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Leveraging GIS in Supply Chain Management for Floriculture Application: Nairobi County, Kenya

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Abstract

Agriculture continues to be the bedrock of Kenya's economy at 24% of the GDP with 80% of the population living in the rural areas. Horticulture one of the sub-sectors in agriculture generates US$1 billion annually. The favorable weather provides an environment for the flower industry to thrive. However, flowers are a very delicate commodity and require appropriate management to minimize losses due to decay. A GIS based system is thus desirable to manage the flower chain from the supplier that is the farms, to distributors and eventually to the florists/consumers. The goal of this study therefore was to leverage the use of GIS in managing the supply chain for floriculture application using Nairobi County as a case study. One of the objectives addressed involved identification of optimal or alternative routes for efficient delivery of flowers from the source to the consumer using Network analysis. Ensuring that customers receive the right flowers in terms of quality and quantity was also addressed using Business Intelligence analysis. Trace analysis was done to provide information to the consumers on the source of the flowers and the growing conditions. From the case study, City Market acted as the link between the flower farms and the florists/consumers. The results obtained were presented using maps, graphs, pie charts and tables. The Central Business District (CBD) was found to be the largest purchaser compared to other regions and the months considered. Karen and CBD were the highest purchasers of Lilies whereas Ferns were preferred in Westlands. The CBD registered high level of satisfaction followed by Karen. Greenhouses and hydroponic methods were used for growing flowers resulting in variations in terms of vase life and stem length. GIS in SCM for floriculture application is useful in understanding the floriculture business environment.

Keywords

GIS, SCM, Floriculture, Network Analysis, Business Intelligent Analysis,

Trace Analysis

1. Introduction

Kenya's economy largely relies on agriculture with the horticulture sector being one of the top foreign exchange earners generating approximately US$1 billion annually. In 2015, the sub-sector contributed 1.45% to the national GDP while flower exports contributed 1.01%. It was estimated that in Kenya, over 500,000 people including over 100,000 flower farm employees depend on the floriculture industry impacting over 2 million livelihoods [1]. The main flowers grown in Kenya are Roses, Carnations, and Alstroemeria. Other flowers include Gypsophila, Lilies Eryngiums, Hypericum, Statice, and a range of summer/tropical flowers [2]. Statistics reveal that it is the lead exporter of roses to the European Union (EU) standing at about 38%. This industry continues to attract investors due to the existing solid infrastructure, favorable climate, global-positioning of Kenya and a productive workforce. It comprises of large, medium and small-scale producers who have attained high management standards and have invested heavily in value addition through the adoption of modern technology in production, precision farming, and marketing. The flower industry in Kenya includes small, medium and larger flower growers whose members subscribe to the Flowers and Ornamentals Sustainability Standard (F.O.S.S) audited annually. The F.O.S.S is based on environmental and socio-economic principles which ensure certified producers foster sustainable, responsible and safe production of flowers. The Standard encompasses governance, good agricultural practice, human resource management, and workers' welfare, health & safety, environmental protection & conservation, and after harvest management. However, the current traditional business management methods of flowers which involve manual record keeping, can only answer questions like, how many flowers were sold in a day and which florist requested for what number and type of flowers. Lack of spatial visualization makes it difficult for the distributor to objectively make decisions regarding the spatial location of the florists/consumers, the optimal routes and the source of the flowers.

2. Concepts of Supply Chain Management (SCM)

SCM involves managing upstream and downstream relationships between suppliers and customers so as to ensure there is value at less cost. It is a collaborative effort of different stakeholders desirous to implement, design and manage a value-added process not only across the organization but also all units of the chain to meet customer needs better than competitors [3].

Global SCM mostly focuses on outsource or in-source production which means it can rapidly and cost-effectively respond to unpredictable changes in the business environment [4] [5]. Consequently, a combination of a successful lean

approach with the SCM philosophy can be applied by those organizations whose goal is to streamline their processes by eliminating waste and non-value-added activities [6]. The floricultural industry is characterized by high uncertainty of both demand and supply. Supply uncertainty is high because chains are vulnerable to product decay, weather conditions, diseases, traffic congestion, and other uncontrollable factors. On the other hand demand uncertainty is due to weather-dependent sales, changing consumer behavior and increasing global competition. This results in high variability of supply capabilities and demand requirements in volume, time, service levels, quality and other product characteristics [7]. In this regard, SCM can improve on the logistics thus leading to cost and value advantage [8].

3. Application of GIS in SCM for Floriculture

Floriculture industry is spatial in nature with respect to where flowers are grown to how they are distributed. Leveraging on spatial tools would be an advantage in solving the many logistics challenges encountered in the industry. In general, any industry that involves transportation for instance DHL, Fargo, FedEx, Skynet the supply chain challenge is that of routing namely finding an optimal path from origin to destination and seeking an alternative route in the event of a barrier. GIS as a tool has proved to be very effective at solving routing problems because it is able to combine many data sets and generate different scenarios with speed and accuracy. The task of supply chain management can be very complex and demanding. However, this task can be simplified by applying GIS, which automatically reduces the complexity by bringing to the fore relevant geographic patterns and relationships that can form the basis of good decisions. GIS endeavors to unleash the inherent potential of location information in most data sets [9]. SCM based on GIS is able to process massive amounts of location-based data to produce actionable information to support decision making. Further, identification of trends and potential delays in the chain will enable appropriate adjustments to be made for smooth operations. This will entail managing data collected by ensuring that it is transmitted back to the office for analysis and update of the GIS database. The actionable information generated should then be relayed to the relevant user in the chain to enable appropriate decisions to be made. Such a system would enable businesses to answer supply chain management questions like: What is my drive time from the central facility? How long will it take to reach delivery locations? Which customer should be in separate service areas? How can I track goods through my supply chain? Further, GIS helps businesses answer transportation questions like; What is the best route for the delivery trucks? What are the alternative routes in case of problems on one route [10]? All these studies demonstrate the power of GIS in applications involving supply chain management.

4. Methodology

Nairobi County was used as a case study. The tools used for data collection were

GPS Essential and questionnaires. GPS Essential was used to obtain the coordinates of the locations of florists and the wholesalers, whereas the questionnaires administered focused largely on attribute data regarding: Name of the flower enterprise, quantities of different types of flowers sold in a month, florist satisfaction based on services received from the wholesalers, how the quality of flowers is assessed, and the quantities and types of flowers sold during the high season months of February, April, August and December; and the low season month of January.

The tools used for data preparation and analysis were the ArcGIS and Smart Map Application. Three types of analysis were performed in this study namely Network, Business Intelligence and Trace Analysis.

