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Bottling Plant Location of Microbreweries in East Midlands Area, UK

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Abstract

Facility location decisions are critical in real-life projects, which impact on profitability of investment and service levels from demand side. In this paper, a project-based facility location problem should be resolved which refers to the establishment of a centralized bottling plant to serve microbreweries in East Midlands area of UK. This problem will be structured by firstly finding a mathematically theoretical location using the centre-of-gravity method and then formulate the problem as a multi-criteria decision making problem applying Analytical Hierarchy Process based on selection of the optimal location out of the four candidate locations where three of those have been given. The second part is modeled by considering several criteria related to both the activities before and after bottling and also issues of surrounding area of the location where the prioritization of those criteria are based on the preferences of the project investor. The final result is obtained by applying EXPERT CHOICE to approach Eigenvalue methods to enhance Analytical Hierarchy Process. The outcome can be clarified with illustration of the sensitivities resulted from the weight changes of criteria and the pull-out of certain criteria.

Key Words: Facility Location, center-of-gravity method, Multi-criteria decision making, Analytical Hierarchy Process

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Chapter 1: Introduction

1.1. Project Background

Currently, the brewing industry of UK has seen one of its growing sectors (to serve UK market) comprising microbrewers who produce cask ale, which values around £1.8bn and accountable for approximately 45,000 jobs. Despite of its growing potential (approximately growth 7% p.a.) in the domestic market, in order to relieve from the possible market saturation, brewers are currently seek opportunities of market expansion by selling bottled beer, mainly conditioning beer, both to add ranges in UK market and export to overseas market, especially China. To support this issue, it has seen the increasing popularity of British craft beer with a mixed pack of six different types of bottles in overseas market. However, in this moment, there are no contract bottling companies central to East Midlands area of UK. Very few microbreweries have their own bottling plant which can majorly serve its own breweries and pubs. In contrast, most of the microbreweries are bottling beer either by hand or outsource to other bottling facilities for a small volume. This project is focusing on exploring the possible opportunity of building one centralized bottling plant to serve the microbreweries with the consideration of potential increase of demand for bottling service, where East Midlands area of UK will be mainly researched on, given over 100 microbrewers in this region.

1.2. Objective and Scope of the problem

This problem in this paper is a project-based facility location problem about selecting an optimal location where there should be already available and appropriate property to set up a bottling plant and some associated facilities. Based on the project requirement, one location will be determined first through a mathematical method from theoretical perspective which is center-of-gravity method. In this part, locating the bottling plant should consider the efficiency of providing the services to the breweries where the distances travelled between bottling facility and breweries can be the main factor.

The main part of this paper is a multicriteria facility location problem when it is further resolved by selecting the optimal one out of four locations, where three candidate locations are provided by Jeremy Avis, one of the project's industrial collaborators. One is a business unit in Millennium Way East, Phoenix Center, Nottingham, which relies on expectations of the investor who has been seeking the possibility of the one near Junction

26 and Motorway 1. But, he still requires some other alternatives to make a comparison. The second alternative is the one of Unit8 in Giltbrook Industrial Park, Nottingham, given the fact that this location is quite close to Blue Monkey, which is one big brewery in East Midlands in terms of production and could be a potential client. Compared to those two which are located in Nottingham, the third one is sited in Mansfield, in Unit B Enterprise Way, Millennium Business Park. And the prime reason of taking this location is the resulted employment advantage which can be explored in Mansfield. For selection purpose, eight aspects will be comprehensively taken in to account, because the business development and future expansion requires a good location can efficiently and effectively provide services under a stable circumstances regarding business and surrounding environment. Analytical hierarchy process is applied to model this part of problem considering selecting one optimal location for bottling facility as the goal with eight criteria and four alternatives. The analysis of this part is based on the understanding of the potential market (the number of microbreweries)this centralized bottling plant can mainly serve, the basic bottling information of breweries of different sizes, the total engaged activities before beer bottling by considering the breweries from the demand side and the activities after beer bottling especially wholesaling and exporting, and also some important issues with the respect to the surrounding area of the potential site. All the analysis should be complied with the business plan by respecting the investor in terms of his preferences.

Besides, to solve the problem, basically, the type of this facility location problem will be identified by referring to historical research, concerning the features it has. And It can be the motivation of exploring this project-based problem to fill the research gap of investigating location problem of beer bottling plant under investment. The whole methodology and analysis can be helpful for future research in facility location problem.

1.3.Outline of the dissertation

The second chapter will start by reviewing the previous literature about the facility location problems by classifying the types of those problems in terms of their typical features. In each category of facility location problem, different methods applied will be grouped and some of those which can be possibly used in this project will be critically evaluated in terms of their advantages and disadvantages. This part will then highlight the facility location problems relevant to the project in previous research, and some detailed issues related to manufacturing plant and even bottling facilities.

In the chapter three of methodology, it will firstly identify this project-based problem along with the main project objective and the assumptions based on it. Secondly, it will describe the sample scheme and data required in this project. After, it will fully demonstrate the tools or methods used in data collection and data analysis. Finally, the limitations and period covered will be mentioned.

The fourth chapter of 'findings and analysis' will describe the data collected from different tools as the findings and then based on the data, providing the analysis to firstly find the theoretically optimal location and then by including that location, illustrating how the final result comes out by providing relevant analysis for selection purpose. There will be some evaluations based on the result. Finally, a short summary will be given to this chapter.

Finally, chapter five will briefly summarize the whole paper.

Chapter 2: Literature review

2.1. Facility location problems: An overview

In recent years, it has seen a growing number of articles and scholars investigating facility location problems, which has been widely regarded as the placement of facilities in a certain community or network (Wagner and Wattenhofer, 2007). Especially since it saw the increase of demand based on strategic planning both for private and public organisations, the term-facility location has been frequently referred to (Owen and Daskin, 1998). And the problems have been broadly studied in many research areas, as Cheng and Li (2004) mentioned, such as management science, mathematics, computer science, operation research, marketing, industrial engineering, geography and urban planning, among which, operation research has been especially popular being researched in since early 1960s. The existing literature, depending on different contexts, does not specify a systematic research in analysing the problems and the correlated issues.

2.2. Facility location problems: Location Theories

Basically, according to Greenhut and Mai (1980), any locational problem of facilities, both private and public, implicates the match between the objective and operational features of the facilities such as budgeting, information channels and their locational characteristics.

Current location theories mainly address the questions of how to translate the facility and location information (i.e. requirements) into particular factors which will be focused on and how to formulate the factors into specific location models to resolve the problems. However, the focuses of the theories can be slightly different when distinguishing the one in international context and that in national context. The global economy location theories which accommodate some elements such as factors of production and international trade are basically product- and market-oriented and undertake the factors more towards macro level regarding the concept of national comparative advantage. As Feiberg (2006) mentioned in his article 'world economy of location theory', the location theory allows researchers to understand the factors not only those in terms of cost but also government policies and economic environment which can probably facilitate multinational companies to locate their foreign operations.

In contrast, more current location theories have been mathematics based and focusing on guiding the location modelling in smaller scale. One of the most important concepts in the location theories can be optimization, which was originally pointed out by Fermat Weber in the sixteenth century, proposing that given a fixed set of locations in the plane, it should attempt to minimize the sum of its distances between the targeted location and those existing ones in that particular area (Drezner and Hamacher, 2004). Therefore, Weber could be the first researcher who recognize the idea of 'median' or 'average' regarding spatial efficiency in location theory. With its development, in facility location optimization, the 'centre' concept was raised by adopting Rawl's theory of Justice to concern with the minimization of maximum distance, more focusing on the enhancement of spatial equity (Ogryczak.W. and Zawadzki, 2002). On the other hand, facility location problems are often formulated into different models depending on various objectives (single or multiple). For example, Weber's Least Cost Theory can be one of the earliest theories adapting the idea of optimization in weighted objectives, considering locating a manufacturing plant where the profit can be maximized through the approach of minimizing cost in transportation, labour and clustering (Carr, 1997). The fundamental theories applied in facility location have been frequently used in different location models based on different context.

2.3. Types of facility location problems and corresponding solutions

Basically, the facility location problem has evolved from very basic Euclidean spatial median problem early in the seventeenth century to more complex ones (Farahani et al, 2010). The way to categorize facility location problems has widely varied from different perspectives in the long and extensive research history. Similarly, even the methods to solve one single problem have been various and even conflicting which have been analysed by different authors from different angles.

2.3.1. Continuous VS Discrete location problems

Firstly, in research, one classification is based on the nature of demand side, under which the problems have been divided into continuous or discrete location ones. Continuous location problems areabout locating facilities in the plane based on a continuous space.

The published academic papers referring to the investigation of continuous location problems have been relatively current and few. And the scope of this problem has been broad under different contexts with different focuses. The Table 2.1 gives a brief overview of current published articles which concentrate on it.

