction fees located within the block. Since *Nxt* does not generate new tokens as a result of block creation, redistribution of Nxt occurs when block generators receive transaction fees. Subsequent blocks are generated based on verifiable, unique, and almost-unpredictable information from the preceding block. Blocks are linked by virtue of these connections, creating a chain of blocks (and transactions) that can be traced all the way back to the genesis block. Block generation time is targeted at 60 seconds, but variations in probabilities have resulted in an average block generation time of 80 seconds, with occasionally very long block intervals. If this specified time for generating a block is not met by the selected node, penalty is set for the delayed block submission and the process for selecting another node to generate the block continues.

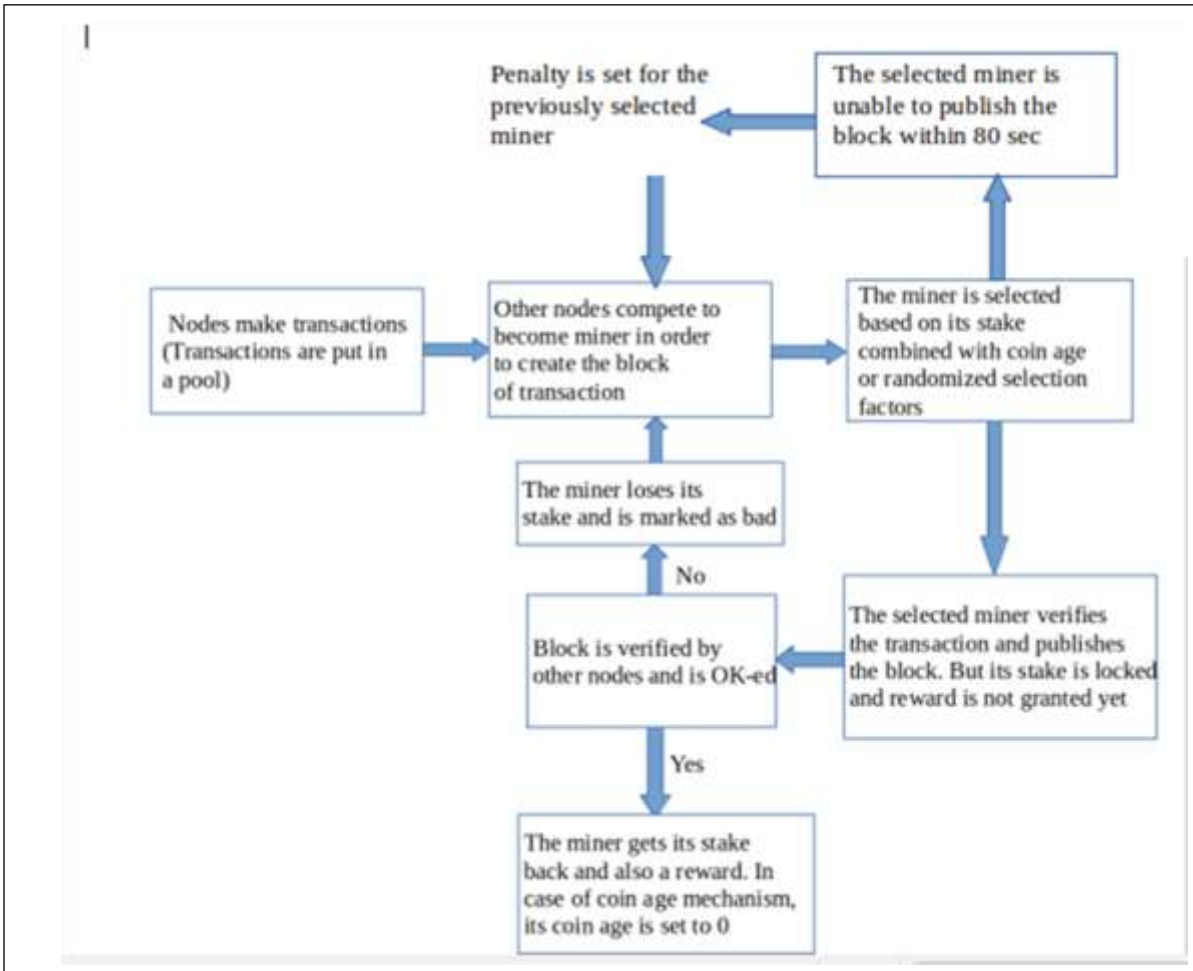

Figure 1: PoS based mechanism workflow

Generally, PoS involves transactions and selection of miners/forgers to validate the transactions. This mechanism is shown in Figure 1.

Variants of Proof of Stake

PoS comes in many variants from minimum to significant changes on the base protocol [6]. The most apparent fashion in which the consensus mechanisms differ is what strategy they implement to decide which node should be eligible to add the next block.

Leased Proof-of-Stake (LPoS)

LPoS [6] is an enhanced version of PoS. In a regular PoS system, each node that holds a certain amount of crypto currency is eligible to add the next block to the blockchain but in the LPoS system, specifically on the waves platform, users can lease their balance to full nodes. With LPoS, the user will have the ability to lease waves from the wallet to different contractors which can pay a percentage as a reward. The larger the amount that is leased to a full node, the higher the chances of that full node being selected to produce the next block. If that full node is selected to produce the next block, the leaser will then receive a percentage of the transaction fee that is collected by the full node.

Delegated Proof-of-Stake (DpoS)

DPoS [8] introduced another party besides the validators into the PoS system, which are called delegate. The delegates are the token holders. Since the beginning, there will be a certain fixed amount of validators/miners selected to forge new blocks into blockchain. Delegates will then vote on which validator to forge the next block. The voting weight is determined by the amount of coin staked. The validator that wins the voting will proceed and create a new block, then the reward will be shared and distributed to the delegates.

Masternode Proof of Stake

In masternode PoS, nodes become masternodes when meeting an amount of stake which is set as minimum. Masternodes are significantly invested with their large amount of stake. Therefore, they are considered more trustworthy than a regular node that exists in a Proof of Stake consensus mechanism. Masternode PoS is usually paired with regular proof of stake or PoW when processing transactions [9].

The aim behind creating such variants is to have an extra and various ways of selecting validators still without diverging from the basic principle of PoS.

Safety features in PoS

The following are included as safety features in PoS so as to keep the system secured.

Penalties for attackers: Some protocols using Proof of Stake include penalties for blockchain attackers. According to this protocol, a malicious validator can lose his entire stake if the network is attacked. Another penalty is in the form of loss in the value of the crypto currency involved, which in turn means loss in the net worth of the attacker.

Barriers to 51% stake: Another safety feature is that it is very difficult for a single entity to purchase a 51% stake in one go. Demand for the coin is bound to push up the price, making it a very costly option.

LIMITATIONS OF PoS

Some of the drawbacks that PoS consensus mechanism exhibits are the following.

Favors the rich

PoS algorithm allows users to stake their holdings as a means to verify the consensus. While investors cannot trade these staked assets, they earn proportionate returns for their investment. Consequently, the larger someone's staked holdings, the larger their return will be. In essence, this enables investors who already retain substantial holdings in a particular crypto currency to gain more shares. Having such staking invariably leads to greater centralization and the rich getting richer.

Reduces transaction flow in the network

Depending on the application, the transaction can be the transfer of a financial value or the execution of a smart contract. Therefore, when we say reduced transaction flow, we mean small movement of the digital currency. In PoS, since it is used as a stake to mine more blocks and get more profit, the miners would prefer to hold on to their stakes instead of moving them as transactions.

Encourages malicious users

This occurs because, in PoS, the staked coins are returned back to the nodes which have not been selected as miners. This limitation was not that frequent in PoW since the computational power used by the miner is non-retrievable [4]. However, in recent years more malicious users are observed in POW (e.g., in Ethereum Classic and Bitcoin gold [20]). Miners can form groups known as mining pools and each miner in a pool uses its capacity, and the mining reward is divided among the miners based on their mining contribution. If a mining pool owns more than 50% of the network's computing power, then it is likely that those miners would be able to prevent the validation of proposed transactions, and consequently stop the transactions between users. This will in turn give rise to the problem of 51% attack.

ADDRESSING THE ISSUES OF PoS

Various consensus protocols have been proposed in order to address different aspects of the drawbacks of PoS which were described in Section ‘Limitations of PoS’.

Rich getting richer

To address the problem of rich getting richer, the following algorithms have been proposed.

Delegated PoS (DPoS)

In order to solve the issue of rich getting richer in the PoS, a protocol called Delegated proof of stake (DPoS) [8] was proposed by Larimer. DPoS selects the forgers based on election rather than on the amount of staked coins owned. Unlike PoS, which follows direct democracy, it works on the concept of representative democracy. It boosts better distribution of reward as people tend to vote for the delegate (could be a casual user not necessarily rich) who will give back most rewards to them, thus favors decentralization. However, this protocol does not consider the case where each node votes for itself and has not been tested yet for its performance and protection against security threats.