1) Network Analysis

For floriculture application, it is important to ensure the flowers get to the customers in the right quantity, quality and at the right time. Network analysis is able to identify optimal routes and establish an alternative route in the event of barriers encountered. City Market being the wholesaler was used as the starting point and Lilies as well as Flower florists were used as the destination to demonstrate how an optimal route can be generated. One of the challenges encountered during transportation of goods are unexpected barriers on the route occasioned by traffic, accidents, diversions due to road construction. Alternative routes are therefore inevitable and this was also demonstrated. Additionally, using the service area solver, it is possible to establish whether the florists are within a range where their products can be delivered free of charge or not. In this study the distances considered for free deliveries were mainly 500 m, 1000 m and 2000 m in consultation with the distributors. The once that fall outside the range have to pay for the transportation of their deliveries.

2) Business Intelligence Analysis

It is in the interest of any business enterprise to be able to profile their customers in order to ensure they meet their needs. In the floriculture industry, the interest is in establishing the quantities and types of flowers being consumed by different florists as well as the level of satisfaction for the high season the months in this case of February, April, August and December; and the low season month of January. In this study Business Intelligence Analysis was used to address the aforementioned issues. In addition to the map, pie charts and bar graphs were generated to show variations of flowers sold in different regions in Nairobi County.

3) Trace Analysis

Consumers of various products are interested in knowing the origin of their products and in the case agricultural products, the growing conditions to assist them in assessing the quality. Trace analysis was used to provide information regarding the location of the farms that supply flowers to the wholesaler in this case City Market for onward distribution to the retailers (florists). In addition, information regarding the growing conditions for selected flowers namely roses and carnations for various farms was also captured.

5. Results

1) Network Analysis

Figure 1 shows the optimal route generated from the origin (distributor-city market) to the Lilies and Florists. On the other hand, Figure 2 is a simulation of an alternative route when a barrier is encountered.

Figure 3 represents service areas within the set 500, 1000 and 2000 meters ranges. The parameters were set according to the driving distance from the Distributor-City market.

The non-overlapping multi-polygon indicates areas that are likely to be traversed in the given distance. The florists that fall within these ranges receive free deliveries from the wholesalers. The once that fall outside the polygons have to pay for the transportation of their deliveries.

2) Business Intelligence Analysis

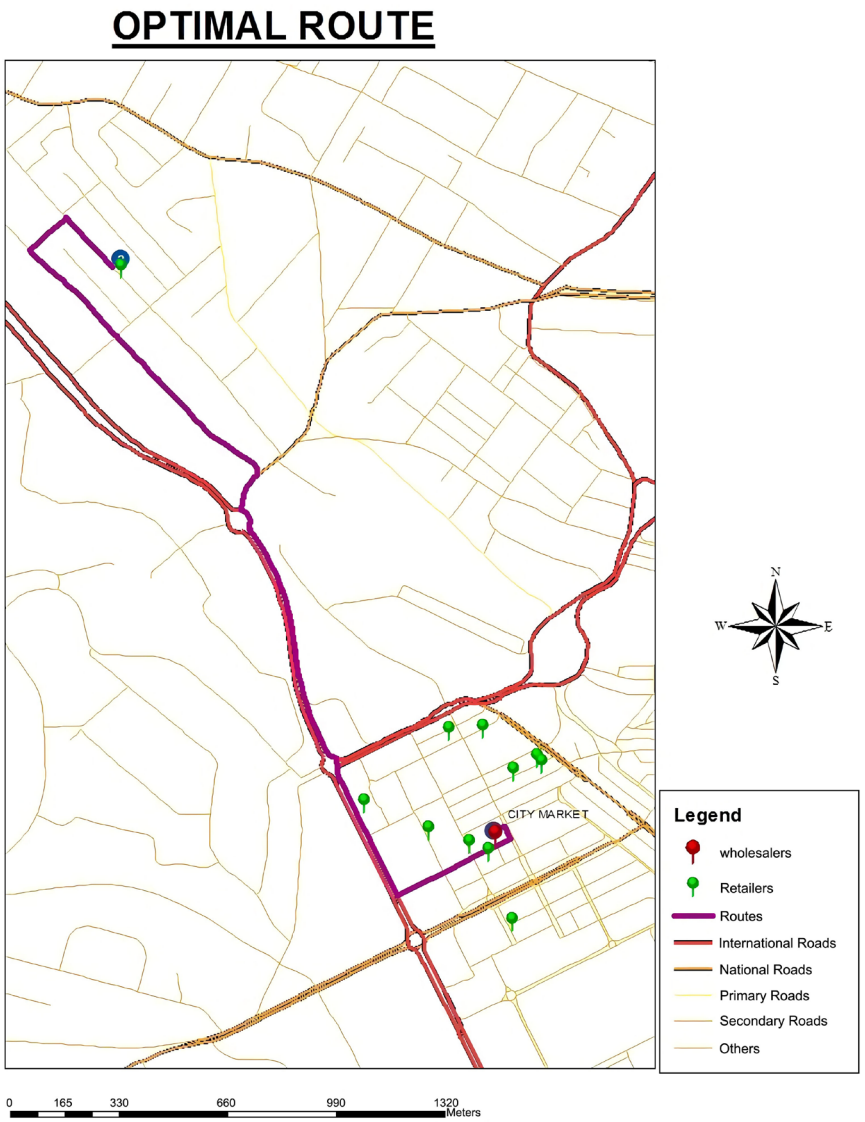

Figure 1. Optimal route to lilies and flowers florist.