Table 2.1 **List of published articles of continuous facility location**

Author	**Year**	**Title**	**keywords**	**Methods used**
Plastria. F.	1987b	Solving general continuous single facility location problems by cutting planes.	Continuous; single facility; minisum; minimax; optimality	Convex programming
Fernandez.J. and Pelegln. B.	2001	Using Interval Analysis for Solving Planar Single-Facility Location Problems: New Discarding Tests	Constrained planar; minisum; single facility	Big Square Small Square; branch-and-bound algorithm
Meira. L. A. and Miyazawa. F. K.	2008	A continuous facility location problem and its application to a clustering problem	Continuous; uncapacitated; Euclidean distance; k-means problem	Primal-dual based algorithm
Novaes. A. G., Souza de Cursi. J. E., Da Silva. A. C. and Souza, J. C.	2009	Solving continuous location–districting problems with Voronoi diagrams	Continuous; single facility; districting	Voronoi diagrams
Iyigun. C. and Ben-Israel. A.	2013	The multi-facility location problem: a probabilistic decomposition method.	Multi-facility, continuous; duality; clustering	A probabilistic decomposition method

In contrast, discrete location problems which undertake a discrete group of demand nodes and candidate sites have been widely investigated. Based on the previous literature, the methods corresponding to this problem have been categorized into two groups. As Revelle, Eiselt and Daskin (2008) summarized, in the recent literature, discrete location models have been dedicated to finding out useful heuristic-based algorithms in different practical context and research scopes such as Lagrangean Heuristics by Agar and Salhi (1998), LP-Based Heuristics by Alfieri.A.,Brandimarte.P. andD'Orazio.S. (2002), and parallel algorithm by Averbakh and Berman (1999). In contrast, Lee and Chang (2007) argued that discrete location problems are always formulated into optimization model (i.e. minimizing total cost) considering the matter of resource allocation, in which the most frequently analyzed facilities can be distribution center such as logistics center and telecommunication support center. Overall, discrete location problems in literature seem accommodate many other different features which can distinguish facility location complications, making the solution procedures varied and unsystematic.

2.3.2. Static VS Dynamic location problems

To review the previous studies in facility location, most existing literature simplified the associated difficulty and environment ambiguity or uncertainty in a static (or deterministic) consideration (Owen and Daskin, 1998). In literature, the static location problems analyzed under unchanged parameters over the plan have been researched since very early ages and the corresponding solutions have been more published. Arabani and Farahani (2012)found out that most research in this area has been focused on three sub-problems: continuous, discrete and network facility location ones. Melo et al (2009) also supported that when viewing facility location models in supply chain context, both discrete and continuous facility location problems can be regarded as static location ones.

Both Kariv and Hakimi(1979) and Revelle (2008) summarized in their article that median problem, especially p-median one is the core part of network facility location problems, which can be NP-hard, normally requiring the implementation of a tree system to resolve it.

In contrast, most of the research dedicated to dynamic aspects of facility location over a planning horizon has witnessed in most current years, but have been increasingly researched on since Wesolowsky (1973) started criticizing the static facility location solutions owing to its nature of no change based on the fact that facilities are supposed to be used over a long time, during which many factors such as costs and demand would be subject to potential incoming fluctuations. However, compared to static location models, the established ones which undertook the dynamic location problems are relatively less structured and systematic due to the more unpredictable analyzing situations. And the dynamic location problems are widely defined as NP-hard; many researchers have been concentrating on investigating solutions based on heuristic approaches, and some even add assumptions to solve the problems due to the related difficulties. For example, Van Roy and Erlenkotter (1982), and Erlenkotter (1978) mentioned a linear programming duality under multiple period decisions making, but with the assumption of complete flexibility of opening and closing facilities. Similarly, Chardaire et al (1996) proposed a dual-based procedure with the combined application of Simulated Annealing, Lagrangian Relaxation and dynamic programming based on a set of constraints.

2.3.3. Capacitated VS Uncapacitated location problems

Some researchers sorted facility location problems as uncapacitated and capacitated ones. According to Fernandez and Puerto (2003), uncapacitated facility location problems which are also known as the 'basic' discrete location problem has been more popularly investigated referring to locating an undecided number of facilities to minimize the sum of both the fixed investment costs and the variable service costs with the respect to fulfil demand from those sites. In the research history, uncapacitated facility location problems (UFLP) can be more popular to be investigated, compared to capacitated one.

Uncapacitated facility location problem is formulated with many restrictions. It usually requires the decision-makers to decide the size of the facilities instead of putting physical, technological or any budgetary constraints for problem modelling. And UFLP mainly concentrates on the manufacturing and distributing of one single product over a single-time period instead of multi one, when the demand of certain production should be assumed to be certain, and the demand side (customer zone) should be treated as a set of discrete nodes (Verter, 2011). This problem has been popularly investigated by using the dual-based ascent algorithm which was developed by Erlenkotter(1978), who formulated UFLA into a dually formatted linear programming and focused on producing ideal dual-based solutions by simple ascent and modifications in order to directly correspond to the primary integer solution and also a branch-and-bound algorithm would be applied if previous procedure cannot give the solution. For example, Tcha and Lee (1984) discussed an uncapacitated facility location problem in a multi-level based distribution network, in which the branch-and-bound method was applied on the basis of a mixed integer program to decide the ideal number of facilities for each level for distribution by minimizing the total related costs.

In contrast, capacitated facility location problem is often treated as the uncapacitated one with one or several capacity constraints which are always related to fixed set-up costs (Klose, 2000; Fernandez and Puerto, 2003). To solve capacitated facility location problem, a Lagrangean heuristics can be one of the most popular approaches which is used to relax certain capacity limitations. For example, Klincewicz and Luss (1986) solved a single-facility capacitated location problem by using the heuristic algorithm of Lagrangean relaxation. Klose (2000) applied the Lagrangean heuristic for location selection of depots with the capacity constraints by flow of product.

2.3.4. Single VS Multiple location problems

Many literatures distinguish the study of single facility location problem from multiple ones. Under this classification, many features of location problem (i.e. continuous or discrete, static or dynamic, capacitated or uncapacitated) are accommodated.

Multiple location problems

Compared to single facility location problems, currently, more literature generally focus on more complex multiple facility location ones. Many multi-facility location problems (also referred to as location-allocation problem), first studies by Cooper (1963), have been dealing with the determination of the optimal locations of a particular number of facilities to serve the demand and properly assign each demand node to one specific single facility. In this research area, the network facility location problem, especially covering problem (majorly categorized into Set Covering Problem (SCP) and Maximal Covering Location Problem (MCLP)) has always been highlighted, focusing on finding the minimum number and the location of facilities, to facilitate the examination of cost effectiveness of each pair of facility locations (Farahani et al, 2012; Church and Revelle, 1971). Other types of facility location problems and the solutions referring to multiple facilities can be various dependent on the complexity and background of it in the literature. Mixed integer programming can be used to solve simple location allocation problems only considering distribution issue. For example, Pirkul and Jayaraman (1998) discussed a multi-plant distribution network problem by using a mixed integer program to solve the warehouse supply assignment problem. Wesolowsky and Truscott (1975) investigated a dynamic multi-facility allocation problem, which applied both mixed integer programming and a dynamic programming to minimize the total costs when allocating the demand. Strategic facility location allocation problems under international context required the application of goal programming and analytical hierarchy process to deal with the complication of the objective conflicts to solve the product distribution problem (Badri, 1999).

Single location problems

In comparison, the single facility location problem, coping with locating one new facility in a particular context, can be one of the simplest types of location problems, and on a large scale, occur in a number of real-life situations such as manufacturing plant, machine instalment referring to facility layout, and warehouse (Moradi and Bidkhori, 2009). Most research in this problem has focused on minimizing the objective of total rectilinear or Euclidean distances between the optimal location of the new facility and a particular number of existing ones. The commonly investigated problems are referred to as Minisum and minimax location problems.

-Minisum problem

To review the literature about minisum problems, a large number of papers in this area have been focusing on the aspect of Euclidean distances. For example, the Fermat-Weber problem (in the basic form of spatial median problem), firstly studied by Fermat Weber is one of the most widely researched single-facility location problems, studying how to place a new facility in one territory that minimizing the total weighted Euclidean distances from m given sites (Bose et al, 2003; Durier and Michelot 1985; Brimberg et al, 1998; Chandrasekaran and Tamir, 1990). Also the famous Weiszfeld's algorithm has been widely studied and modified in solving minisum location problem with Euclidean distances (Vardi and Zhang, 2001; Katz and Vogl, 2010). However, as Miyagawa (2010) pointed out, although models based on Euclidean distances which can well estimate direct travel distances have been widely applied in spatial analysis, the rectilinear distance seems more appropriate for cities with a road network. In contrast, the study of single-facility location problem related to rectilinear distance has been relatively old and few. Academic books of facility layout translated minisum location problem with rectilinear distances into the one referring to minimize the cost of movement in both X and Y direction, and the solution is based on finding the optimal x and y coordinates regarding the cost function as convex function (Tompkins, 2010;Francis et al, 1992). However, it seems that the application of this approach is relatively more helpful the researching case is in small scale such as facility selection in one city, or even department selection referring to material handling.

-Center-of-gravity method (used in Minisum problem)

One of the simplest mathematical techniques which has been widely investigated for single-facility minisum problem with rectilinear distance is the centre of gravity method in location planning which seeks to compute geographic coordinates for a potential single new facility that minimize the distance (and the resulting transportation costs) between the existing facilities and the new facility location (Ballou, 1998a).