Proof of Space (PoSpace)

Dziembowski et al [10] proposed proof of space (PoSpace) also known as proof of capacity where a miner having enough disk space wins the right to generate the next block in the chain. It generates all the random solutions, also called plots, using Shabal algorithm in advance and store it on the hard drive. This stage is called plotting and it may take days or even weeks

depending on the storage capacity of your drive. Then on the next stage, miners match their solutions to the most recent puzzle and the node with the fastest solution gets to mine the next block. Although this protocol consumes less energy and does not favor the rich, it can be prone to malware attacks as the plot of hashes stored in the hard disk can be easily attacked and tampered. Moreover, the miner does not burn any energy or coins in order to mine the block, encouraging malicious users to generate invalid block.

Proof of Believability (PoBelievability)

PoBelievability [11] was proposed in 2017. In this algorithm, the role of a miner is performed by a validator, where the validator with the highest believable score is selected for the generation of a block. Being developed by the Internet of Services Token (IOST) team in 2018, it implements a new sub-token called servi, which is awarded to good actors and cannot be traded. It serves to create a “believability score" of a particular node and verify it. Other factors that influence this process include IOST balance, the number of positive reviews of the node, and previous behaviors. Moreover, the validators are selected both randomly and algorithmically, so that the proven validators may participate along with the new ones.

Proof of believability avoids rich getting richer because the miner is not selected only based on the amount of coin he holds but based on believability score which is a combination of different factors. These are the amount of tokens, positive review and previous behaviors. This makes it not depend solely on the amount of coins. However, it has not been evaluated for security and privacy issues.

Proof of Elapsed Time (PoET)

PoET [12] was developed by Intel in 2016 to solve the issues of rich getting richer and centralization of the network, using trusted execution environment (TEE) along with Intel's software guard extensions (SGX). In PoET, each validator is assigned a wait time T for block construction which is assigned and monitored by the protocol. The first validator, who finishes the waiting time, creates and publishes the requested block on the network. The protocol works as the hybrid of first come first served and random lottery fashion. PoET requires the use of specialized SGX hardware developed by Intel. The dependency on specific hardware makes Intel as the controlling authority and thus the system less decentralized.

Reduced transaction flow

The following algorithms are proposed to address the reduced transaction flow problem.

Proof of Importance (PoI)

The crypto currency platform NEM introduced PoI [13] to address the issue of reduced transaction flow existing in the PoS protocol where the miners do not perform transactions in order to increase their chances of mining. Instead of considering only nodes' balances to determine the next winning node for solving the next block, it takes into account factors including a node's reputation and the number of transactions to or from that node. Therefore, this method of consensus considers productive network activity of nodes which is more efficient than only nodes' balances. PoI also discourages malicious users from mining invalid blocks as the miner is selected based on the recent transactions and the transacting parties. However, if a group of malicious attackers performs transactions amongst

themselves, then the network security might be compromised. In addition, PoI implicitly favors the rich as the calculation of the importance score is based on the number of vested tokens, and the number and size of recent transactions.

Proof of Stake Velocity (PoSV)

PoSV [14] was proposed by Ren in 2014 to promote more active network participation, which is necessary for an economy to grow. This is done by using an exponential growing function for the coin age calculation as compared to linear function used by PoS. PoSV is designed to encourage both ownership (stake) and activity (velocity). Due to the exponential decay in the growth rate of coin age, the newly accumulated coins will dominate the stale coins encouraging the stake holders to actively move their stake by transacting with counter parties. But if the counter parties exchange crypto currency with each other just for the purpose of reinitializing the age of the coin, then the economy will not benefit from this financial flow. Moreover, the protocol still favors the rich since it encourages higher stake.

Malicious users

The following algorithms are proposed to tackle the issue with malicious users which disrupt the functioning of the technology and the service it provides.

Proof of Burn (PoB)

To address the issue of high energy consumption in PoW and the problem of retrievable staked coins encouraging malicious users in PoS, Ian Stewart proposed Proof of Burn (PoB) in 2014. In PoB [15], the miners need to burn the coins by sending them to an irretrievable address, known as eater address. However, PoB favors the rich because the probability of a miner to be selected is higher if he burns more coins. The algorithm has not also been tested for its performance.

Proof of Authority (PoAuthority)

PoAuthority [16], a reputation-based consensus protocol was proposed in 2017 where the reputation or identity of the miner is at stake instead of coins. The identity is staked by a group of validators (authorities) that are pre-approved to validate transactions and blocks within the respective network. The group of validators is usually supposed to remain fairly small (25 or less) in order to ensure efficiency and manageable security of the network. But this algorithm makes the blockchain network less decentralized as the mining is performed by the fixed group of validators. Moreover, it has not been tested for its performance and protection against security threats.

Proof of History (PoH)

PoH was proposed in 2017 by Yakovenko [4]. It uses SHA-256 hashing algorithm that runs over itself continuously with the output being the next input. The node that verifies the transaction is called leader and it is selected based on the amount of stake the node holds. The leader runs the hash function for a random starting value, and passes the output as the input for the same function again. The leader records the output of the function every time and the corresponding counter value indicating the iteration. When a transaction takes place in the network, the leader verifies and combines it with the current hash output. This combination is then used as the next input and the counter value, the transaction and the hash output are recorded in the ledger. In this way, the transaction is recorded to have happened before and after a particular counter value.

The ledger state is then passed to the verifiers who verify the transaction validity and recalculate the hash output for all the counter values. However, PoH favors the rich for the selection of the leader making the process deterministic and centralized.

Proof of Activity (PoA)

PoA is a hybrid of PoW and PoS, and attempts to bring the best of both [17]. In PoA, the mining process starts, in the first phase as a standard PoW process with various miners trying to outpace each other with higher computing power to find a new block. When a new block is found (mined), the system switches to PoS, with the newly found block containing only a header and the miner's reward address. In the second phase, PoA selects N validators referred to as stakeholders based on the number of coins they have by using the PoS algorithm. Each selected stakeholder verifies and signs the block, and broadcasts it into the network. The more crypto coins a validator owns, the more chances the validator has for being selected as a signer. This mechanism suffers from the issue of high energy consumption as in PoW and it favors the rich as in PoS.

RESEARCH GAPS IN THE STATE OF THE ART

When looking at all the algorithms that have been implemented to solve the limitations of Proof of Stake, there are gaps in how the mechanisms handle the service to function correctly. These gaps are:

Raising another issue when solving one

This research gap occurs because of the fact that the previously proposed mechanisms only aimed at solving one of the three issues that exist in proof of stake, which in turn gave opportunity for the other issues to still exist and new issues to arise. For instance, in order to avoid the rich getting richer problem, Proof of Space provides capacity as a stake and not coins which in turn encourages malicious users to generate invalid blocks since the miner does not burn any energy or coins in order to mine the block.

Making the blockchain network less decentralized

The low degree of decentralization results from the fact that the applied consensus mechanisms require each node to agree on a certain state to reach total finality before a new transaction is committed to the distributed ledger. If a node owns some amount of stake in the network, then it means the node owns that much vote in the network. Given that most of the stakes in the network are not uniformly distributed, then those nodes that have more stakes exhibit more authority in the network and can influence the networks consensus which could easily lead to less decentralization.

Not being tested for performance or protection against security threats

A developed system needs to undergo performance testing using various metrics. It should also be provided with protection against threats. One of performance metrics is 'Throughput' which is calculated as the number of requests the system can process in unit time. The other metrics is 'Latency' which is evaluated as the time required processing a transaction from its initiation to final confirmation. On the other hand, security threats could be software flaws or malwares that can range anywhere from malicious crypto mining software to code that could shut down a company's servers. Crypto jacking is a type of malware which, simply put, is unauthorized and often unnoticeable takeover of a computer's resources to mine crypto currency. Although

crypto jackers don't directly steal money from their victims, the malware they inject causes performance issues, increases electricity usage, and opens the door for other hostile codes. Some of the proposed consensus mechanisms lack performance test and protection against security attacks.

Vulnerable to 51% attack

A 51% attack on a blockchain refers to a miner or a group of miners trying to control more than 50% of a network's mining power, computing power or hash rate. People in control of such mining power can block new transactions from taking place or being con_rmed. Whenever a transaction is carried out on a blockchain, be it by Bitcoin or any other crypto currency, it is usually put in a pool of unconfirmed transactions. Miners in return are allowed to select transactions from the pool to form a block of transactions. To be able to initiate such an attack one would need to spend an enormous amount of money to acquire mining hardware capable of competing with the rest of the network. However a bug in the code of a blockchain could in some cases open the door for a miner to produce new blocks at a much faster rate thus be in a position to initiate a 51% attack. In fact, an attack was performed in April 2018 on the Verge (XVG) blockchain. In this specific case, the attacker found a bug in the code of the verge blockchain protocol that allowed him to produce new blocks at an extremely fast pace [18].

FUTURE DIRECTION

From the research gaps mentioned in Section ‘Research gaps in the state of the art’, there can be a number of ways that can be undertaken so as to provide some kind of solutions or workarounds. Here, we will discuss some recommendations for each of the research gaps.