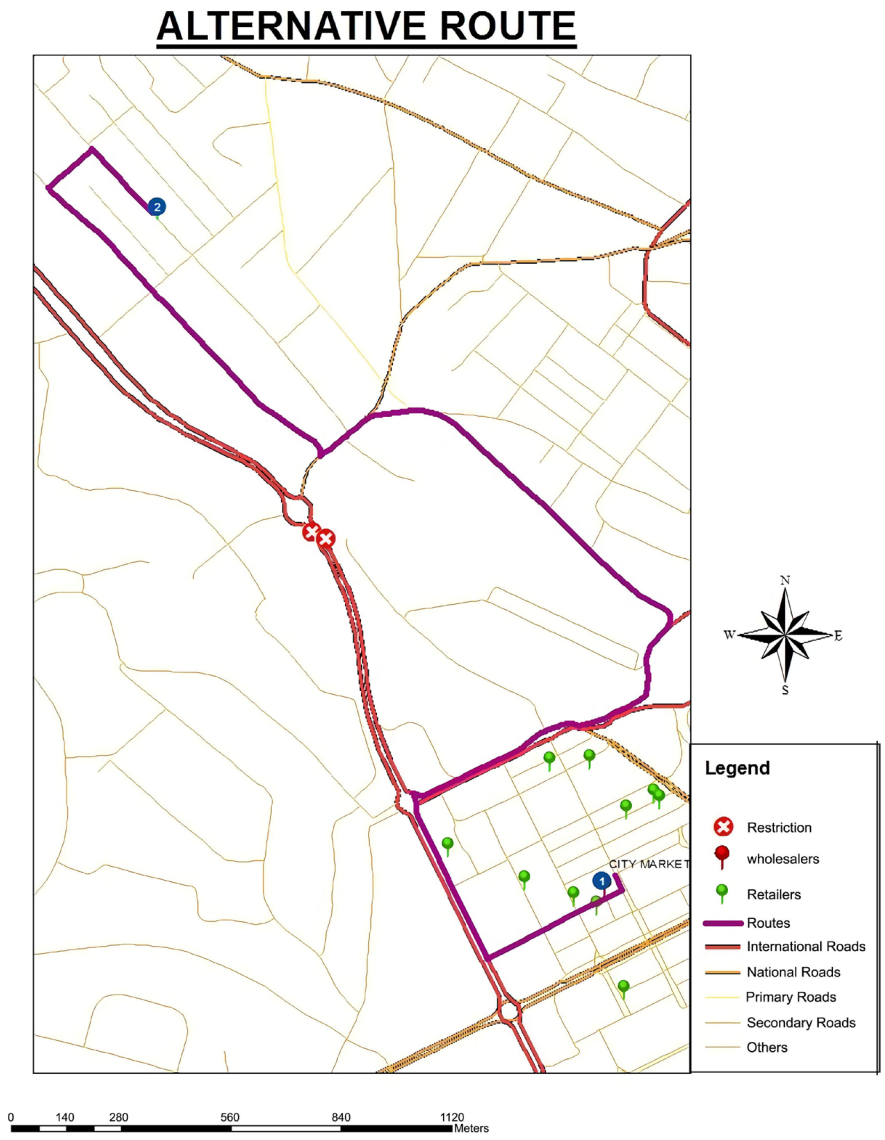

Figure 2. Alternative route to lilies and flowers florist.

Figures 4-8 show the sale of flowers in the month of January, February, April, August and December respectively in Dagoretti, CBD/Starehe, Westlands and Karen within Nairobi County. In terms of the types of flowers namely Roses, Lilies, Carnations, Ferns, Babys Breath sold in different areas in Nairobi this is represented in Figures 9-13. Another important aspect of Business Intelligence analysis is the level of customer satisfaction. In this case the florist was considered as the customer since they received the flowers from the main distributor which was the city market. Figure 14 shows the levels of satisfaction for different florists in the various regions in Nairobi County.

Nairobi CBD registered the highest number of flower sales as compared to the other regions followed by Westlands, Karen and Dagorreti.

Nairobi CBD registered the highest number of flower sales followed by Karen, then Westlands, and Dagorreti.

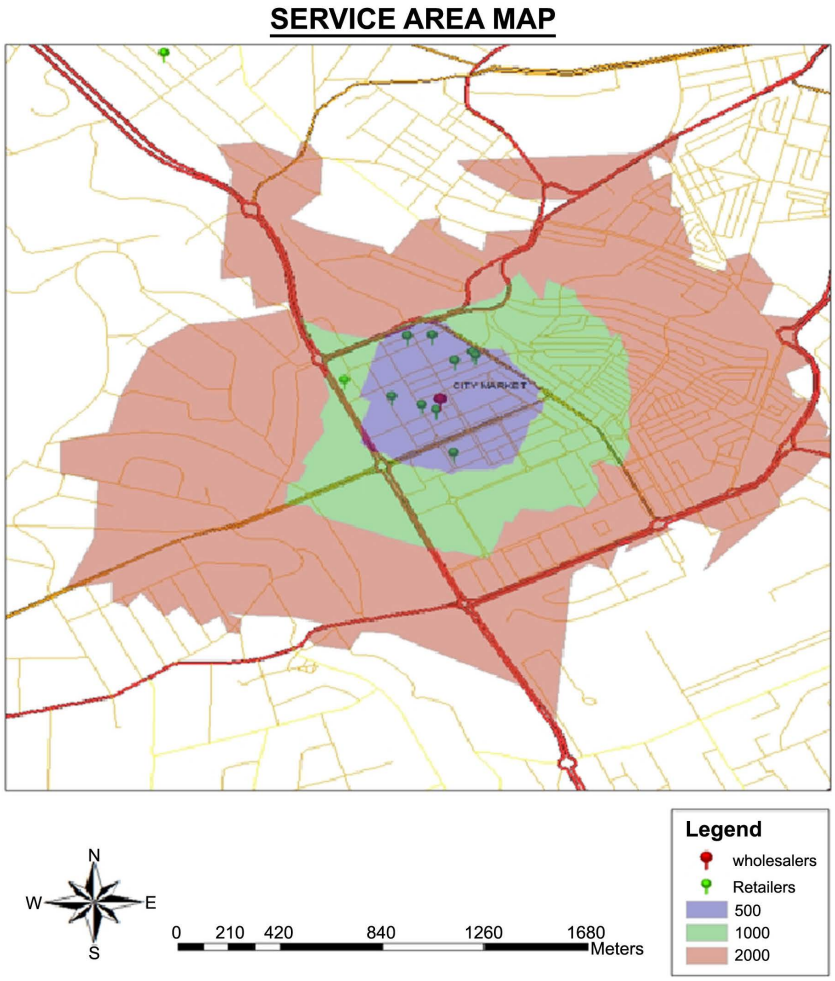

Figure 3. Service area of city market.