The centre of gravity method can be used in a larger scale, even under international context, and also consider the minimization of rectilinear distances based on the supposed volume of shipping activities (Schniederjans, 1999). Ballou (1973b) believed that centre of gravity approach has had continuing appeal to be used in first approximation in more mathematically sophisticated models which are required to deal with the problems of locating warehouses, freight terminals, manufacturing plants and so on. However, in his article, he also argued that this method, cannot select the optimum location under all circumstances and the potential error resulted is probably from varying structures of transportation rate, numbers of supply and demand points, their respective supply or demand levels and geographical configurations. Similarly, both Ballou (1985c) and Sule (2009) have tried a series of experiments and argued that when all points are of equal weight (there is no dominating demand from one source of existing facilities), there are many optimum locations. To obtain the optimum location for the new facility one should only examine the location of existing facilities although it is probably difficult to predict which of the existing facilities will provide the minimum cost solution. Schniederjans (1999) pointed out that in domestic context, this minisum methodology rarely deal with the complexity resulted from the network of lines representing the interaction (or transportation of units) between the existing points and the centroid which requires more considerable quantitative analysis. Likewise, Shamos and Hoey (1975) also mention the importance of discovering the closeness of demand points in a finite set when solving the single facility geometric optimization problems, highlighting the concept such as closest pair, clustering. However, in research, many authors focus on investigating the application of fast-algorithm techniques or advanced geometrical tools to deal with the complexity of this demand point connections, which can be difficult to common people. Therefore, actually, regardless of clustering of demand amounts, if there is significant dispersion of the transportation activities with the respect to demand points, the centre of gravity method can be an appropriated tool to find an optimal location involved in a road network under a two-dimensional situation.

-Minimax problem

In comparison, the literature regarding minimax location problems seems difficult to be unified, and the considered aspects and methodologies used vary significantly. Drezner (1981) presented an $n^2 \log n$ algorithm along with some computational experience to study the one-center model (also called single facility minimax location in the plane). Drezner and Wesolowsky (1991) investigated the minimax facility location problem considering the change of the weights associated with each demand point over time horizon and researched on finding time breaks in terms of location changes with modified conventional algorithms regarding rectilinear distances. Elzinga and Hearn (1972) developed efficient and finite solution procedures based on geometrical arguments to study four closely related minimax location problems: the Delivery Boy problem and Messenger Boy problem referring to rectilinear distances, the Delivery Boy Problem and Messenger Boy problem referring to Euclidean distances. However, as Matsutomi and Ishii (1998) mentioned, minimax location problems are usually dealing with the situations under which the set of demand side should be in a continuous basis instead of discrete one.

2.3.5. Single- VS Multiple-criteria location problems

Since the concept of multi-criteria decision making arose, many researchers have started investigating multi-criteria location problems, and exploring on different methods from those of single-criterion. Location science has a long history in single-criterion location problems. As Francis et al (1992) reported, those single facility problems referring to minisum and minimax issues were commonly recognized only considering one single objective function, normally total cost.

In contrast, the research on multi-criteria location problems has been very few for many years, but has seen a growth trend in the past decades as more published journal articles focusing on this problem in different business. As the aim of a site-selection problem has been increasingly recognized as to find the optimum location that satisfies a number of predetermined selection criteria, Farahani et al (2010) classify certain location problems into 'multi-attribute' and 'multi-objective' ones, the latter were further divided into Bi-objective and k-objective (k ＞=3). Current et al (1990) classified in the literature, the objectives can be categorized into commercial costs, profit maximization, environmental considerations and demand coverage. And in operation research, those objectives have been quantified under minimax, minisum, maximin considerations and the corresponding location problems have been majorly concentrating on various aspects such as location allocation, profitability, capacity, routing, competition and desirability (Farahani et al, 2010;Current et al, 1990).

Therefore, the multi-criteria location problems seems consist more facility location elements for analysis purpose such as number of facilities, budgeting and demand attributes (continuous or discrete). Also, many multi-objective location problems have been undertaken based on the formulation in a quantitative basis. For example, Ohsawa (1999) has concentrated on quadratic Euclidean distance model of one single facility in the continuous space, given the convex combination of minisum and minimax aims of both efficiencyand equity. Bhattacharya and Tiwari (1993) developed a fuzzy goal programming for a multi-facility location problem with minisum and minimax objectives regarding rectilinear distances. Myung et al. (1997) have formulated an uncapacitated facility location problem with two maxisum objectives based on investment profitability and net profit into an integer programon fractional and linear basis.

In contrast, multi-attribute location problem can be relatively more broadly investigated which can include more qualitative criteria.

Methods in multi-criteria facility location problems

Basically, according to Anderson et al (2009), in the field of management science, the commonly used techniques referring to multicriteria decision making are goal programming which has been developed to handle multi-criteria situations within the general framework of linear programming, scoring model as a relatively easy way to identify the best decision alternative for a multi-criteria problem, and analytical hierarchy process. However, to review previous studies, there is almost no article mentioning the application of scoring model in facility location. There have been various methods under research either based on general investigation or for the selection purpose in different location types and different context. For instance, Liang and Wang (1991) developed an algorithm based on hierarchical structure analysis where the scores of alternative sites under subjective criteria and the weight of every criterion are assessed in linguistic expressions exemplified by fuzzy numbers. Ishizaka et al (2013) have investigated PROMETHEE, weighted Sum method and TOPSIS to solve the location problem for the purpose of building a casino in London. Chou, Hsu and Chen (2008) implemented the fuzzy analytical hierarchical process for the selection of global tourist hotel, using the triangular fuzzy number by involving the concept of ideal and anti-ideal.

The following three methods can be regarded as the most popular ones which have been investigated in multi-criteria facility location problems.

-Analytical Hierarchy Process

The analytical hierarchy process (AHP), developed by Thomas L. Saaty in 1977, is one of the popular qualitative decision-making modals which can be used to identify a limited number of alternatives, from a broad geographical area, incorporating the preferred selection criteria. It also allows decision makers to express personal preferences and subjective judgments about the various aspects of a multi-criteria problem. And the output of AHP is usually a prioritized ranking of the decision alternatives based on the overall preferences expressed by the decision makers (Anderson et al, 2009;Saaty, 1990).

This method has been used for various decision makings in fields such as government, business, industry, healthcare, education and also facility location problems. For example, Ballis (2003) used the analytical hierarchy process (AHP) for an airport-site selection on the Island of Samothraki, Greece. Vahidnia et al (2009) suggested a fuzzy AHP method for determining the optimum site for a hospital, and Mohajeri and Amin (2010) applied AHP in railway site selection.

Some researchers admire the analytical hierarchy process method given different reasons. Chang, Wu and Lin (2006) believes that AHP is capable of integrating all the opinions of the decision-makers into a final resolution, without consulting the utility functions based on both objective and subjective criteria, but through pairwise comparisons regarding the alternatives. This is supported by Zahir (1999), who considers that AHP can support group based decision making by consensus through the calculations of pair-wise comparisons individually by geometric approach. Macharis et al (2004), pointed out that this method can clarify the relative importance of each criterion when decomposing the decision-based problem and building up the hierarchy. Ramanathan (2001) thinks that AHP gives users some degree of flexibility when doing changes according to that those changes will not influence the essential structure of the goal. Millet and Wedley (2002) agrees that AHP is able to analyze and undertake the way changes made at one of the levels influences the other levels, and they also viewed AHP as the tool which is able to customize model circumstances referring to case-based risks or uncertainties. As Wei et al (2011) pointed out, with the trend of solving problems subjectively based on objective reality, analytical hierarchy process can be more superior to those general mathematics methods which are difficult to formulate and solve problems.

In literature, many researches have not been solely focusing on the implementation of AHP, but combining it with some quantitative techniques to resolve facility location problems due to increasing complexity of real-world cases. For instance, Chuang (2001) gave one of the views to combine Quality function deployment (QFD) techniques with AHP to resolve location decision from a requirement perspective. Han et al. (2001) agreed that it is significantly important to transfer the opinions of customers into the selection process when proposing a comprehensive hierarchical framework for criteria. Wang et al. (2009) integrated geographical information systems with AHP to select a landfill site for solid waste in Beijing, China. Badri (1999) proposed the use of the Analytic Hierarchy Process and multi-objective goal-programming methodology to strategic global facility location-allocation decisions.

Some researchers have partially criticize the analytical hierarchy process about less capable of dealing with complexity. Norat et al (2013) mentioned that AHP becomes mathematically difficult to identify and detect the perceived inconsistencies, when the number of criteria or alternatives increases. This idea is supported by Miller (1956) who claimed that the synchronized comparison of more than seven items can be difficult for human beings; seven items should be the maximum tolerance for the comparison matrices. Similarly, Tavakkoli-Moghaddam and Mousavi (2011) pointed out that AHP is only utilized to prioritize selected criteria, without the process of selecting most influential criterion and also can be hard to choose the best alternative that satisfies all ranking criteria when solving complicated plant selection problems. Wang and Chen (2008) mentioned that the conventional analytical hierarchy process was not able to process imprecise or vague knowledge, although it could probably modal expert opinions.

A number of researches have focused on fuzzy AHP, applying the fuzzy set theory, to rationalize uncertainty and enhance hierarchical structure analysis. As Torfiet al (2010) pointed out that fuzzy analytical hierarchy process can be used to determine the relative weights of evaluation criteria, with the demonstration of fuzzy membership function and related calculations of prioritization, which is different from the conventional AHP through which the weights are normally determined by the preferences of decision makers. Nevertheless, the fuzzy AHP is more likely to be applied to determine the location of facilities for public purpose where the valuation of evaluation criteria cannot be determined by one or several specified decision makers. In literature, for example, Ka (2011) applied fuzzy AHP in the location selection of China dry port; and Kuo et al (1999) researched the problem of locating convenience store by fuzzy AHP. Although it may probably more objectively prioritize the selected criteria thus the candidate locations, the complication of the mathematical analysis sometimes can make it less capable to be used widely.