For the first problem of "Raising another issue when solving one", the way forward can be to have an implementation of hybrid algorithms. The focus can be on integrating some of the algorithms existing within the category of capability based consensus algorithms rather than on combining compute-intensive with capability based or voting based protocols. It will help to come up with a solution that could address all the three limitations of proof of stake or two of them at the same time. This can be achieved by first understanding the specific problems that each of the algorithms address. Afterwards, selecting one from each, the mathematical logic and implementation of those algorithms, their structure or architecture will be studied in depth.

Through this, one's implementation can be incorporated with the other with no conflicts arising or security concept being compromised. Putting into consideration the working platform of each algorithm and pulling out the rules that best describes the protocol or pinpoints its strongest capability, it can be possible to come up with a strong and efficient protocol. It needs deep investigation into each algorithm but as a first footstep: Proof of Believability, Proof of Importance and Proof of burn can be further studied and integrated to address the issues behind Proof of Stake.

When looking into the second issue of "Making the blockchain network less decentralized", despite envisioned decentralization; the high cost of mining has led to considerable centralization of consensus in practice. In order to share the risk of spending resources and the problem of failing to win the competition, groups of miners form mining pools. This resulted in just a few mining pools validating most transactions. Although, in practice achieving consensus is more centralized than it was envisioned, a certain degree of

decentralization is still retained. In order to make the network more decentralized, we can incorporate a consensus algorithm for instance Proof of Believability (PoB).

In PoB mechanism, the entry barrier to becoming a candidate is lower than other networks; therefore more community members are able to participate. At the same time, the committee members will have increased variation with higher frequency. The committee's mobility is very dynamic, and the degree of decentralization is much higher than others, thereby achieving better community autonomy while also guaranteeing higher security.

In order to address the third issue of "Not being tested for performance or protection against security threats", in blockchain, security issues range anywhere from malicious crypto mining software to code that could shut down a company's servers. This can be solved to some extent through applying software traceability links which makes it easier to track and verify vulnerabilities for product integrity. Software traceability is the ability to inter-relate any uniquely identifiable software artifact to any other, maintain required links over time and test their performance. Usually the apps built on top of the blockchains are still susceptible to bugs. Therefore, it's important that they need to undergo rigorous testing and review. This is where traceability links come in handy. Traceability links are important factors for the reuse, testing and maintenance of software system components. The tracelinks can be applied on the software artifacts based on user requirements, which can then be visualized periodically on a dashboard and in turn can give a better chance of identifying threats. Additionally, any reputable application should have redundant security measures in place. The number of requests the system can handle should be measured. If there's an issue with the performance value, action should be taken to check whether there are mysterious programs running or for any presence of security loopholes.

For the fourth issue of "Vulnerable to 51% attack", generally, 51% attacks are one of the most recognized blockchain security issues. In 2018, several notable crypto currencies, such as ZenCash, Verge, and Ethereum Classic were victim to 51% attacks [19]. Overall, attackers walked away with over USD 20 million due to this blockchain security issue. Most of the time, the pools vulnerable to these kind of attacks are small pools or the ones implementing proof of work consensus mechanisms. As a solution, being vigilant of mining pools, implementing merged mining on a blockchain with a higher hashrate, or switching to a different consensus mechanism are all viable options [19]. All the options seem possible but the merged

Table 1: Proposed Future directions

No	Gaps	Future direction
1.	Raising another issue when solving one	Implementation of hybrid capability based consensus mechanism
2.	Making the blockchain network less decentralized	Incorporate Proof of Believability algorithm and have more community members
3.	Not being tested for performance or protection against security threats	Applying Software traceability links and perform scheduled checking
4.	Vulnerable to 51% attack	Using merged mining of capability based consensus algorithms through allowing different crypto currencies to be combined

mining could yield a better result and be more appealing especially for smaller pools. Merged mining is a mechanism that allows different crypto currencies, which use the same algorithm, to be mined together. The benefit is that every hash the miner does, contributes to the total hash rate of both (all) merged currencies, and as a result they are all more secure. The big advantages of merged mining are greatly reducing the investment costs for miners since they won't need to buy brand new equipment. Miners can also earn extra rewards by maintaining the secondary chain. The other advantage is crypto currencies with lower hashrate can gain additional hashing power by piggybacking off a crypto currency with higher hashrate and thus eliminate the problem of 51% attacks. Currently, merged mining is performed on blockchains that are implemented based on PoW mechanism. However, here it is stated as a future direction to be applied in PoS implemented blockchains. It can be carried out in such a way that an encrypted puzzle is provided and if a miner successfully solves it, the corresponding block and the solution are combined and put into their respective blockchains.

In Table 1, each of the identified research gaps and their corresponding proposed future directions are summarized.

CONCLUSIONS

Blockchain technology was introduced over a decade ago with the intention of carrying out digital transactions without the need for third party. This technology has been applied to different sectors other than finance which include health, agriculture, advertising and many more. Through this, various architectures and consensus algorithms have been proposed to produce a specific kind of blockchain system. Generally, the structure of blockchain system falls into these three categories: public, private and consortium while each of them is being used for specific purposes. The consensus protocols include compute-intensive, capability based and voting based. A deep dive into the implementation and limitations of Proof of Stake consensus mechanism, which is the pioneer of capability based protocol, has been done. This is because Proof of Stake is more affordable for less developed countries and can further be applied for supply chain traceability, property record system and other sensitive and critical areas. This work has highlighted the consensus algorithms which are proposed considering the main drawbacks of proof of stake algorithm. It can be noted that the algorithms implemented to solve one of the issues from the three limitations identified, i.e., rich getting richer, reduced transaction flow, and malicious users, usually end up with the other issue still being present and untouched.

As it has been identified in this work, there are four main research gaps that exist currently in the state of the art which are raising another issue when solving one, making the blockchain network less decentralized, not being tested for performance or protection against security threats, and vulnerable to 51% attack. Recommendations are laid down in order to address these gaps which include implementation of hybrid capability based consensus mechanism, incorporate Proof of Believability algorithm and have more community members, applying software traceability links and checking them frequently, and using merged mining through allowing different crypto currencies to be combined respectively.

Overall, putting into consideration the blockchain platform and its specific applications, the directions stated above

could be used as one of the possible ways through which one can try to address the aforementioned issues.

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A CLASSICAL HEURISTIC ALGORITHM IMPLEMENTATION FOR LOGISTIC ANALYSIS OF WASTE COLLECTION PROBLEM: A CASE OF ADDIS ABABA ARADA SUBICTY

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ABSTRACT

This paper intended to implement classical algorithms for logistic problem especially in revers logistic by using waste collection process to demonstrate. Along with its strategic nature and possibility for realization using analytical method, waste collection process considered as a vehicle routing problem, which is beyond solid waste management, instead a city logistic problem where optimization is demanding. For the case problem, mixed integer programming mathematical model deployed to node routing problem-capacitated vehicle routing with the objective of minimizing total collection cost. Local search based on 2-Opt and Or-Opt improvement heuristics used to solving model based on initial solution obtained from Clark and Wright (saving method). Model relaxed to both Hamilton cycle and Hamilton path to accompany case problem and verified by problem instant with optimal solution cited. Due to relative operational data availability, Arada-subcity considered and coordinate of waste bin obtained using geodetic information on the Google earth while problem parameters determined based on the secondary data. . Model validation done using distance traveled and utilization of vehicles in the route and substantial result obtained with a saving of about 29.453 % in kilometers traveled per year and an increase of vehicle utilization from 68.19 % to 95.46% for each route. The finding shows a need of revision on the current practices of waste collection process in one hand and how classical heuristic are both potential and essential for solving problem of interest in the other hand.

Keywords: Classical heuristic, Logistic Analysis, Optimization, Vehicle routing

INTRODUCTION

In a solid waste management, the collection process estimated to consume 70 up to 80 % of operational cost [1] in developing country and 60-80% at global level [2-4].Whereas according to the report by World Bank and USAID, of the annual allocated budget of the municipal, 20-50% spend to solid waste management [5]. Consequently, since collection rout design is viable [4] in mitigating the problem ,integrating and combining those factors like storage facilities route, transporting mechanism and vehicle distribution and disposal strategy is becoming interest of research[1,2,4], [6,7,8,9,10] and in fact is a kind of an optimization problem. Optimization of waste collection routing as city logistic[11], is therefore, a decision upon for example, which streets must each vehicle follow, which containers should each one of them collect and how many trucks should a fleet for a given city have.

The minimum cost at the underlying of customer satisfaction should be addressed and cost reduction in waste collection routing consist (i) minimizing vehicle trip to disposal site, (ii) optimizing the collection routing and (iii) maximizing the number of full loaded trip to the disposal site.

In its search space, optimization process is either continuous or combinatorial and combinatorial optimization problem (COP), deals to find the optimal solution (i.e. arrangement, grouping, ordering or selection) from a finite set of objectives to optimize (maximize or minimize) a function of discrete variable. Of course, the task of researchers in the area is to make ready the optimization problem for converting to decision problem, which always is either p or NP class [12]. The waste collection routing problem that can be simply taking as vehicle routing problem is an NP-hard, as it is difficult to have Polynomial algorithms to find the solution [13].