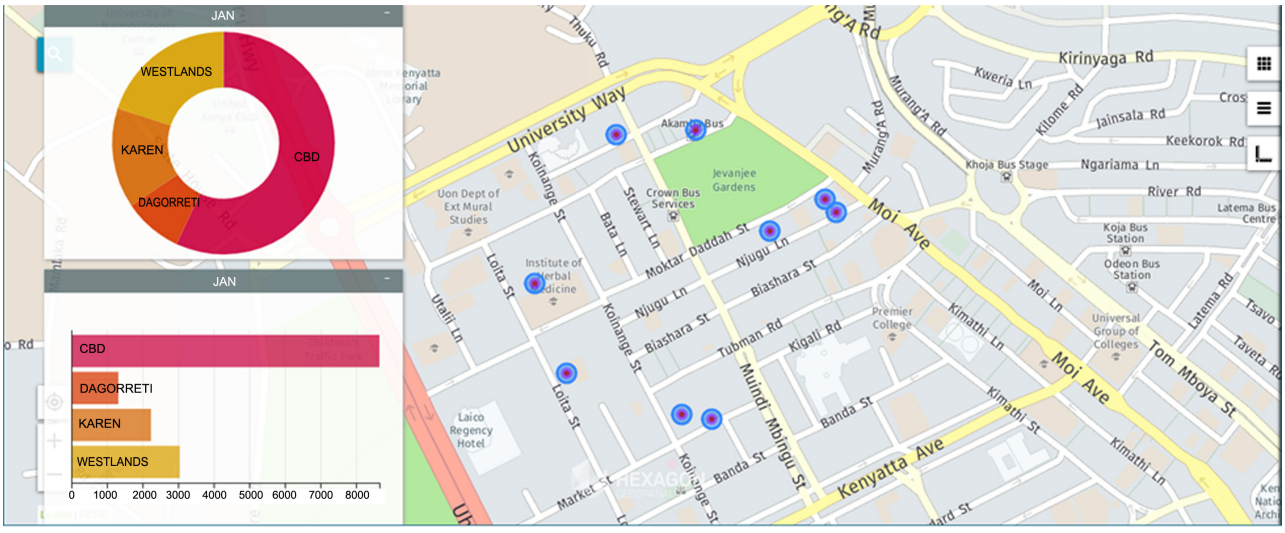

Figure 4. Sales of flowers in different regions in January.

In the month of April, Nairobi CBD had the highest number of flower sales followed by Westlands, then Karen, and Dagorreti.

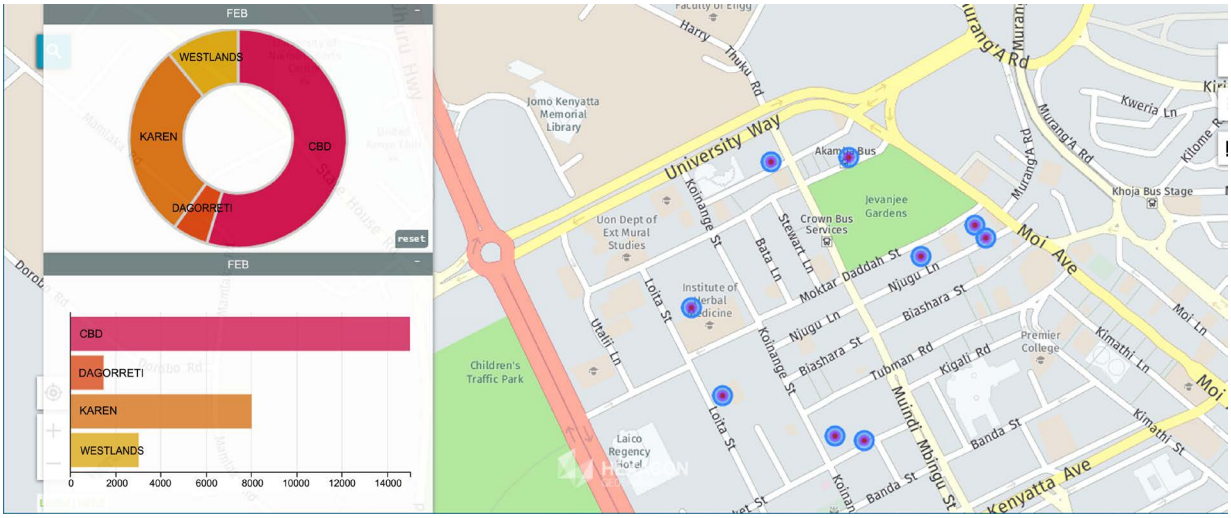

Figure 5. Sales of flowers in different regions in February.

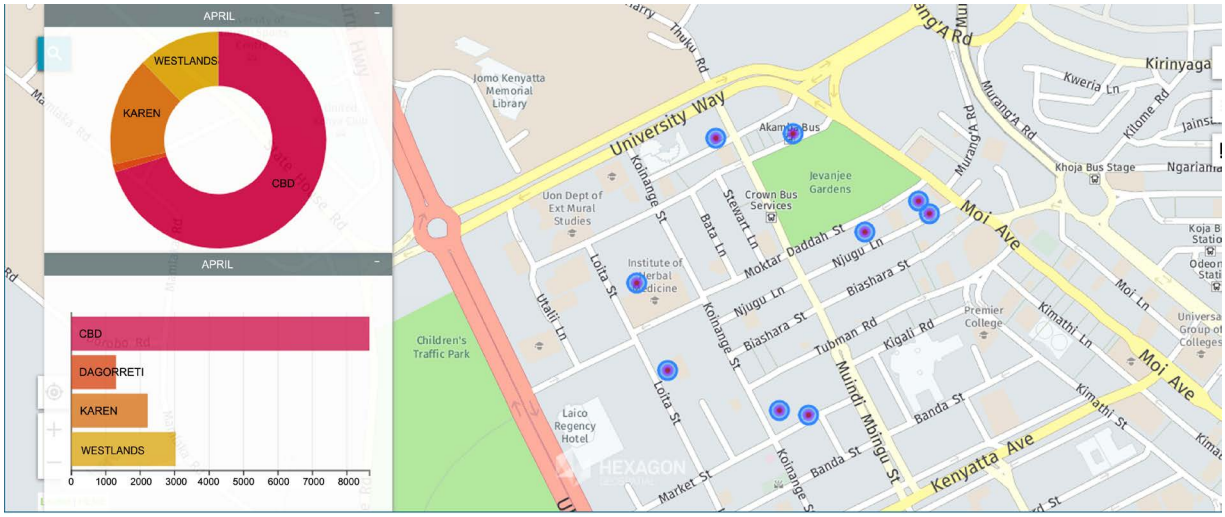

Figure 6. Sales of flowers in different regions in April.