-Goal programming

Goal programming can be used to cope with multi-objective situations within the framework of linear programming, which is also widely used in solving multi-criteria location problems.

Pati et al (2008) built a goal programming to undertake a multi-facility network location problem based on paper recycling in India, which studied the correlations between different objectives such as product quality enhancement, environment improvement and cost reduction of reverse logistics. Zanakis (1981) applied a large-scale integer goal programming (with 175 binary variables and 81different goals) to comprehensively solve location allocation problem of healthcare facilities in one region. Uno et al(2007) emphasized on the goal programming model to solve multi-objective single facility location problems in competitive environment, and its solution algorithms focused on maximizing the number of their customers regarding the provision of location convenience. However, in the article, they also points out that in real-world situation, the objectives involved could be subjectively determined or vague.

Goal programming has been criticized by not sufficiently dealing with situations in uncertain environment. Chang et al (2010) claimed that goal programming model can only formulate the problems into structures only when there is highly detailed information (i.e. clarified targets). Werczberger (1976) argues that facility location problem usually cannot be analysed sufficiently or feasibly through underlying goal programming modals and this method will confine the scope of the problems when being formulated, because goal programming should be implemented strictly based on the fact that all objectives can be expressed in the form of linear constraints and the resulted set of constraints will hardly have a clarified ideal solution. Sometimes the original definition of objective constraints will bias the level of expectations, leading to no feasible solution resulted.

-Mixed integer programming

The mixed integer programming, the branch of linear programming, is popularly applied to solve facility location problem especially with the features of costs, timing and job assignments, which mainly consider the distribution of certain materials or products from one single or multiple facilities, with the application of binary decision variables for facility location selection (Pochet and Wolsey, 2006). Many researchers investigated mixed integer programming as optimization models to solve facility site selection problem. For instance, Fuller et al (1976) applied mixed integer programming to build a plant-location model of site selection for one processing industry by setting the objective function of minimizing the total expenditures of processing, storage and assembly by considering spatial and time-based flow of raw materials. Likewise, Chen et al (2011) focused on analyzing fixed-charge transportation and distribution problems with the target of finding the shipping plan of a minimum cost.
Nevertheless, this method has been increasingly treated as a multiple-criteria or multiple-objective decision-making approach accommodating many distinguished factors into one complex formulation. In research, Haug (1985) once investigated a mixed integer programming model for selection of multinational facility location with the overall objective of maximizing after-tax profit by considering and quantify several factors such as labour features, politic risk, regulations, host-country incentives, sourcing issues, and time. Xie et al (2009) pointed out that, when deciding the site of one bio-refinery facility, in comparison with other mathematical models involving the procedure of decomposing the problem into small parts, applying mixed integer programming can save considerable multiplication time and at the same time include several factors (i.e. candidate sites, biomass delivery, and road system). Apart from it, mixed integer programming model has been investigated for cases of long-term horizon or multiple periods. For example, Liu et al (2011) has developed a superstructure multi-period based mixed-integer programming to strategically plan a chemical centre over a long-term horizon, by dividing it into several time intervals, and over which it can be established and even expanded.

In literature, the mixed integer programming is popularly used to solve both uncapacitated and capacitated facility location problem with generally non-linear setup costs and consists of a fixed term and several second terms to select one or several facilities based on resources or customer distributions (Wu et al, 2006). According to Revelle et al (2008) most discrete location problems which can be categorized as median and plant location problems and center and covering problems are often formulated as integer or mixed integer programming problems. Those discrete location problems are mainly multi-facility and focusing more on location allocation issues. But Marín et al (2009) have found out that most basic discrete location problems referring to p-median and uncapacitated ones have been extended to include more considerations such as multi-echelon structure, facility choice, strategic supply chain planning and time dynamics, which makes the problems difficult to be formulated and solved solely by mixed integer programming.

In addition, Chen et al (2011) mentioned that mixed integer linear programming indicates that all required data should be given, which can be considered as one common problem in linear programming models. Hilger et al (1977) argued that to solve the complexity resulted from locating a facility within a distribution network by using mixed integer programming can lead to considerable effort and cost which can be reduced considerably using heuristic approaches.

2.3.6. Facility location problems under VS not under competitive environment

In literature, some facility location problems were investigated by considering a number of competitors nearby, where the research scale was often narrowed by considering single facility locations. There is very little literatureanalysing the problem of single facility location selection in competitive environment since Hotelling (1929) firstly mentioned the competitive facility location in his article' Stability in Competition'. One of the few papers was written by Drezner (1994) who discussed the location of a single new competing facility in a continuous planar space referring to Euclidean distance, relating the utility function method to calculate the break-even distances. Some researchers have focused on utilizing deterministic utility or random utility model to analyze mainly static competitive facility location problems in the measurement of the attractiveness level of the facilities determined by certain functions of attributes. For example, Küçükaydin et al (2011) developed a bi-level programming model measuring the attractiveness of facility by considering customer's utility function. Plastria (2001a) reviewed Huff's gravity-based model to include an attractiveness function for measuring the market share captured by new and existing facility. In comparison, the published literature referring to CFL problems under uncertain or vague demand can be rare and relatively complicated and various methodologies have been mentioned recently.

2.4. Facility location problems in project background

2.4.1. Facility location problems relevant to this project

There are very few literatures discussing about location selection especially under project investment. Cheng and Li (2004) grouped these problems into four clusters based on the amount of investment for each project (small/large) and the project types (independent/chain business). However, they also mentioned that, only research in retailing projects related to spatial matters currently has mature analysis referring to spatial theories and relevant models involving the use of maps, trade area analysis and regression techniques. But in location selection, there are no methods either quantitative or qualitative which can systematically solve different project problems. However, many articles classify this type of facility location problems as multi-criteria ones. Bhutta et al (2003) investigated an investment model for selecting a site for multinational corporation which decomposing the whole problem into several parts considering facility structures, distribution plans and production levels to study the interactions of the units and applying the mixed integer programming to formulate it. Roberto (2004) emphasized the criteria of public infrastructure, level of demand, labor issues and stock of competitors which should be considered when selecting among candidate locations when making investment in Italy. Erbıyıka et al (2012) applied analytical hierarchy process to solve location selection of retail store under long-term investment and summarized the criteria which should be considered, including plant feature, distance, market attractiveness, potential demand level, economic factors (i.e. transport cost and rentals), competition, transportation or accessibility and trade area.

2.4.2. Manufacturing plant location issues

The literature analyzing location selection problem of manufacturing plant based on investment purpose have focused on different research questions, varying from capacitated or un-capacitated location problem, single or multiple facility location to distribution or allocation ones, among which capacity and related cost issues can be popular under investigation. For example, both Jaramillo et al. (2002) and Ghiani et al. (2002) explored generic method to solve the capacitated plant location problems dealing with the selection of one or more subsidiary plants out of a number of candidate sites to minimize associated fixed cost and operational costs. Verter and Dincer (1995) integrated facility location with capacity acquisition to investigate the models of capacity expansion given a number of existing candidate locations, aiming at deciding the size of the newly established facility when selecting the optimal location.

On the other hand, overall, different aspects have been focused on when this type of problems are undertaken in different context. For example, Lindberg (1953) analysed the site selection of paper manufacturing plant in Sweden by considering total costs of the input transportation (mainly raw material) on a large geographic scale and output transportation for exporting. Head and Swenson (1995) explained a location selection model based on the investment of new Japanese manufacturing plant in US, which highlighted the concept of agglomeration by aggregating manufacturing related activities given unmeasured criteria favourable to the locations of suppliers and assembly plants. Ulph and Valentini (1997) simulated how downstream and upstream companies affected the decision making of single-facility plant location problems without the consideration of capacity by testing in two industries of two countries.

2.4.3. Site selection of bottling facility in different contexts

Currently, the literature can be scarce specifically explaining appropriate location model for selecting a bottling facility for any type of business. And, mainly news gives ideas about how the site selections of different kinds of bottling facilities are decided. For example,

The Morning Call (2012) reported that the water bottling plant of 'Ice River Springs Water Co' was newly established in 2012, where the primary criteria which the company considered is the accessibility advantage towards its main markets to serve customers and the cost effectiveness in terms of stuffing and energy utilization in Lehigh Valley. Cunningham, J. (2012) stated the postponement of settling a milk bottling plant due to the less consideration of the proximity of milk producer- 'Continental Dairy of Coopersville' and its existing problems about neighbourhood. Area Development (2012) reported that the decision making of locating a bottling facility of 'Ocean Spray Cranberries' to serve the juice products both from Ocean Spray and Nestle's was mainly focusing on the government incentives towards infrastructure development and the advantage it could explore in local community based on the factors such as employment rate. Packaging-gateway.com (2006) informed that Leven bottling plant (serving Diageo, a large alcohol drinks manufacturer) was newly launched for expansion purpose to accommodate 198 million litters drinks which majorly considered the proximity to existing 17 bottling lines as the selection criteria, dedicating to efficiency.