Vehicle routing problems (VRP) is a generic route management problems that could possibly extended in to various VRP variants. The mathematical formulation proposed by Baldacci, et al., [14] for generic VRP is based on the various assumptions regarding with capacity utilization, depot type, vehicle homogeneity, rout vehicle combination etc. Regarding to the actual logistic operation especially in urban areas the problem is a type of combinatorial optimization problem and can be formulate using two different mathematical problems, node routing problem [15] (the classic VRP/CVRP) and Arc routing Problems (ARP)[16].

Practically, the solid waste collection system in case of Addis Ababa city seems well fit for both modeling. For the latter case, those organized collectors are expected to collect the various inhabitants' waste along the road near whilst the waste collection process by the agency using the transfer stations "the containers" is a kind of node routing and is the concern of this study. The waste collection process of the case study has been characterized with that of (i) containers have been emptied more than a week (ii) vehicles sometimes found Visiting collection points without service, "deadheading operations" and (ii) in balance route , overflow of wastes resulted from vehicle overload in some street and routes with under load capacity in other routes. The annual vehicle load utilization however found to be about 68%.

The study aims to optimize vehicle routing for the waste collection process by formulating a mathematical model and selecting the solution approaches for optimal vehicle routing. The remaining of the paper includes in section two a review of optimization solution approaches and waste collection optimization while section three about methods and material presentation. Result and discussion presented in section four with an optimal solution of the case study. Finally, conclusion is made and future work drawn in section five.

LITERATURE REVIEW

Solid waste management is the action of collection transportation, storage recycling or disposal [4], [8] while solid waste management system consists of plans for how to manage the waste and plants for treatment [17]. The objectives behind solid waste management are vast but with at the heart of minimizing the adverse effect of the solid waste Tanaka, M (1998) in [15]. Concerning to the collection process the objective is either of travel time and /or travel cost, minimize number of vehicle route compactness, personnel and workload balancing [4], [8]

Different solid waste management models like Cost Benefit Analysis (CBA), Life cycle Analysis (LCA) and Multi-Criteria Decision Analysis (MCDA) being forwarded [18]. The distinguishing factor for those models however, is either the goal or the methodology. It is the Cost benefit Analysis that hysterics with aim of this study problem From the logistic point of view, the municipality solid waste system has two basic planning tasks, location of facilities (plants, depots, warehouse, i.e. containers in this case etc.) and routing of vehicle and a kind of Strong NP-hard problem combining these two task is known to Location Routing problem (LRP).

To the best of our knowledge, the first article related to the optimization of waste collection routing is a paper studied in United States of America[19] for New York and Washington Dc cities. Following USA countries like Trabon, Turkey [10], Barcelona [20], Athens, Greek[21],Hanoi, Vietnam [22], and Porto Alegre, Brazil [23] tried to minimize the cost by optimizing collection routes. Related to the application of VRP variant to the solid waste collection process, it is VRPTW that has been employed in a great extent [11], [24], [25].

Waste collection process modeling problem and solution approach consequently become an important question in the optimization process and the vehicle routing problem for waste collection process is not far away for effect of the mathematical expression. To mention such mathematical model for instance linear programming [26] to optimize the solid waste disposal system, [27] to minimization cost of collection, transfer, refuse to energy (RTE) and disposal .However, due to the requirement of real world problems, a restriction has been invited on the domain of the decision variable and mixed integer programming (MIP) is to be mentioned especially when there is a need to make an entity either passive or active. The municipal solid waste generation model based on cost optimization by [28] at different level of the waste management stage, a non-linear model for decision support of planner to the optimal number of landfill [29] are MIP. The comparative analysis made by Hasit and Warner [30] between linear programing (LP) and MIP shows that the latter performs well especially for increased facilities and discrete size of resource. Solution approaches must always come next and in an optimization problem, it has been generalized to have exact method, approximate method and heuristics method [31].

In exact method, the advantage is in getting of best solution (exact solution) despite of the unreason able amount of time needed especially when size of problem increase. Branch and bound and dynamic programming are the most approaches in an exact method that researchers has employed [32-34]. For an increase problem size, the aim is not to have exact solution rather an optimal one and an approximation method has been proposed to be employed as approach based on the approximation ratio α for the feasible solution.

For the optimization problemsO_p, if the algorithm θ solves the problem instance$I_n \in O_p$ and θ can give a feasible solution forI_n, the definition for the approximation ratio α depend on the measure of the $\theta(I_n)$ and the measure of an optimal solution Opt(I_n) that is, $\alpha(\theta) = min \frac{m_{I_n\theta}(I_n)}{m_{I_n}\mathrm{Opt}(I_n)}$. Beside the degree of the final solution obtained, there is another very important difference between exact and approximate method, that is exact method can prove that no solution exist in the case problem.

Heuristic method is either rout building that start from scratch or route improving by which an algorithm that tries to produce an improved solution because of an already available solution.

Having of the computational complexity $O(n^2 \log n)$ as an advantage to be solved in a polynomial time the Clark and Wright method since it introduced several enhancements have been proposed for it. Gaskell (1967) and P. Yellow (1970) in [34] for instance proposed $S_{ij} = c_{i0} + c_{j0} - \lambda c_{ij}$ for route shape λ parameter weighing relative importance of c_{ij}. For the other parameter μ Paessens (1988) in [34] improved the saving algorithmto $s_{ij} = c_{i0} + c_{j0} - \lambda c_{ij} + \mu|c_{io} - c_{jo}|$.

Remarkable improvement even from the best known solution was obatined by Gilbert, et al. [35] when the parallel version of Clark and Wright method combined with a 3-Opt local search heuristcs. The result obtaine by the paralle saving method outperform the sequential one and it was on average of 6.71% above the best known solution when combined to 3-Opt.

The 3-Opt. method however is an improvement hueristic under the general terminology of the r-Opt(or sometimes called K-Opt) by which about r arcs are to be removed and replaced by the other r arcs and the neighborhood obtained and cannot be improved further is an r- Opt optimal. Both 2-Opt and 3-Opt improvements are a local search heuristics under r-Opt, r $\in (2,3, \ldots . n)$ and ncreasing the value of r guarantees a better solution with higher computational effort [36]. As a modification for r-Opt, several approaches has been researched like Lin and Kernighan (1973) and Or-Opt by Or (1976) in [35]. While it is the Or-Opt which aims in displacing strings of three, two or one consecutive vertices to another location utilized in this study These three options of the Or-Opt denoted in this study as Or-Opt [3], Or-Opt [2] and Or-Opt [1] respectively to the three, two and one vertices displacement. As cited in [37] about local search in a combinatorial optimization, E.Aarts and J.K Linstra (1996) found that the 3-Opt outperforms the 2-Opt only by 2% for 100 customer problem. While the 4-Optalgorithm is not better than 3-Opt algorithm, the longer the value of r the longer it would take the computational time. Or-Opt algorithm on the other hand has an advantage over the 3-Opt. In 3-Opt it is must to reverse the direction of route and there is a possibility of obtaining infeasible solution whereas the Or-opt operator can keep the route direction and guarantee a feasible solution.

Output quality of the local search heuristics however depends both on the initial solution and the mechanism of the neighborhood used and that is why the Clark and Wright method applied here to intiate the solution.

Generally, with respecte to modeling issue and from the logistic point of view, the municipality solid waste system has two basic planning tasks, location of facilities (plants, depots, warehouse, i.e. containers in this case etc.) and routing of vehicle. As a gap identified theoretically, local search or improvement heuristic potentially depends on both the initial solution and the mechanism of the neighborhood use*d, whereas* of the reviewed result what a researcher have emphasized for is the latter and no literatures found to deploy construction heuristics to initiate improvement heuristics as what we perform by using saving.

Methods and Materials

For the realization of the cas study waste collection process the problem has to be defined and a coceptual model supposed to be develpbed alnog with decicion variable and parameters of the problem.

Problem Description and Concetual Model Development

Tomodel mathematicalythe case study, a description of the prblem made based on the generic capacitated routing problem (CVRP) and a single depot with a homogeneous fleet of vehicle. For set of homogeneous vehicles K, set of collection point P, the CVRP mathematically can be described by a directed graph$G = (V, A)$, which consists (n+1) vertex for $V = n = 1$ the depot, $V =$,2,3 ….n are collection points and $V = n + 1$ the landfill. While$A$ represents the arcs for $A = \{(i, j): i, j \in V, i \neq j\}$to form a connection between depot and collection point and among collection points. The vehicles leave the depot empty, collect the waste of each customer at each collection point P to transport to the dump site and return to the depot empty. The objective of the study is to find the set of vehicle routes servicing all the customers with the minimum total distance.