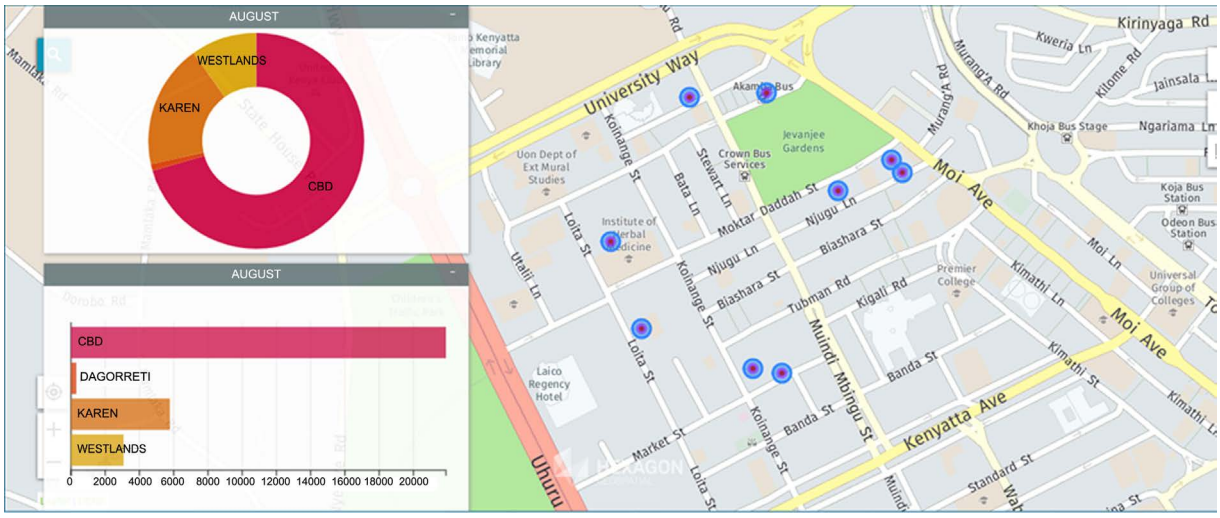

Figure 7. Sales of flowers in different regions in August.

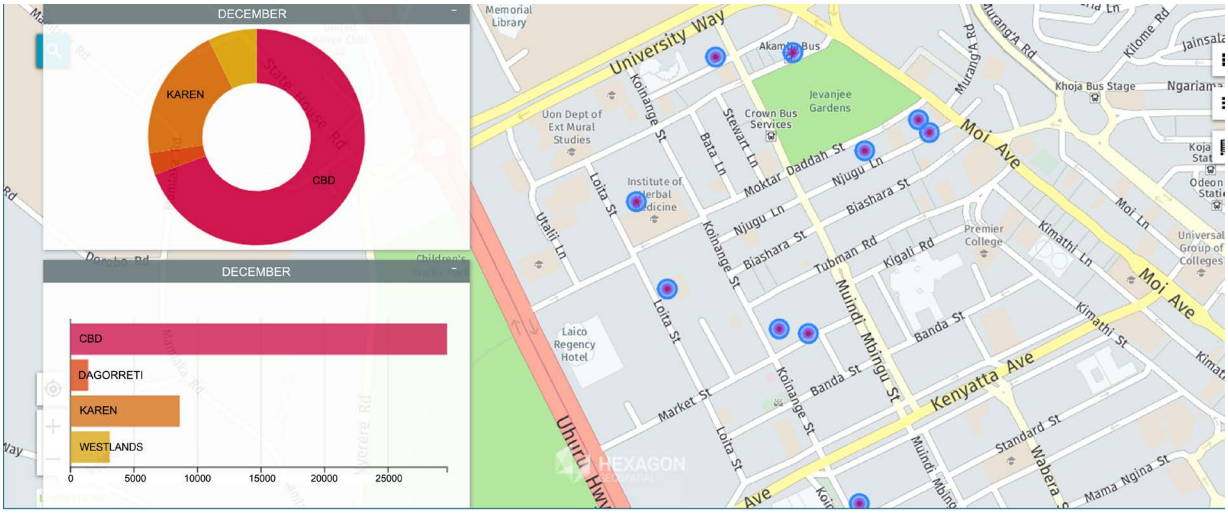

Figure 8. Sales of flowers in different regions in December.

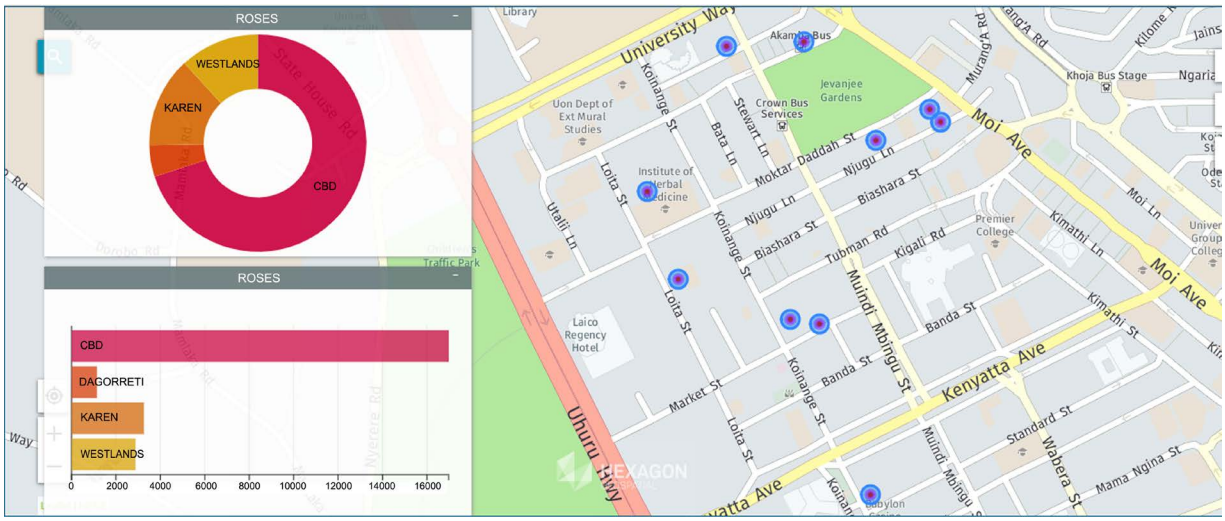

Figure 9. Sale of roses in different regions.