2.5. Summary of literature

To summarize, the previous literature of facility location problems can be mainly classified into six groups: Continuous or discrete, static or dynamic, capacitated of uncapacitated, single or multiple, single-criteria or multi-critiera, competitive environment or non-competitive environment. In the first type, continuous location problems are relatively new and current, which have been investigated in a wide scope, with different considerations (number of facilities, capacity issues and distance optimality).The solutions are unsystematic based on problem context. Discrete location problems are explored more intensive, with mainly two groups of solutions: heuristic-based one and optimization model. To the second group, static facility location problems have been systematically summarized into 3 major categories: continuous, discrete and network ones. In comparison, dynamic location problems are various and relatively difficult, which normally require one or even several heuristic approaches to resolve. In addition, the uncapacitated facility location problem without restrictions of investment cost is usually solved by Erlenkotter's dual-based ascent algorithm by applying linear programming and then branch-and-bound algorithm. In contrast, capacitated one with fixed set-up cost is normally solved by Lagrangean heuristic. In terms of single or multiple facility location problem, multiple one is comparatively more difficult with the focus on facility allocation, which is investigated widely based on background and complexity. By contrast, single facility location problems are mainly classified into minisum and minimax ones, where minisum problem is more popular and can be further divided by the consideration of rectilinear and Euclidean distance. The problem referring to rectilinear distance can be close to real-life cases. The center-of-gravity method is reviewed by grouping both its advantages and disadvantages. But minimax one is mainly continuous-based and relatively more difficult. Furthermore, compared to old single-criteria location problems, multi-criteria ones are more current, which deal with multiple objective and multiple attributes. The three methods of it (AHP, goal programming and mixed integer programming) are critically reviewed. Then the problems referring to competition are very few and listed. Finally, the facility location problem under investment highlights the concept of multi-criteria. And various manufacturing-plant and bottling-facility based location problems are listed. This literature review can be quite linked with the study of this project, and can be helpful for defining and classify this project-based facility location problem. This study will abstract the essential ideas from different types of facility location, and investigate on building a location model for this project.

RESEARCH target: location selection for bottling plant of serving microbreweries in East Midlands area,UK, based on finding one single facility firstly, and then selecting the optimal one among four candidate locations.

Chapter 3: Methodology

The methodology chapter will firstly define the project objectives, identify the project problem and highlight the assumptions in it. Then it will provide a graphic framework of the way this project problem will be structured and analysed. A sampling scheme will be determined before illustrating the procedure of data collection, which will primarily include a data description according to the primary and secondary data classifications, and then explain the particular tools for data collection. Afterwards, data analysis methods will be described in detail. Finally, it will list the limitations of this research and mention the time horizon of this project investigation.

Methodology, according to Rajasekar, Philominathan and Chinnathambi (2006),can be defined as a procedure of studying the way a research is to be undertaken by defining, explaining and indicating the investigated situation with a systematic work plan. As New Age International (2013) referred, methodology is not only about the way to develop models, formulate problems, application of research techniques, but also include the justification of the relevance referring to different methods, their underlying assumptions, indications, and also the criteria based on which particular method can be valid. In other word, researchers should customize the methodology for each specialized problem by designing particular procedures, tailoring research techniques under certain background with assumptions or limitations.

3.1. Project Objectives

The main objective in this project is to find the optimal location of a centralized bottling plant to serve the breweries which are willing to cooperate with it in East Midlands area, with the consideration of a series of relevant requirements.

3.2. Identification of the problem

The first part of this facility location problem can be regarded as a Minisum problem by minimizing the total weighted rectilinear distances from all the responded breweries to the bottling plant.

In the second stage, this facility location problem in the project has two main features:

1. It can be identified as a single facility location problem due to the fact that only one site will be selected without the consideration of assignment issues.
2. It should be a multi-criteria problem, because under the investment environment, a number of criteria should be carefully analysed before making the final decision. The issue of competition

exposure in facility location which is pointed out as one focus in literature review can be included as one criterion as well.

In addition, because all the locations of the breweries can be regarded as a discrete set of demand nodes, it can have the feature to be a discrete facility location problem instead of continues one. However, this feature sometimes can be included in single facility location problems especially minisum problems which was referred to in literature review.

3.3. Assumptions

In this facility location problem, two assumptions are made before building a proper model.

1. Uncapacitated

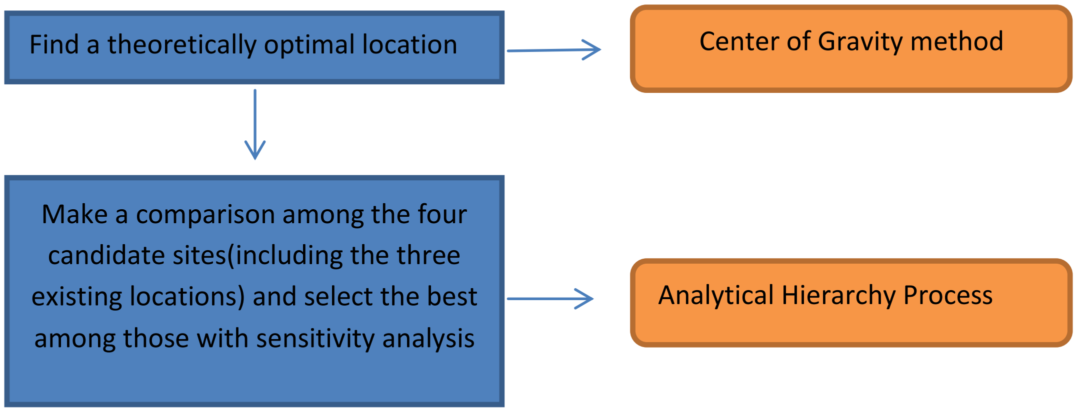
   It assumes that this facility location problem will be analysed without limitations in terms of funding. From perspective of investment, the target of the project is more likely to find the location which can probably minimize the cost rather than restrict the options by giving fixed investment funding.
2. Static

   It assumes that the models are based on solving static facility location problem by simplifying the associated difficulties due to environment changes, that is, to ignore the issues such as close or reopen of the bottling plant in the first five years of the investment time horizon.

3.4. Framework

Basically, the project aims to find an appropriate site to build a centralized bottling plant to serve the East Midlands area of UK. This problem, as the Graph 3.1 illustrated, can be further broken down into two parts: finding a theoretically optimal location and selecting the best location among those four candidate locations(the investor proposes three of those). Based on this framework, two methods are normally required in different stages.

Graph 3.1 Framework of the whole problem



3.5. Sampling Scheme

Basically, as Cochran (2007) concluded, it can be unrealistic to undertake the full population, instead of which, sampling can be more practical to deduce statistics about the whole population without investigating each individual, reducing cost and workload.

According to Bathla.H. (2013),Sampling scheme can be mainly classified into probability and non-probability ones. A probability sample is the one selected on the behalf that each unit among the whole population has a pre-set probability in the random selection. In contrast, a non-probability sample is selected through a non-random procedure, which can include judgement sampling, voluntary-response sampling and convenience sampling. (Doherty, 1994 ;Bathla, 2013). Voluntary response sample is the one obtained through which participants out of whole population choose to respond or not voluntarily (Statistical Consulting Program, 2013). This project seeks to find out the possibility of building a centralized bottling plant by consulting the opinions of existing breweries in East Midlands area. Therefore, it should be based on a voluntary response sampling, allowing those breweries which are interested in using the bottling facility to respond which can be voluntary. However, because this sort of sampling cannot accurately demonstrate the true value of the population due to the lack of information of probability in the selection, it is not capable to fully indicate the phenomenon in the future when more, even all the breweries tend to participate in this project.

3.6. Data collection

3.6.1. Data description

Generally, in this project, the data required is basically categorized by answering the following questions:

1. What are the attitudes of the microbreweries in East Midlands in terms of using contract bottling? What are the current bottling options of those breweries?
2. How many breweries will be treated as the potential clients of the project-based bottling plant?
3. What is the required size (in terms of layout) of the bottling plant to accommodate all the volume of beer sent from potential clients?
4. What are the markets which the microbreweries mainly serve and their post-bottling activities?
5. How fierce is the current competition which is supposed to be faced by this bottling plant?
6. What are the other external factors which can probably be considered for the location decision making?

In detail, the first two questions are trying to explore the possibility of building a new centralized bottling plant in East Midlands area of UK, which require the location details (physical address, county, city and postcode) of those microbreweries having need of contract bottling. These details might be partially included in previously collected information in terms of 88 microbreweries in East Midlands (See AppendixI) provided by Jeremy Avis who is one of the industrial collaborators in this project. The third question necessitates the data on the demand side, which should be the production details of each brewery (number of barrels produced per week), and the percentage of the production which are supposed to be bottled. In addition, the information required to answer the fourth questions are normally the exporting and wholesaling issues considered after bottling. The competition consideration can be based on clarifying the potential competitors which can be the current bottlers for those potential clients or those exist in terms of competitive location, pricing or size. The last questions will be mainly required in the second stage of selecting among the four candidates sites, which can be qualitative and secondary-research based. The Table 3.1 which is demonstrated below can give the data classifications and clarify the description of the data required.