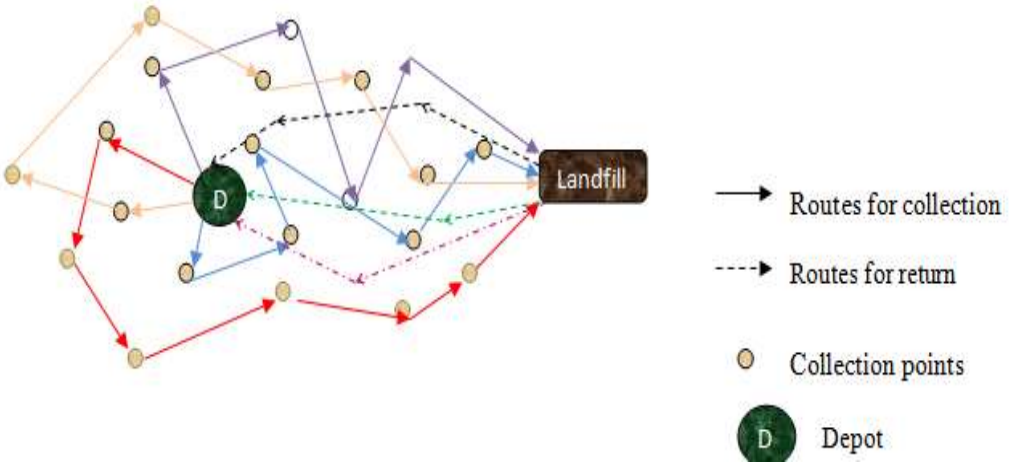

Figure 1 Schematic representation of collection route path

Variable, Parameters and Mathematical Model

x_{ij} : The binary variable "decision variable" and x_{ij} is one if the vehicle k traverse arc (i, j) otherwise zero.

Q: The maximum allowable capacity of the vehicle (in kg)

q_i : The amount of waste at a collection point i, for$i = 2 \ldots . n, q_i = 0\ for\ i = 0\ and\ i = n + 1$.

d_{ij} : Euclidean distance between points $i\ and\ j$.

Moreover, each collection point (v= 2...n) can designated as C ∈ $(c_1 \ldots \ldots \ldots . . c_n)$

An assumption then drawn for the implementation of integer programming as follow

i. The collection process of the waste for the model starts at the point where residential waste accumulated and ends at the landfill
ii. No consideration is given to the separation of the waste at all
iii. The collection point for the solid waste is for all waste generator agents (residential, institutions, industries)
iv. Transpiration cost is a function of the distance traveled
v. All tours start and end at the single depot
vi. The effect of the traffic congestion on the total cost for the objective function is trivial

vii. All collection centers are nearby to the street of the truck

The conceptual model assumes no plant for recycling, compositing or incinerating. Hence, the objective is to minimize the total distance traveled to reduce the transportation cost of the solid waste from various collection point to the disposal site. The mixed integer-programming model is formulated and each of the constraints like degree constraint, flow constraint, capacity constraint and sub tour constraints considered by respective equations.

$$Minimiz\ Z = \sum_{i\in V}\sum_{j\in V\setminus i}\sum_{k\in K} d_{ij} \quad (3.1)$$

$$\sum_{i\in V}\sum_{k\in K} x_{ij} = 1, \quad \forall j \in c \quad (3.2)$$

$$\sum_{j\in V}\sum_{k\in K} x_{ij} = 1, \quad \forall i \in c \quad (3.3)$$

$$\sum_{1}^{k} x_{1j} = K, \quad j = 2 \ldots n \quad (3.4)$$

$$\sum_{1}^{k} x_{j,n+1} = K, \quad j = 2 \ldots . . n \quad (3.5$$

$$x_{n+1,i} = k, \quad for\ i = 1 \quad (3.6)$$

$$\sum_{i\in V} x_{ij} = \sum_{j\in V} x_{ji} \quad \forall i,j \in V\setminus\{1,n+1\} \quad (3.7)$$

$$\sum_{i\in C} q_i \left[\sum_{j\in V} x_{ij}\right] \le Q\ \forall ij \in v, i \ge 2, i \ne j \quad (3.8)$$

$$u_i^k - x_j^k + Qx_{ij}^k \le Q - q_i \quad (3.9)$$

$$q_i \le u_i \le Q, \quad \forall i \in V\setminus\{0, n+1\} \quad (3.10)$$

$$x_{ij} \in \{0,1\} \quad \forall i,j \in V, k \in K \quad (3.11)$$

$$Q, q_i\ and\ d_{ij} \ge 0, \forall \quad (3.12)$$

A two-phase local search applied, the Clark and Wright method in the first phase, 2-Opt and Or-Opt heuristic implementation in the second phase. This is because of that the outcome of the local Search is dependent to both initial solution and mechanism of the neighborhood used and hence this study applied the Clark and Wright method to initialize the solution.

For the vehicle capacity Q and customer demand q_i at each point, Clark and Wright method implemented using the following procedures.

- Generating rout r_i, $for\ i = 1, 2..n$ to get for instance, $r_1 = 1 - i - 1$ and $r_2 = 1 - j - 1$ for customer $i\ and\ j$ and starting point of 1 (depot.) (figure 3)
- Calculate the savings S_{ij}using $S_{ij} = d_{1i} + d_{j1} - d_{ij}$
- sorting down the list of saving in decreasing order
- Assigning the customer to the route starting with the highest saving

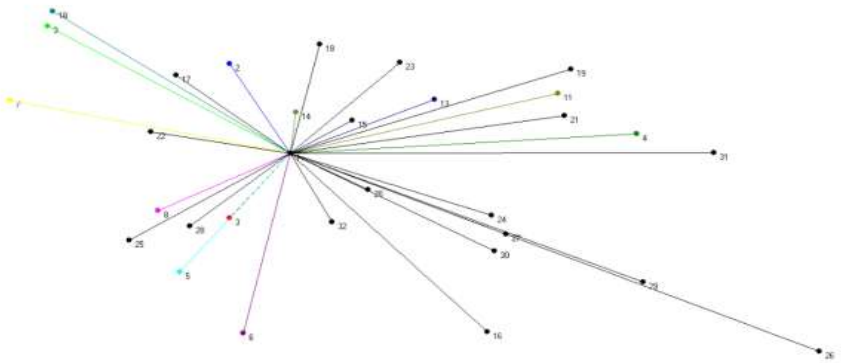

Figure 2 Generated route (for 31 customer points)

The generated route then has to be combined keeping that (a) the combined route cannot exceed vehicle capacity ($d_i + d_j \leq Q$, (b) no insertion is possible in the interior of the tour. While merging the rout combination operation applied iteratively to pertain the parallel version of the saving method. Constraint 3.5 gets relaxed both in the initial solution and improved one to a a Hamilton path with d_{jl}^{e} denotes the distance between the end customer point j and the landfill, d_{1l} is the distance between depot and landfill and hp_{di} is the Hamilton path of route i. Once the initial solution initiated using the saving method, the local search improvement heuristics deployed based on (i) intra- route (figure 6. a) and (ii)

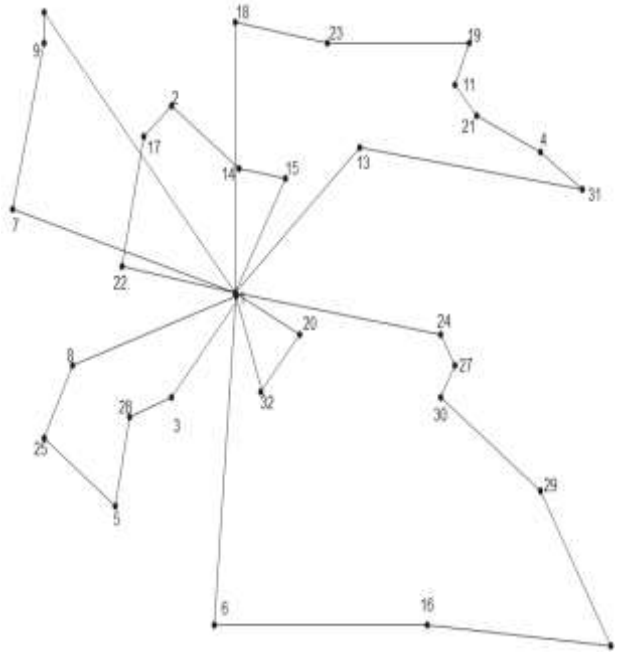

Figure 3 Hamilton cycle of the initial solution (obtained from VRP-solver)

inter-rout (figure 6. b) operations to improve the solution. while applying the immprovement heuristics ,instead of chossing the best pairing of route at each step, a pair of routes sellected at random so as not to be trapped locally and choose the best overall solution.

dummy distance d_{jl}^{e} between each customer of the rout and depot of the Hamilton cycle (figure 4). Equation 3.13 gives the total distance of the optimized solid waste collection route (Rd_{opt})

$$Rd_{opt} = \sum_{i=1}^{R}\sum_{j=1}^{R}\left(d_{jl}^{e} + hp_{di}\right) + m * d_{1l} \qquad (3.13)$$

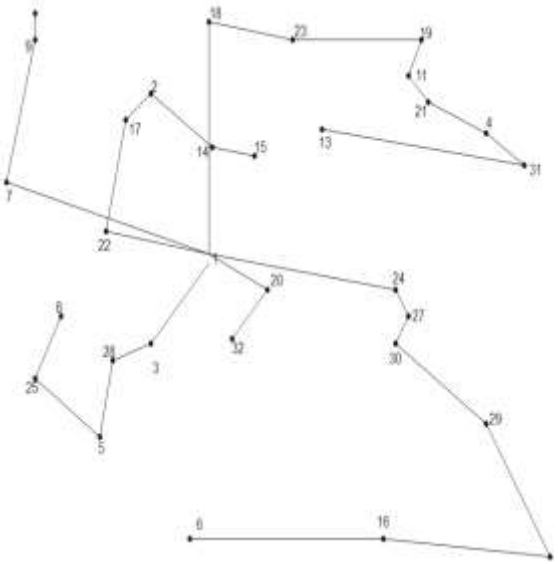

Figure 4 Hamilton path of the initial solution

The 2-Opt operation is an intra-rout operation and for a given feasible tour T the improvement algorithm repeatedly performs atour modification based on exachanging or moves until a tour is reached for which no operation yileds an improvement (locally optimal tour). To effect this k routes randomlly sellected from the resultd saving algorithm then two edges from the hamiltation path are removed (edges with doted line in figure 5) to have a paire of arcs $(i, i+1)$ and $(j + j + 1)$ and removing of these edge is to replace one edge by another .i.e. $\{i, i+1\}\{j, j+1\} \rightarrow \{i, j\}\{i+1, j+1\}$.
The 2-Opt algorithm adpoted is based on $O(N^2)$ so as to sellect two arcs (a_i) to be replaced in order to construct a new cycle (route).