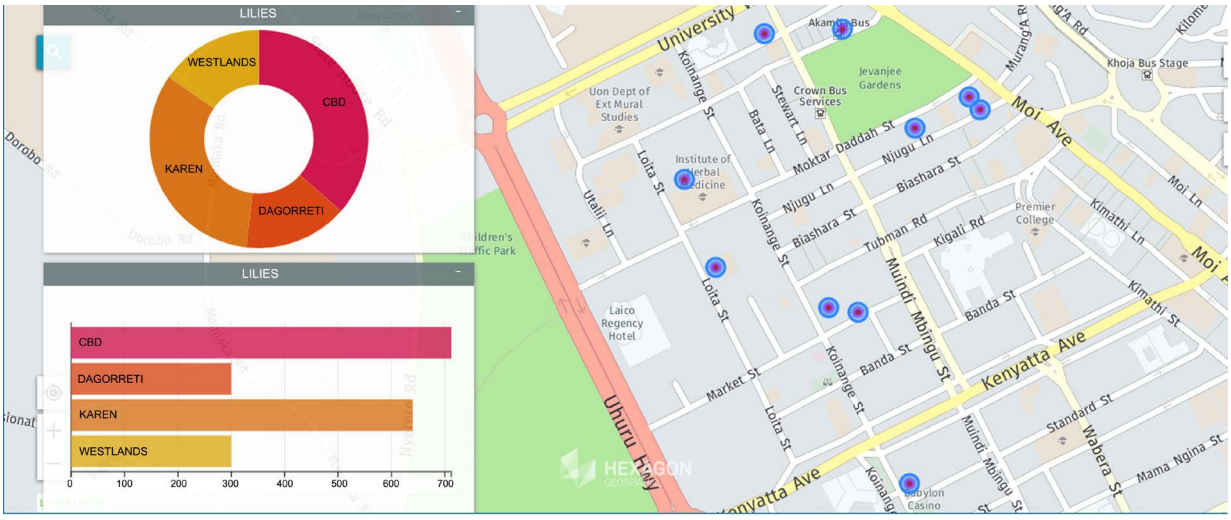

Figure 10. Sale of Lilies in different regions.

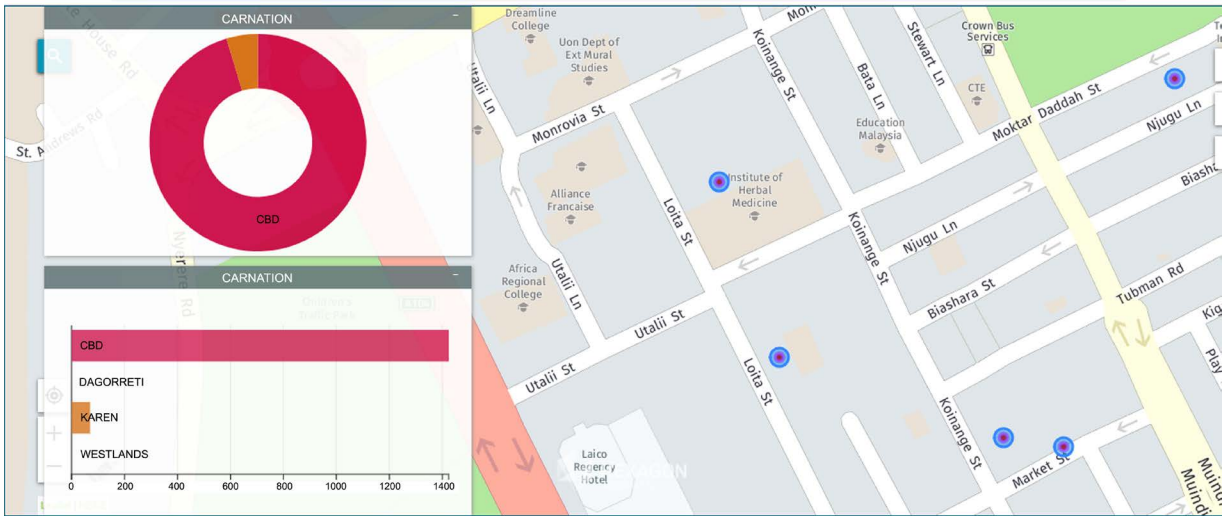

Figure 11. Sale of Carnations in different regions.

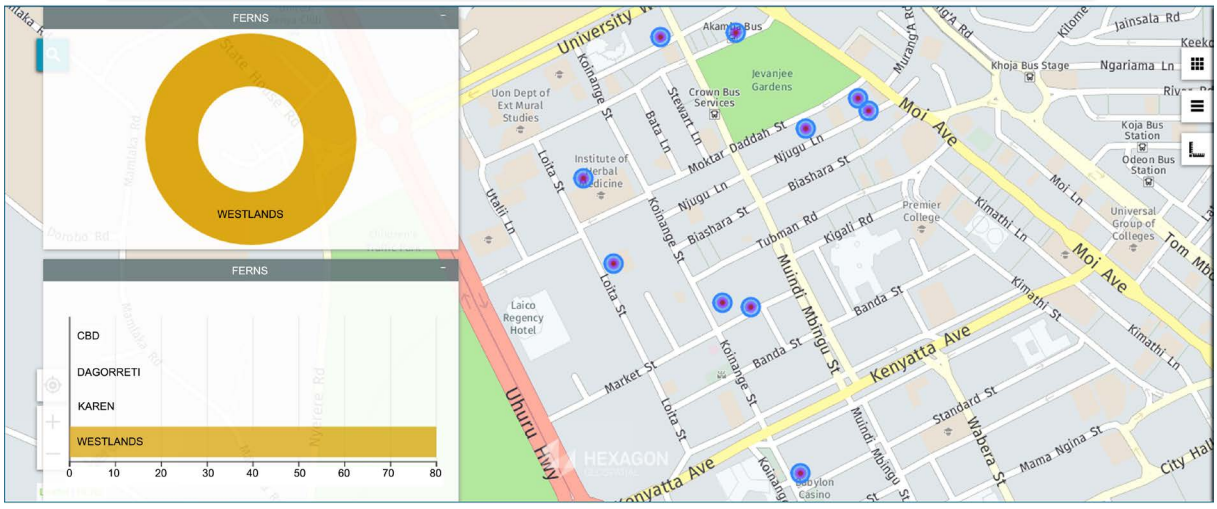

Figure 12. Sale of Ferns in different regions.