Table 3.1. Data classifications

Required data description	Data classifications
Production details by the breweries	Primary data
Current bottling facts by the breweries	Primary data
Likelihood of using the centralized bottling facility	Primary data
Potential competitors of bottling plant and their current size, detailed location, pricing facts	Primary data
Market information of the breweries	Primary data
Return rate (number of bottles) of each brewery	Primary data
Exporting and wholesaling issues	Primary and secondary data
Bottle company details	Secondary data
Employment rate in the relevant regions	Secondary data
Required facility features	Primary and secondary data
Other information for analysis	Secondary data

3.6.2. Data collection tools

Primary data will be mainly collected through three approaches: survey, observation and meeting. Firstly, according to OECD (2013),survey focuses on investigating the features of a certain population normally by acquiring data from a sample for estimation purpose through certain statistical methods. As Sincero (2012) summarized, survey, conducting standardized questions, can obtain very high reliability by the elimination of researchers' subjectivity, and conveniently accessed by participants in a cost-efficient way. Basically, survey in this project is built through an online questionnaire, which aims at finding the possibility of locating a centralized bottling plant in East Midlands area, as a result of which, targeted population is all the microbreweries which producing conditioning beer in that region. Google Form is applied to conduct the questionnaire, which provides live form for breweries to respond and allows users to view responses instantly. The whole questionnaire is divided into five parts. First part is a commitment made to announce the purpose of the survey and declare the confidentiality of the information obtained from breweries. The main body consists of three parts: company information, outsource bottling process and outsource bottling facilities. The final part is asking for further suggestions. Basically, question types can be categorized into text, multiple choices, choose from list, scale, and open-ended. See Appendix II of the screenshot of the questionnaire.

Observation is normally a way of collecting data through watching activities, behaviour, or noticing physical features of the natural situations. It is especially used when it is necessary to understand an on-going process and requires interactions with people (Centers for Disease Control and Prevention, 2008). Two brewery visits and one visit to bottling plant are scheduled to understand the basic concepts and processes of beer brewing and bottling, the reasons for location selection, the major activities after bottling and also the structures and layout of the facilities. In these three visits, there will be frequent interactions with staffs for better understanding.

Meetings with Jeremy Avis and the investor will mainly inform the expectations of the outcome, the preferences towards the aspects will be focused on, and requirements or suggestions in the analysis.

Secondary data will be gathered through books, journals and online research, in which website-search is the core tool and Google scholar and Science Direct will be the two main databases to be used.

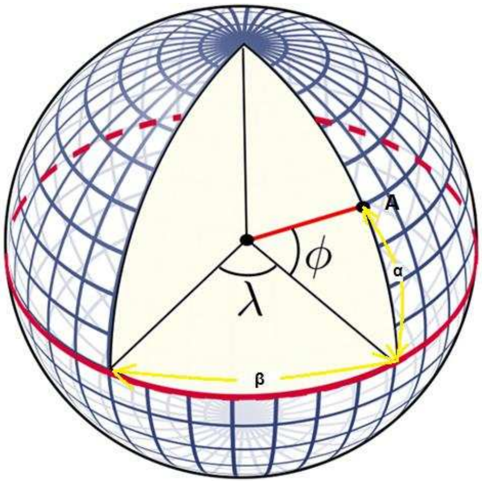
3.7. Data analysis tools

3.7.1. Center-of-Gravity method

Basically, locations of existing facilities on demand side (the breweries) should be placed in a coordination system. To determine the X coordinates and Y coordinates of each location of the breweries, the arc lengths of the earth corresponding to different latitudes and longitudes are roughly used. Given all the postcodes of the involved breweries, both the latitude and longitude can be obtained for each location by using Google Maps. Due to the fact that latitude is defined as the angle varying from 0° to 90° at the equator (North or South) (Oxford Dictionary, 2013), (as the graph illustrated, φ can represent the latitude where A locates), the arc length α can be used as the Y coordinate, by using the following formula to convert that latitude into.

Arc length=$n^o/360^o \times 2\pi r$, where r is the radius of the earth, amount to approximately 6371 km

Similarly, X coordinate can be the arc length β corresponding to the longitude λ using the same formula, given that longitude can be measured as an angle east or west, varying from 0° where from the Prime Meridian, to +180° eastward and −180° westward (Oxford Dictionary, 2013).



To improve the accuracy, the original point is changed into somewhere approximately at the boundary of UK, where the latitude is 49.9 and the longitude is -5.3. Therefore, the X coordinates and Y coordinates of the location for each microbrewery should be amended according to the formula (3.1) and (3.2):

X coordinate=φ/360°× 2πr- 49.9/360°× 2πr(3.1)**whereφis the latitude of the location of a microbrewery**

Y coordinate= λ/360°× 2πr- (-5.3)/360° × 2πr(3.2)

whereλis the longitude of the location of a microbrewery

By using the formula (3.3) and (3.4), both X and Y coordinate of the theoretically optimal bottling plant can be obtained, considering the number of barrels of beer (that the breweries are supposed to send to the centralized bottling plant) as the weight.

$$\text{X-coordinate}=\frac{\sum_i d_{ix}Q_i}{\sum_i Q_i} \qquad (3.3)$$

$$\text{Y-coordinate}=\frac{\sum_{i} d_{iy} Q_i}{\sum_{i} Q_i} \quad (3.4)$$

Where d_{ix}= x coordinate of brewery i

d_{iy}= y coordinate of brewery i

Q_i=Weekly production of brewery i, because the bottling plant will undertake production turns on volumes of the minimum number of barrels and its above instead of bottling the required volumes of breweries in customization, as a result of which, here, it roughly uses the term of weekly production .

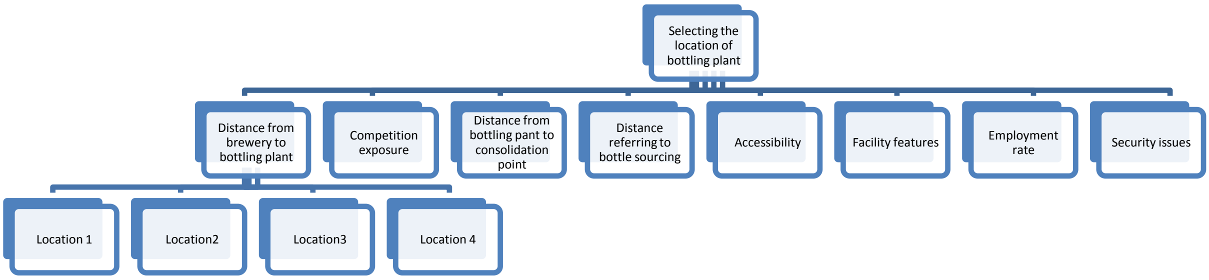
Besides, if the obtained site is not exactly located in an available warehouse or distribution centre, the theoretically optimal location which is obtained by center-of-gravity method is taken as the centre of a circle and expanding the radius until there is one available property for warehousing or distributing.

3.7. 2. Analytical Hierarchy Process

- Problem modelling

Based on the rationale of analytical hierarchy process, this facility location problem should be firstly structured by giving an explicit hierarchy expressing criteria and alternatives,which is shown in the Graph 3.2 where the eight criteria has been determined and alternatives are the four candidate locations.

Graph 3.2 Problem modelling in Analytical hierarchy process



- Judgement scaling and pairwise comparisons

The comparison scaling table which shows in Table 3.2 should contribute to pairwise comparisons among those pairs of criteria. The preference of criteria given by decision maker (the investor in this project) in terms of ranking, as the Table 3.3 demonstrated, should be firstly translated into numerical rating in pairwise comparisons. The numerical rating can be measured by consulting the relative positions of the criteria in ranking. For example, the rating can be 2 to compare the first and the second criterion in the ranking list, and it is 3 to do the first and the third criterion. By parity of reasoning, the comparative importance between those pairs of criteria can be determined, which should be put into pairwise comparison matrix first.

Table 3.2 Judgement scaling of pairs of criteria

Verbal judgement	Numerical rating
Extremely More Important	9
	8
Very Strongly More Important	7
	6
Strongly More Important	5
	4
Moderately More Important	3
	2
Equally More Important	1

Table 3.3 Ranking of criteria

Criteria	Ranking
Distance from brewery to bottling plant	1
Competition exposure	2
Distance from bottling plant to consolidation point	3
Distance referring to bottle sourcing	4
Accessibility	5
Facility features	6
Employment rate	7
Security issues	8

To each criterion, there should be pairwise comparisons among those pairs of candidate locations, given numerical ratings by each of those. To determine the ratings among the pairs by referring to guideline in Table 3.4, some analysis will be given correspondingly to finally fill in 8 pairwise-comparison matrices (See Table 3.5).

Table 3.4 Judgement scaling of pairs of alternatives

Verbal Judgement	Numerical rating
Extremely preferred	9
	8
Very strongly preferred	7
	6
Strongly preferred	5
	4
Moderately preferred	3
	2
Equally preferred	1

Table 3.5 Pairwise comparison matrix of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AT)	1	a	b	c
Location 2(NG16 2RP)	1/a	1	d	e
Location 3(NG16 7US)	1/b	1/d	1	f
Location 4(NG19 7JY)	1/c	1/e	1/f	1

-Methods involved in criteria analysis

To analyse some criteria can not be very straightforward. Therefore, specialized methods will be used into this. In terms of competition exposure, the rationale of Huff's model is applied to quantify the concept of competitiveness (Plastria, 2001), using attraction function to identify the market share which each candidate bottling plant can gain when competing with potential competitors in East Midlands area. The formula of the attraction function is illustrated below:

$$\boldsymbol{MS}(\boldsymbol{\alpha},\boldsymbol{x}) = \sum_{i\in \boldsymbol{I}} \boldsymbol{Wi}\frac{\boldsymbol{attr}\ (\boldsymbol{i},\boldsymbol{x})}{\boldsymbol{attr}(\boldsymbol{i},\boldsymbol{x})+\sum_{\boldsymbol{f}\in \boldsymbol{CF}} \boldsymbol{attr}\ (\boldsymbol{i},\boldsymbol{f})} \qquad (3.5)$$

Where

-MS (α,x) = the market share of a single new facility (candidate bottling plant) x

-CF = the set of existing competing facilities

-Wi = the supply amount by consumer (weekly volume required for bottling)

-attr (i,x) (similar to attr (I,f))= the attraction felt by brewery i towards bottling plant x (competing facility f)

where $attr(i,x) = \frac{\alpha}{c(dist(i,x))}$, attraction is decreasing as distance between brewery and candidate bottling plant (c(dist(i,x))) but increase with quality (α). In this case, α is the capacity of the bottling plant and also distance is selected as the measurement indicator in the attraction function.