K is the number of arcs being replaced and N is the total number of arcs available in the route while letter G is the graph of the cycle that consists of $a_1\, a_2 \ldots a_{N-1}$ arcs with a Hamilton cycle of total length TL (G). $G_{current}$ Indicates the incumbent graph of the problem which possibly replaced by the new graph G'.In the 2-Opt operator the neighborhood of graph G searched by removing arc(i,j) and $(i+1, j+1)$.

The process continues until no improvement is made and it is the total length, which helps in determining the exchange. As described Or-Opt is a modification of K-Opt and its advantage over 3-Opt is it can keep the route direction (figure5) and and guarantee a feasible solution. Of course Or-Opt can be considered as part exchange of 3-Opt (i.e. a section of route/s (one, two or three continuous points) between two points.

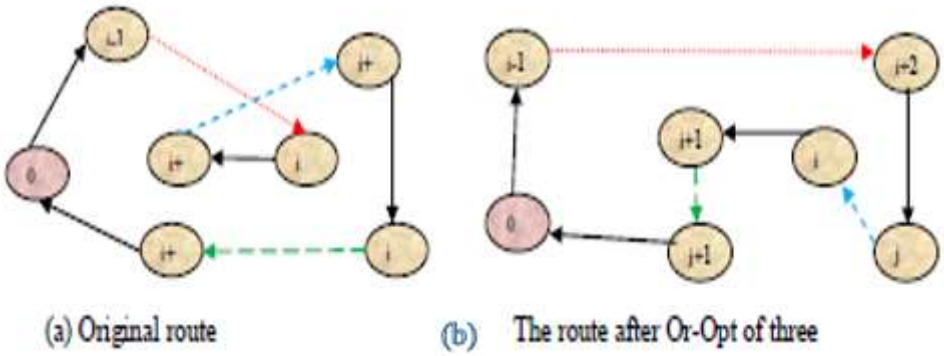

Figure 3 The Or-opt operator procedures (adapted from[38]

The relocate operator in Or-Opt algorithm works as if customer i is in route B= $(1,..,i,i+1 \ldots 1)$ and customer j is in route A $= (1,\ldots,j,j+1 \ldots 1)$ removing customer i from route B (shirking of route B') to insert in to route A (expanding A') so as to get the new routes$B' = (1,..,i-1,i+1..1)$ and $A' = (1,\ldots,j,i,j+1..1)$and the shrinking and expanding of routes continuous till no possibility is occurred due to constraints (capacity).

The standard Or-Opt[n] for n∈ (1,2,3) considers moving of n customers to another position of the same route (intra-route). One of the important contributions of V. Snyder's VRP solver is the possibility of applying Or-Opt (n) operators for inter route improvement. Applying improvement heuristic, however, the total cost of the Route distance (Rd) decreased from 810.04 kilometer to 780.9 kilometer and the vehicle utilization (Vu) in percentage increase from 76.6 to92 after 69 swap,7 2-Opt, 2 Or-Opt[1], 395 Or-Opt[2] and 222 Or-Opt[3] moves .

The number of route "number of vehicle" also reduced from six to five. With the same procedures for other nine instances, table 2 shows the comparison between the optimal solution, classical Clark and Wright method solution and proposed model solution of the study.

The comparison is in terms of solution quality (cost) and as it is clearly shown in the table for the value of CWVSPR (comparison between the classical Clark and Wright method and proposed approach) in column five each values are positive (in percentage) and indicates that the proposed model outperforms the classical CW method.

While the values given in column six are comparison, values for proposed model (PR) and the optimal solution by author (Opt). The negative sign given in column six indicates the deviation of proposed. Solution from the optimal one

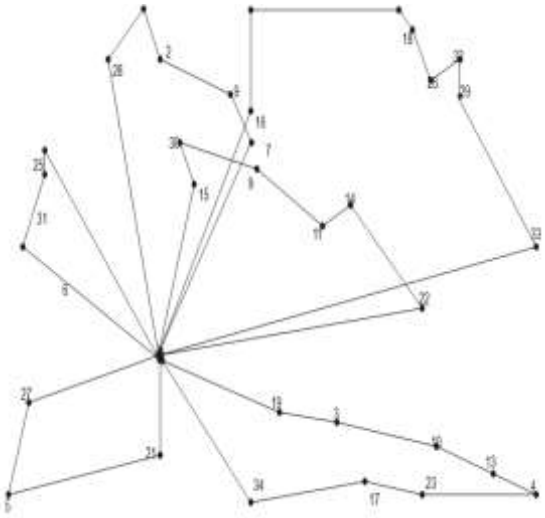

Figure 4 (a) Initial solution routes for A-n34k5 instance

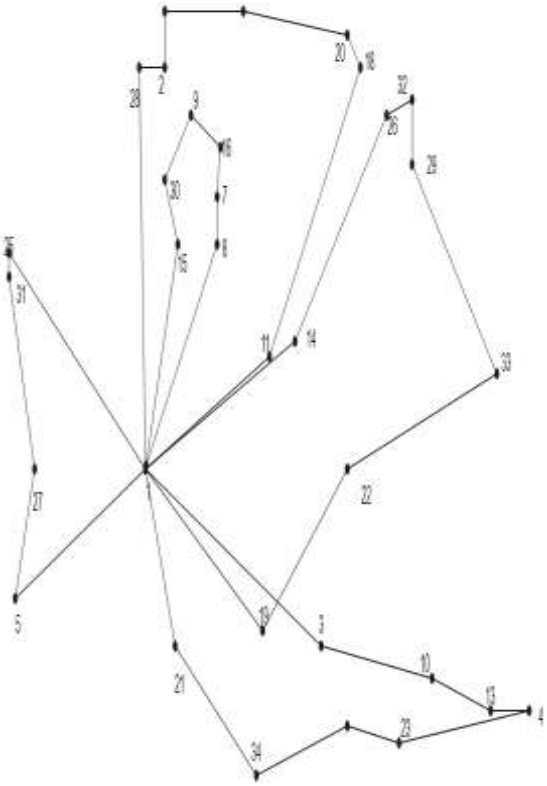

Figure 6 (b) Improved solution routes for A-n34k5 Instance

Possible to say almost all values, in column six are below one and this indicates the performance of the application of the local search is to some extent inevitable and would bring a solution approximately near to the optimal one. In all cases the vehicle capacity is 100 cubic meter. $\text{CWVSPR} = \frac{(V_{CW} - V_{PR})}{V_{CW}} * 100\%$, and $\text{PRVSOpt} = \frac{(V_{Opt} - V_{PR})}{V_{Opt}} * 100\%$.

Results and Discussion

The daily waste generation rate of the Addis Ababa city is 0.4kg per capita per day [40] and there is only open dumping site called "Repi or Koshe located 13 km away from the city center and vehicle (truck) from the various residential zones hauling the wastes to the dumping site.
The compactor truck is expected to make a maximum of two to three trips per day with a capacity of caring 27000 kg per a trip.

There are about 668 collection points in the city and found in scattered manner as depicted in figure 8. The compactor has to visit different collection points until it gets fully loaded. In the current collection process however, there is no any clearly defined routing for a vehicle where to start and end for a trip. On the other hand, the planned amount to be collected for 2014/15 was 497,264.562 ton and only 311,844.303ton collected which is 62.71% of the plan.

The case sub city selected for this problem, Arada sub city, has a total of 474.3cubicmeter solid waste was collected through seven trips each. Each of the vehicles has to be returned to the depot and the distance from the landfill to the depot is 6.06 km i.e., a total distance of 61.92 km per day.

The annual average vehicle utilization is 68.65% with the total distance coverage of 23290.513km per year.