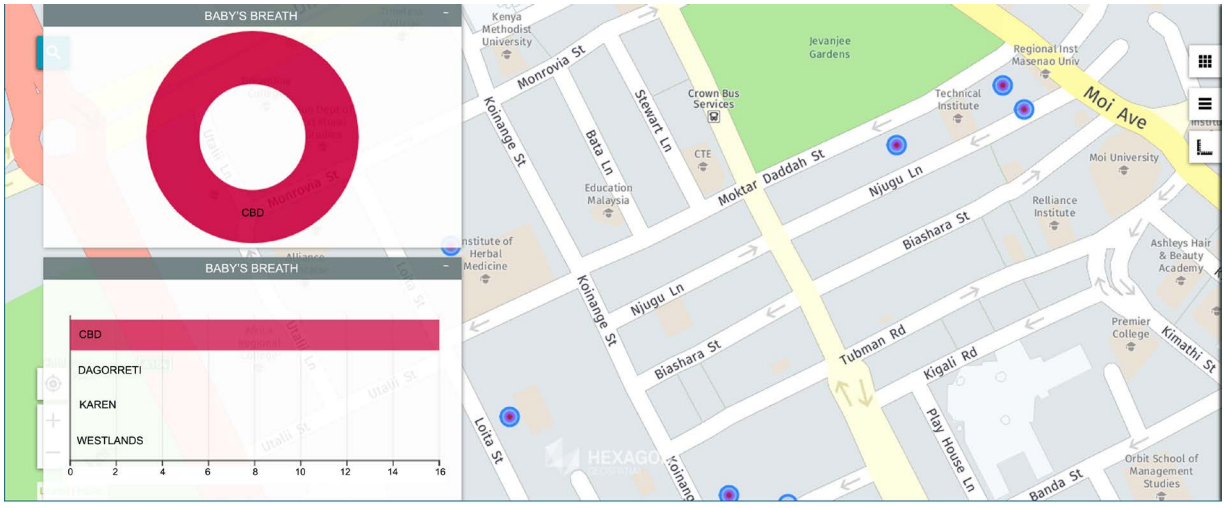

Figure 13. Sale of Baby's Breath in different regions.

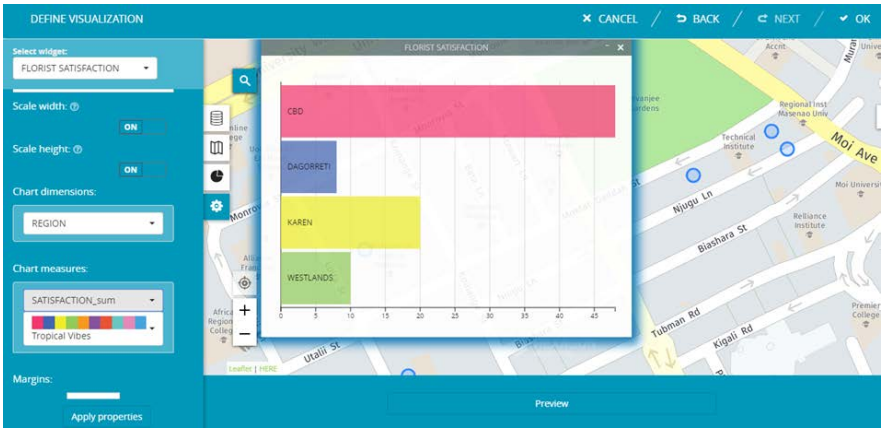

Figure 14. Level of satisfaction of florists in different regions.

In August, again Nairobi CBD registered the highest number of flower sales as compared to the other regions. Karen was second, then Westlands and Dagorreti had the least.

December assumed the same trend as August with Nairobi CBD having the highest number of flower sales as compared to the other regions. Karen was second, then Westlands and Dagorreti had the least.

Nairobi CBD consumed a lot of Roses. This was followed by Karen and Westlands whose difference in terms of uptake of Roses is minimal with Dagoretti registering the least.

There was generally good uptake of Lilies in all the regions within the Nairobi County with the CBD and Karen topping. Westlands and Dagorreti had almost a tie.

The preference for carnations is largely in the CBD with minimal uptake in Karen and none at all in Westlands and Dagorreti regions.

Only Westlands region registered an interest in Ferns all the other regions had none.

The uptake of Baby's Breath was only in the CBD and no other regions in Nairobi County registered any sales.

An analysis of the level of satisfaction of florists in the four selected regions in Nairobi County indicated a high level of satisfaction with CBD followed by Karen, Westlands and Dagorreti. This seems to be aligned to the general uptake of flowers in terms of quantities and types.

3) Trace Analysis

In order to assist the customers assess the quality of the products in this case flowers, this study looked at the source of the various types of flowers in terms of the farms and the growth conditions. Specifically two types of flowers were considered namely Roses and Carnations. Figure 15 shows the origin of flowers from various farms located within and outside Nairobi County. The radial lines are color-coded to represent certain types of flowers *i.e.* cyan represents tropical flowers, brown represents tropical flowers and roses, green represents carnations and purple represents roses. Table 1 contains information regarding the grow-

ing conditions and characteristics of Roses in six different farms, whereas Table 2 is for the Carnations in two farms.

It is evident that the farms that distribute flowers to the City Market are distributed in different regions *i.e.* Kajiado County, Nairobi County, Nakuru County, and Machakos County. For the Farms surveyed, Roses tend to be more commonly grown compared to Carnations and Tropical Flowers. This is supported by Figure 9 which shows the uptake of Rose Flowers in terms of quantity by different regions in Nairobi County.

Different farms used different methods to grow Roses from natural, greenhouses to hydroponic. This gives rise to the variations in terms of vase life and stem characteristics as indicated in Table 1.