- Priority derivations

After filling all the matrices of pairwise comparison, the calculations of priorities can be enhancedto determine the most optimal location for bottling plant. The software of EXPERT CHOICE, which is a multi-criteria decision making tool based on AHP, will be used to conduct the formulation of problem and calculation of the priorities of criteria and alternatives, because the eigenvector method in pairwise comparison expressed below which AHP uses can be very complicated if being used manually especially when there are more than three criteria.

<u>Eigenvalue method(</u>Sekitani and Yamaki, 1999):

P_1/P_1	**P_1/P_2**	**…**	**P_1/P_n**
P_2/P_1	**P_2/P_2**	**…**	**P_2/P_n**
…	**…**	**…**	**…**
P_n/P_1	**P_n/P_2**	**…**	**P_n/P_n**

$$\begin{bmatrix} \frac{P1}{P1} \frac{P1}{P2} \ldots \frac{P1}{Pn} \\ \frac{P2}{P1} \frac{P2}{P2} \cdots \frac{P2}{Pn} \\ \cdots \cdots \quad \cdots \\ \frac{Pn}{P1} \frac{Pn}{P2} \cdots \frac{Pn}{Pn} \end{bmatrix} \begin{bmatrix} P1 \\ P2 \\ \cdots \\ Pn \end{bmatrix} = \text{n} \begin{bmatrix} P1 \\ P2 \\ \cdots \\ Pn \end{bmatrix}$$

$$\text{A}= \begin{bmatrix} \frac{P1}{P1} \frac{P1}{P2} \ldots \frac{P1}{Pn} \\ \frac{P2}{P1} \frac{P2}{P2} \cdots \frac{P2}{Pn} \\ \cdots \cdots \quad \cdots \\ \frac{Pn}{P1} \frac{Pn}{P2} \cdots \frac{Pn}{Pn} \end{bmatrix}$$

The formula of eigenvector method:

A p = n p

where p : vector of the priorities
n: dimension of the matrix
A: comparison matrix

- Sensitivity analysis

After the optimal location is selected, it will conduct a sensitivity analysis by removing some criteria and changing the relative weight and priorities of the criteria to seek different possibilities of selection among the alternatives. The application of Expert choice presents the 'what-if' scenarios by changing the weight of different criteria to see the corresponding changes of final valuation of the alternatives.

3.8. Limitations

The analysis can be constrained based on the data obtained from the voluntary respondents of the online questionnaire, which cannot best estimate the real feasibility of building bottling plant in this region. Also the design of the methodology may not make it possible to undertake the analysis comprehensively only concerning the limited dimensions which can be focused on, partially due to the computation difficulties in AHP and also the limit of number of criteria its software of Expert Choice.

3.9. Period Covered

This project will last for approximately three months, starting from 10th of June to 20th of September.

Chapter 4 Findings and Analysis

This chapter will firstly provide the findings from online questionnaire, observations and meetings,where the survey results will be presented by listing the respondents and abstracting results which can facilitate and be relevant to the discussion in facility location part. And then the analysis will be undertaken by utilizing the collected data going through the steps which mentioned in the framework part of the methodology chapter. Sensitivity analysis will be provided as recommendations. Finally, there will be a summary of the whole chapter.

4.1. Findings

4.1.1. Survey Results

Basically, 13 responses in all are obtained from the targeted over100 potential respondents, only constituting approximately 10 per cent of response rate for this survey. To view the filling rate based on the responses, 9 out of 13 respondents answer all the questions, and the other four respondents answer all except the final open-ended question. All the answers obtained from the online survey are arranged into three tables. See Appendix III.

This survey is mainly conducted to answer Question 1, 2, 3, 5 and the part of post-bottling activities of Question 4 which mentioned in 'Data Description' part of methodology chapter. Firstly, in terms of the attitude of the respondents, when viewing the likelihood of using a contract bottling service, there are six breweries choosing the option of 'strongly likely' rating at 5, meanwhile, three breweries showing their attitude by 'strongly unlikely'. Four breweries are currently using contract bottling in which two are contracting with Cumbrian bottling, and the other two are contracting with leek brewery and Holdens bottling correspondingly. Except those four breweries, five breweries tend to outsource bottling by contract within six months and another two may probably consider this within one year. In the same subject, the brewery of Handley's seems have no intention for beer bottling, which shows consistency when looking at its negative attitude showing the 'strong unlikely' of using contract bottling service. Also, according to the comments make at the end of the survey, Handley's mentions that it is just a small brew-pub and tend not to bottle beer on anything other than a tiny scale. But Langton Brewery can be still considered using outsourcing bottling in the investment time horizon which might probably think about this more than two years later. Raw Brewing Company shows its attitude by possible switch from current contractor only if the kegging service is included as well. Brampton Brewery also mentions about the flexibility of the services which the bottling plant should consider by adding services such as bottling kegs, keykegs, petainersetc as well as doing sterile-filtered or carbonated beer.

Secondly, with the respect to the volume on the demand side, Funfair Brewing Company, SPIRE BREWERY, Nutbrook Brewery and Brampton Brewery are relatively bigger in size based on average weekly production, among which only two are currently using contract bottling. Funfair Brewing Company has the highest maximum capacity, which is capable of producing 120 barrels of beer per week. Apart from of it, six breweries have their maximum weekly capacity of more than 25 barrels, and two below 5 barrels. And 10 out of 13 respondents are willing to expand their capacity in the future. Barlow Brewery suggests that it may expand its capacity to 6 barrels per week and use at least half of its production for bottling. Regarding the percentage of production which requires for bottling, six breweries have relatively high demand given more than twenty percentage of their production, in which three breweries demand between 40% to 60% of it. On the other hand, the volume which those four breweries mentioned before send for contract bottling ranges from 5 to 10 barrels coincidently. In terms of the frequency of beer bottling, except Handleys and Langton Brewery which have not given the answer by showing their current attitude, five breweries tend to send beer twice a month and four require once a month, leaving the other two breweries requiring less than once a month.

Thirdly, concerning the post-bottling activities, the return-rate part answered in the survey can be summarized as: Raw Brewing Company and 8 sail brewery require all of the bottled beer back and Nutbrook Brewery and Brampton Brewery need approximately 80 percentage of it; whereas, other 8 breweries only need equal or less than half of it to be back; and most breweries require the bottled beer back within two weeks (three breweries need it back within one week (between 3 to 7 days); seven breweries require it between 1 to 2 weeks after bottling). Barlow Brewery is considering of exporting after bottling but still struggling with the space storage problem.

Finally, in terms of current competition by regarding price, the survey gives the results of current bottling price and that under expectations. To view the current bottling payment in terms of every 500 ml, which have already considered the elements such as volume, bottling options (in-house or contract bottling), the unit price varies significantly, ranging from ‘less than’ 15p to ‘between 46 and 65p’. To bottle less than 5 barrels of beer, half of the respondents expect more than 36p to bottle a 500-ml bottle, and another half expect it to be less than 35p in which four breweries expect that to be even less than 25p. Only 8 respondents give the answer to the last two columns when bottling 6 to10 barrels and 11 to 20 barrels respectively. Most breweries (five) want the bottling price to be below 45p and above 26p if bottling 6-10 barrels. Half of the respondents expect the unit bottling payment to be below 25p when bottling 11 to 20 barrels. Pheasantry Brewery mentions the criteria of cost-effectiveness for picking the contract bottler. To other aspects of competition, Derventio Brewery Ltd made comments that it would consider this bottling contractor other than its current contractor if this could cut down both the transportation cost but also time taken to deliver and collect.

4.1.2. Observations

Three micro-brewery visits are enhanced during the project horizon. One visit is conducted in a newly-established small brewery called Lincoln Green without bottling plant, and another two in Thornbridge Brewery and Bath Ales with their own bottling plants. Bath Ales is relatively more formalized in terms of bottling equipment and its personnel distribution. First two visits took around 2 hours and 40 minutes respectively and the third one took approximately one day.

Basically, the three visits provide explicit and relevant information about location, size, layout of the bottling plants and breweries of different sizes and categories. They also imply the current bottling conditions of breweries based on size. More importantly, the observations to some extent can generate the understanding of the whole process of running bottling servicesand the associated activities.

In detail, firstly, in terms of location selection, the two breweries with own bottling plants are commonly sitted inside industrial zones. Thornbridge Brewery (Bakewell, in Chesterfield) and Bath Ales (sited in Bristol, north west of Bath), are located in where the surrounding areas are relatively quiet, and are far away from the town centre. Thornbridge especially closes to the National Park, with sufficient water source nearby.