The stochastic recyclable fraction (SRF) of the stochastic overall waste generation rate (SOWG)[41] method followed to consider dynamic nature of the case study. A one year collection points monthly generation rate with mean of 15.4 and 11.00 standard deviation guarantee (With a value of $p = 0.005$) the distribution of solid waste generation of each collection point is a triangular distribution with a value of $a = 5.5, \mu = 14\ and\ b = 40.5$.

The test result of the analyzed data for normal distribution gives a good fit of each point but with a p value of 0.009, the less the p value the less the chance of being uncertain. The analytical stochastic recyclable fraction described as equation 4 for probability distribution $f(X)$ of SRF and cumulative distribution function (CDF) $F(x)$.

$$f(X) = \begin{cases} (x-a), & if\ a \le X \le \mu \\ (b-x) & if\ \mu \le X \le b \end{cases} \quad (4.1a)$$

$$\begin{cases} \int_a^X f(x-a)d_x & if\ a \le X \le \mu \\ \int_x^b f(b-x)d_x & if\ \mu \le X \le b \end{cases} \quad (4.1b)$$

$$= \begin{cases} a + \sqrt{2u} & if\ a \le x \le \mu \\ b - \sqrt{2-2u} & if\ \mu \le X \le b \end{cases} \quad (4.1c)$$

A random number generated between zero and one (0, 1) for the value of $u = F(X)$ to generate the value of SRF =x based on equation 4.1c gives a distribution of figure 7 and the daily solid waste generation 497.26 cubic meters after five years.

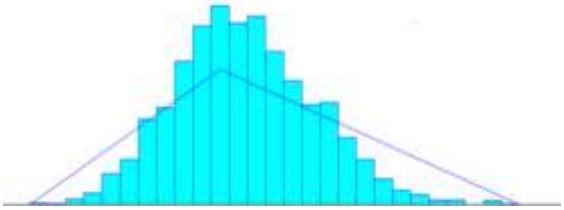

Figure 7 Distribution of solid waste generation

City of Addis Ababa located at 9°1′48″N38°44′24″E Coordinates and Arada sub city geographically located between 9°2′9.6″Nand 38°45′8.28″E and the longitudinal and latitudinal point of each -collection point determined from both Google earth and Google map engines.

Table 1 solution for A-n34-K5 *instance based on CW and Improvement heuristics*

Route	Clark and Wright (CW)				Improvement heuristics (IH)			
	Sequence	RC	RD	VU (%)	Sequence	RC	RD	VU (%)
1	**1**-34-17-23-4-13-10-3-19-**1**	92	165.9	92	**1**-2-5-31-6-27-5-**1**	89	146.5	89
2	**1**-27-5-21-**1**	48	77.59	48	**1**-8-7-16-9-30-15-**1**	86	102.14	86
3	**1**-6-31-25-**1**	54	92.45	54	**1**-11-18-20-1-24-2-28-**1**	93	176.42	93
4	**1**-7-9-2-24-28-**1**	99	131.09	99	**1**-21-34-17-23-4-13-10-3-**1**	96	166.88	96
5	**1**-33-29-32-26-18-20-12-16-**1**	100	209.06	100	**1**-19-22-33-29-32-26-14-**1**	96	188.96	96
6	**1**-15-30-8-11-14-22**1**	67	134.32	67	-			
Total		460	810.41		-	460	780.9	
Average		**76.67**	135.067	**76.6%**		92	156.18	**92%**

A Cartesian coordinates known as Geocentric coordinate used to determine the x, y coordinate of each collection point.

$$x = R.cos(LAT).cos(LON) \quad (4.2a)$$

$$y = R.cos(LAT).sin(LON) \quad (4.2b)$$

A Euclidean distance measure followed and the distance matrix obtained using the formula

$$d_{ij} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}.$$

Using equation 4. 2 the coordinate of the 31 collection, the depot and location of the landfill determined (figure 9). The direct graph mathematical model from equation 3.1-to 3.12 then treated for the value of V=n=1 the depot, V= 2 (32)

Table 3 gives the solution for the problem and the total travel distance of 45.1 kilometer per day confirmed. this solution is obtained after performing of 12 times three collection points, 23 times two collection points and 5 time one collection point relocation by using the Or-Opt move operation and two time 2-Opt as well as a six time exchange of customers between two route by swap operator. The total time to compute this solution is about 0.09 second with a building time of .00 second on the VRP solver of version 1.3. Based on the data obtained from the case company the minimum and maximum trip a compactor should make respectively is two and three and there are four compactor vehicles. The average-loading time in each collection point estimated to be15 minutes while the time for unloading at the landfill is 7 minutes.

The working hour per a day is 18 hour and the speed of the compactor is restricted to 40km per hour. Based on this input, the proposed solution guarantees a total time of 8.88 hours and makes us chanceful to assign one vehicle for more routs keeping the maximum trip. Hence, if the plan is to work with a maximum trip per a day, only two vehicles required and three vehicles are sufficient to work at a minimum trip plan. , Total distance covered for the existing system for one-day eight trip was 61.92 kilometer.

Using the Clark and Wright (CW) the total distance reduced to 52.7-km which is an improvement by 14.87% extend the model to the implementation of improvement heuristics (IH), the model gives a total distance of route per day 45.14 kilometer, a 27.385% improvement of the daily distance of the existing system.

Table 1 Comparison of the model

Instance (A)	CW	(PR)	(Opt)	CWVSPR (%)	PR VS Opt (%)
A-n32-k5	842	787.08	784	6.523	-0.393
A-n33-k5	713	662.1	661	7.139	-0.166
A-n33-k6	775	735.78	742	5.061	**0.838**
A-n34-k5	810.4	780.94	778	3.635	-0.378
A-n36-k5	826	814	799	1.489	-1.840
A-n37-k5	705	672	669	4.681	-0.448
A-n37-k6	975	950.6	949	2.503	-0.169
A-n37-k6	765	730.5	730	4.510	-0.068
A-n39-k5	898	821.7	822	8.497	0.036
A-n39-k6	861	833.4	831	3.206	-0.289
A-n44-k6	974	937.8	937	3.717	-0.085
A-n45-k6	1005	946	944	5.871	-0.212
A-n45-k7	1200	1145.3	1146	4.558	0.061
A-n46-k7	940	915.6	914	2.596	-0.175
A-n48-k7	1110	1074.1	1073	3.234	-0.103
A-n53-k7	1098	1011.8	1010	7.851	-0.178
A-n54-k7	1199	1169.2	1167	2.485	-0.189
A-n55-k9	1098	1075.1	1073	2.086	-0.196
A-n60-k9	1416	1354.8	1354	4.322	-0.059
A-n61-k9	1099	1035.7	1034	5.760	-0.164
A-n62-k8	1346	1289.1	1288	4.227	-0.085
A-n63-k9	1684	1617.1	1616	3.973	-0.068
A-n63-k10	1352	135.2	1314	2.722	-0.091
A-n64-k9	1489	1403.2	1401	5.762	-0.157
A-n65-k9	1230	1175.2	1174	4.455	-0.102
A-n69-k9	1206	1161.3	1159	3.706	-0.198
A-n80-k10	1859	1777.05	1763	4.408	-0.797

On the other hand, there were seven routes for the existing system with route capacity of each between 61.05 and 71.69 cubic meter of solid waste, which yield a daily average of 68.19 cubic meters per a route. However, the route capacity for the proposed model varies between 91.65and 100.00 cubic meters. Based on the design capacity of the compactor's which 100cubic meter, the daily utilization of Vehicle for the existing system is 68.19 % while in the proposed model 95.466%.

Table 2 Optimal route and route utilization

Route	Collection points	Rc (m^3)	VU	Rd (km)
1	**1**-6-16-26-29-30-27-**33**	97.06	97.06%	10.68
2	**1**-7-9-12-10-**33**	100	100%	8.38
3	**1**-8-28-25-5-32-**33**	95.02	95.02%	7.95
4	**1**-14-15-23-18-2-17-22-**33**	91.65	91.65%	8.74
5	**1**-20-24-31-4-21-11-19-13-**33**	93.60	93.60%	9.39
Total		477.33		45.14
Average		95.466	95.466%	9.028