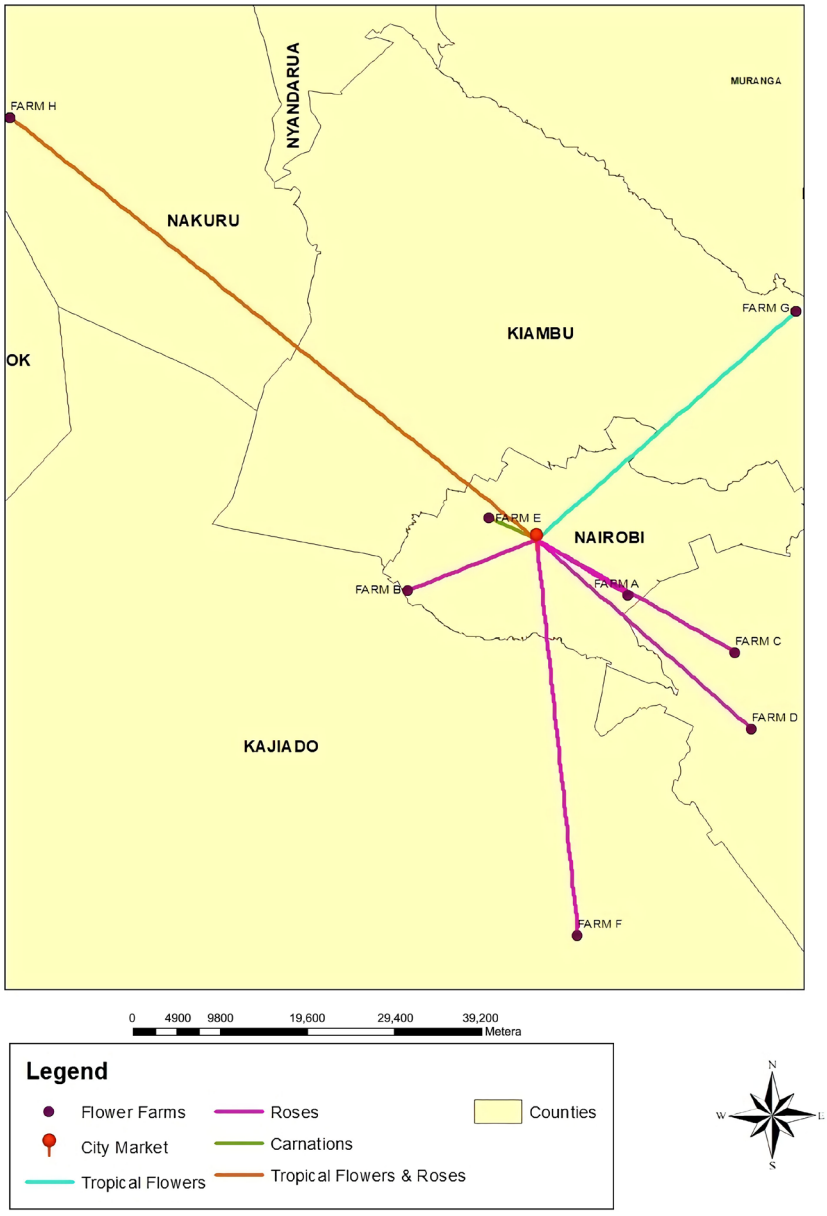

Figure 15. Flow map showing the origin of different flowers.

Table 1. Growth condition and characteristics of roses.

FARM	GROWTH CONDITION	VASE LIFE	STEM LENGTH
FARM A 	Roses are produced in greenhouses to protect them from rain, wind and extreme temperatures.	10 - 12 Days	30 - 80 cm
FARM B 	Roses are produced in areas of altitude between 2010 m to 2070 m above sea level. The temperatures range from 11˚C to 32˚C and a relative humidity of 85% at night and 34% during the day which help with the management of pest and disease.	12 - 16 Days	40 - 70 cm
FARM D 	Roses are produced in greenhouses to protect them from rain, wind and extreme temperatures.	13 - 15 Days	40 - 70 cm
FARM F 	Roses are produced in greenhouses to protect them from rain, wind and extreme temperatures.	10 - 14 Days	4.5 - 6.5 cm
FARM H 	80% of flowers are grown hydroponically. Instead of soil, they are grown in water and mineral solution.	7 - 10 Days	35 - 82 cm
FARM C 	Greenhouse cultivation management and crop protection are applied for the productions of a consistently uniform crop of the highest quality.100% of the flowers are produced and natured in a hydroponics system.	10 - 15 Days	50 - 100 cm

Table 2. Growth condition and characteristics of carnations.

FARM	GROWTH CONDITION	VASE LIFE	STEM LENGTH
FARM J 	Carnations thrive in fertile, well-drained, slightly alkaline (pH 6.75) soil. The optimum temperature for growing Carnations ranges from 50 - 59˚C at daytime and 41˚C - 46˚C at night.	14 - 21 Days	40 - 60 cm
FARM H 	80% of flowers are grown hydroponically. Instead of soil, they are grown in water and mineral solution.	14 - 21 Days	40 - 60 cm

Just like in the case of Roses, different farms exercise different methods of growing carnations. Evidently, the final product varies in terms of characteristics namely vase life and stem length.

6. Discussions of the Results

The elements of SCM for floriculture application in this study composed of farms, wholesalers, florists, and customers. The linkage existing between the elements results in a system that lends itself to leveraging GIS in SCM for floriculture application. These elements have a spatial dimension which when analyzed can provide useful and actionable information. Spatial data was identified

and obtained for each component and in-cooperated into a database dedicated to SCM for floriculture. Farms are located in different geographical locations and produce different/similar flowers under different conditions.

Wholesalers who are the link between the farms and the florists located within the City Market. Their spatial location was obtained and this acted as the focal point of flowers distribution. Network analysis was carried out using the network dataset that enabled the approximation of the distance and time used when traveling from the City Market to various florists. To obtain accurate information on the drive time, real-time and historical traffic data was used within the ArcGIS environment to obtain the time that will be used to get to a particular florist taking into consideration the nature of traffic namely high, moderate or low. This resulted in time differences for example from the results the time spent to get to florists on Monday was more than the time used to get to florists on Saturday due to the traffic difference between the two days.

Business Intelligence was performed based on data on florists' geographical positions, their sales and their level of satisfaction with the services they receive from the Distributor- City Market. Pie charts and bar graphs were generated which gives a statistical overview of the number of sales in different regions where the florists are located. As an example, the sale of Roses was found to be higher in CBD as compared to other regions and lowest in Dagoretti.

The difference in the sales of flowers is attributed to by the absence or presence of factors such as events that require flowers to be purchased e.g. cooperate events, weddings, and funerals. Another major factor is the demand for flowers at the international market. If it is high it means that the farms will export most of their products and few flowers will be released into the local market. In addition to the international market, factors such as flower diseases e.g. Botrytis and Colombian Datura Virus have also been found to lead to a decrease in the number of flowers in the market.

The high sale season locally is brought about by low demand for flowers and price inflation at the international market which results in the farms opting for sale the flowers in the local market. High production of flowers by the farms also leads to flooding of flowers in the local market. This results in high sales if the local market has high demand or it might lead to losses if there is a low demand for flowers by the local customers.

7. Conclusion

Incorporating GIS in Supply Chain Management for floriculture applications revolutionizes various aspects ranging from delivery, monitoring the quantity and types of flowers distributed, doing a satisfaction survey as well as being able to trace where the flowers originate from and their growing conditions. Network, Business Intelligence and Trace Analysis have been employed generating useful results that support the floriculture industry. The identification of an optimal route and in the event of a barrier or obstruction of an alternative one us-

ing Network analysis demonstrated how the flowers can be moved from the distributors to the consumers efficiently thus minimizing loses. Consumers have varying interests, and therefore the distributor should be equipped with this knowledge to ensure that the required flowers are delivered in the right quantity and quality. In addition, customer satisfaction survey helps businesses to continuously reinvent themselves so that they address the dynamic and sometimes complex needs of the customers. This study successfully employed Business Intelligence analysis to show how consumer profiles can be used to understand their needs and preferences. One of the key thing customers use to assess the quality of their product, is the source. Trace analysis in this case was used to provide information on the origin of the flowers and their growing conditions. It has been demonstrated that the growing conditions even for the same species of flower as in the case of roses and carnations produce flowers with different characteristics in terms of vase life and stem length.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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