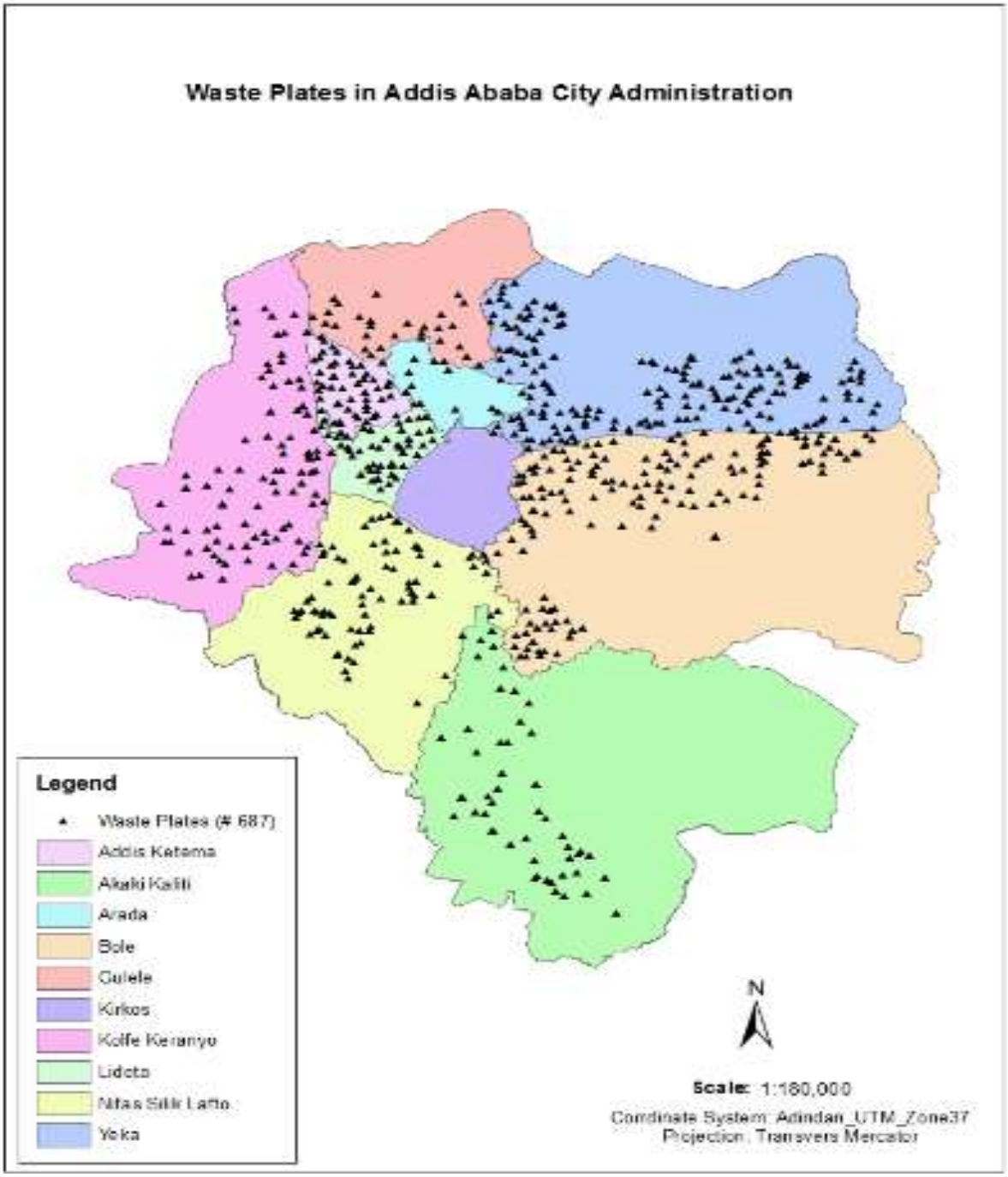

Figure 8 Distribution of the waste collection points in each sub city

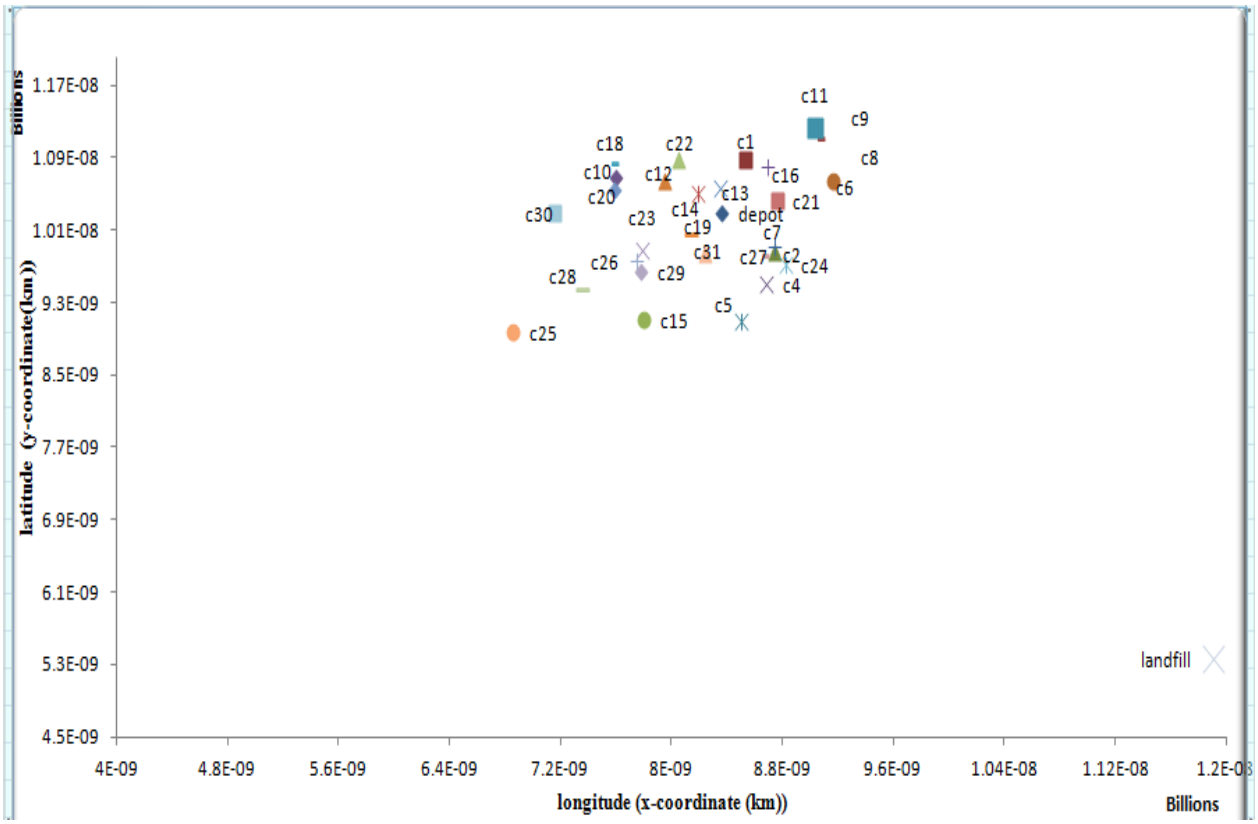

Figure 9 x, y coordinates of the depot, collection points and landfill (km)

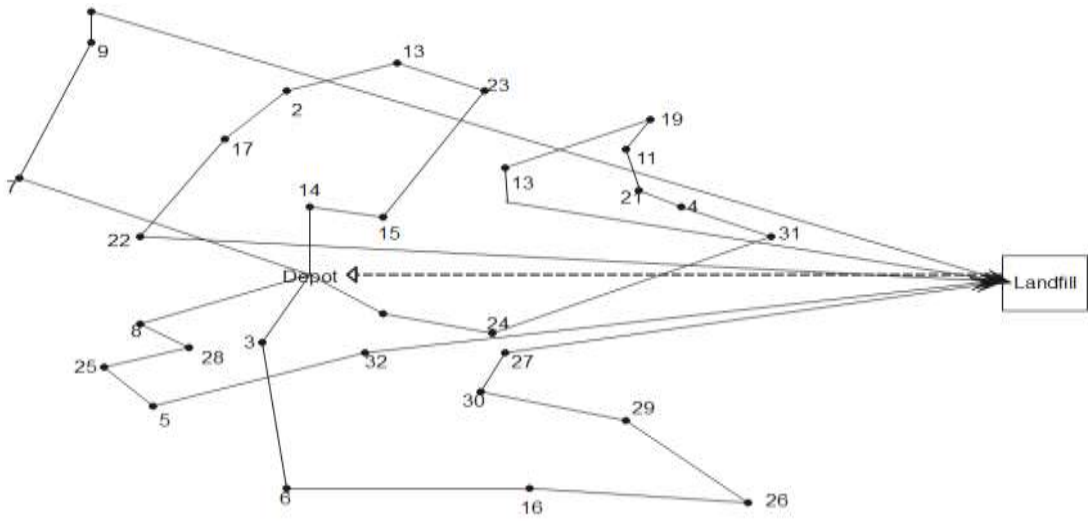

Figure 10 Final route of the waste collection problem in Arada Sub City

Conclusion and Future work

As part of a city logistic problem, the waste collection process considered as both facility location and a vehicle routing problems. The latter emphasized here and the node routing problem with a capacitated vehicle routing problem modeled using mixed integer programming to obtain an optimum distance. Bench marking problem instance used to verify the solution approach, 2-opt and Or-Opt improvement heuristics applied and a remarkable solution obtained. Based on the proposed model the distance that a collection vehicle could cover is about 16430km and guarantees a saving of about 29.45% over the existing system and the utilization of vehicle in a route increases in average from 68.19% for the existing system to 95.5 % by the model.

With the support of the result, we are on the position to conclude that classical algorithms are sufficient, if managed well, in solving problem of interest and important implication of the result however, implies the need of redesigning to case problem.

Finally, an integrated municipal solid waste management system based on multi-criteria decision analysis recommended from the solid waste management perspective, more importantly considering the problem at stochastic nature with the help of deploying sophisticated metaheuristic algorithm are future interest of the problem domain.

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