Basically, in terms of the size of the breweries, Lincoln Green is relatively small in scale, and only serve the pubs within 25 miles away from it. Its weekly production is only 5 barrels. It has only four personnel working in this brewery (two brewers, one driver and one administrative personnel). In contrast, Thornbridge brewery owns its own pub and has 30 staffs both in brewing and bottling part, whose maximum capacity of production is 120 barrels. Bath Ales owns a chain of ten pubs mainly in Bristol and Bath, one in oxford, and employs more than 200 people serving for the whole supply chain also including marketing, HR and finances, among whom 8 people are hired in bottling plant.

In terms of layout and space utilization, Lincoln Green is rather simple, which mainly has the equipment for brewing and it only uses simple hand-bottling equipment for its beer bottling. Thornbridge Brewery combines the brewing part and bottling part in one working plant, without explicit barrier to separate those. The floor area of the bottling plant can be relatively narrower. In contrast, Bath Ales has its bottling facility in an independent working plant. Bath Ales has more formalized bottling equipment, which mainly consists of holding vessels, triblock(rinser, filler and capper), dryer, labelling machine, inkjet marker, closing machine, semi-automatic pallet wrap, machine referring to cabinet tape management, and temperature and pressure control devices. There are 4 types of holding vessles: 3,000, 5,000, 7,000 and 10,000 litters. In comparison, Thornbridge only have the major equipment of bottling, capping and labelling, without the machine for wrapping, managing of cabinet tape and marking. And for both of the breweries, all the equipment is commonly placed in a circular shape for space efficiency.

In addition, concerning warehousing, Lincoln Green does not have specific warehouse for beer storage. Bath Ale is currently expanding its facilities, where a bonded warehouse is newly placed, with two big shelves mainly holding its own beer and a small proportion for others for wholesaling purpose. Also, it also warehouses the amount which is to be exported (approximately 1% of the toal production) to the countries such as Italy, New Zealand, Germany. In contrast, Thornbridge only bottle its own beer and serve its own pubs, without export. It does not do the wholesaling for other breweries and does not have very formal warehouse as well.

Bath Ales is the only one providing contract bottling services to other breweries, which has 22 clients. Its bottling rate is 2200 bottles per hour, equivalent to 60000 bottles every week. The hourly capacity of Thornbridge brewery is 1500 bottles. In contrast, hand bottling rate can be much lower, 320 bottles per day in Lincoln Green.

The observations in Bath Ales give some more information about transportation, competition and bottle sourcing. Bath Ales is not responsible for transportation and delivery of beer. But there is a third party transportation agent whom Bath Ales is currently cooperating with, which is just located next door to it. There are 6 vehicles are normally used. Bath Ales is located approximately 40 miles away from its nearest competitor, which sometimes cooperates with Bath Ales to share clients during the peak time for contract bottling. And empty bottles are sourced by 52 pallets per load, where one pallet is decomposed into 5 packs, with 247 bottles per pack.

4.1.3. Meetings

There are several meetings with Jeremy Avis, and one meeting with the investor of this project.
The relevant information can be sorted in terms of expected criteria. Firstly, based on wholesaler, there can be mainly two scenarios for beer wholesaling: in both, the bonded warehouse can act as the wholesaler, where the difference is that, in one situation, retailers come and collect several pallets of mixed bottlers, and customers can buy bottled beer from those retailers; in another, customers can come directly to buy a large volume of beer instead. However, there possibly can be another opportunity to explore one big wholesaler which wholesales beer, spirit, soft drink, alcohol in East Midlands. Also, it can be difficult for individual breweries to be distributed to some retail chain such as supermarket. Thus, doing the wholesaling can be a way for the bottling facility to expand its market if it can provide this service.

Secondly, for exporting, in the moment, UK market is almost saturated for those microbreweries. And UK is currently ranking 4th in North America and Europe concerning export activities, which can be one of the main driver. So, it can be a possible solution if they are willing to export to overseas market such as Asia, especially China when people are interested in British craft beer (i.e. a pack of 6 mixed bottles). And also, in terms of individual breweries, it can be very expensive to consolidate and freight forwarding. Thus, those microbreweries are looking for agents to do this economically, where the premises can probably take the responsibility of holding the bottled beer and let 3rd party transportation agents to collect mixed packs (i.e. 12 tons) for further consolidating and freight forwarding (considering the port of Felixstowe). One or two consolidation points or freight forwarder can be considered in Derby. The wholesaling and related exporting services are depending on the space, both of which will possibly be done in a low percentage.

Thirdly, to bottle sourcing, it should be important to consider an economic way to decide the quantity which should be sourced each time. And if there is spare space left, it is better to have approximately 20 days stocks to prevent the situations such as late deliveries, disruptions.

In addition, concerning the layout, how empty bottles are loaded is discussed, and that should be done manually from cost perspective. And CIP (Cleaning in process) set will be utilized for automatic cleaning. It requires certain degree of flexibility to staffing, but minimum number of staffs should be 3. Then, when discussing about mezzanine, it can be less productive for operation and expensive to construct, but maybe good for customer or client visits and retailing. Other information which probably will be used in layout includes the type of beer to be bottled where only the one already sterilised will be considered from capacity perspective. See Appendix IV with Questions and Answers in meeting with the investor.

4.2. Data analysis

4.2.1. Result of the theoretically optimal location

Based on survey result, the brewery of Handley's is not necessary to be counted into the list to be one of the potential clients of the incoming bottling plant. Therefore, there are a total of twelve breweries which will be used to determine the theoretically optimal location. Given the brewery name and location details, the exact latitude and longitude can be found by Google Maps (2013), which are translated into respective arc lengths by using the formula of$n^{o}/360^{o} \times 2\pi r$, where r=6371km. See Table 4.1.

Table 4.1 Location details of thirteen responses

	Brewery name	Average weekly production	County	Postcode	Latitude	arc length α	Longitude	arc length β
1	Lincoln Green Brewing Company	20	Nottinghamshire	NG15 7SZ	53.0327	5896.967	-1.1876	-132.055
2	Funfair Brewing Company	50	Nottinghamshire	NG23 5NS	53.0235	5895.944	-0.8665	-96.350
3	Pheasantry Brewery	15	Nottinghamshire	NG22 0SN	53.2557	5921.764	-0.8693	-96.662
4	Raw Brewing Company	16	Derbyshire	S43 3LS	53.2633	5922.609	-1.356	-150.780
5	Nutbrook Brewery	25	Derbyshire	DE7 6LA	52.97	5889.995	-1.3629	-151.548
6	Barlow Brewery	3.5	Derbyshire	S18 7TR	53.2694	5923.287	-1.4853	-165.158
7	SPIRE BREWERY	30	Derbyshire	S43 3YF	53.2763	5924.054	-1.3523	-150.369
8	Brampton Brewery	25	Derbyshire	S40 2AR	53.258	5922.019	-1.907	-212.049
9	Derventio Brewery Ltd	15	Derbyshire	DE22 1DZ	52.9299	5885.536	-1.4988	-166.659
10	Amber Ales	10	Derbyshire	DE5 4AP	53.0503	5898.924	-1.4081	-156.574
11	Langton Brewery	12	Leicestershire	LE16 7TU	52.5254	5840.558	-0.9059	-100.731
12	8 Sail Brewery	7	Lincolnshire	NG34 9JW	52.9757	5890.629	-0.2951	-32.814

Based on the rationale provided in methodology part, the X and Y coordinate can be obtained by putting into the formula (3.1) and (3.2) correspondingly. The results can be shown as follows in Table 4.2.

Table 4.2 Coordinates of the breweries.

	Brewery name	X coordinate	Y coordinate
1	Lincoln Green Brewing Company	348.340	457.278
2	Funfair Brewing Company	347.317	492.983
3	Pheasantry Brewery	373.137	492.671
4	Raw Brewing Company	373.982	438.553
5	Nutbrook Brewery	341.368	437.786
6	Barlow Brewery	374.660	424.175
7	SPIRE BREWERY	375.427	438.964
8	Brampton Brewery	373.393	377.284
9	Derventio Brewery Ltd	336.910	422.674
10	Amber Ales	350.297	432.760
11	Langton Brewery	291.931	488.602
12	8 Sail Brewery	342.002	556.519

Therefore, when filling into the formula of center-of-gravity method, the location of the theoretically optimal bottling plant can be determined; with X coordinate 353.656 and Y coordinate 453.648.

$$\textbf{X-coordinate}= \frac{\sum_i d_{ix} Q_i}{\sum_i Q_i}$$

$$= \frac{(348.340*20+347.317*50+373.137*15+373.982*16+341.368*25+374.660*3.5+375.427*30+373.393*25+336.910*15+350.297*10+291.931*12+342.002*7}{(20+50+15+16+25+3.5+30+25+15+10+12+7)}$$

=353.656

$$\textbf{Y-coordinate}= \frac{\sum_i d_{iy} Q_i}{\sum_i Q_i}$$

$$= \frac{(457.278*20+492.983*50+492.671*15+438.553*16+437.786*25+424.175*3.5+438.964*30+377.284*25+422.674*15+432.760*10+488.602*12+556.519*7)}{(20+50+15+16+25+3.5+30+25+15+10+12+7)}$$

=453.648

The exact latitude and longitude of this location should be translated back based on the X and Y coordinates given above.

Latitude of the location $= \frac{(353.656+49.9*2\pi r/360)*360}{2\pi r}$= 53.08050503

Longitude of the location=$\frac{\left[453.648+(-5.3)*\frac{2\pi r}{360}\right]*360}{2\pi r}$ = -1.220249672

By using the UK Grid Reference Finder (2013), the theoretically optimal bottling plant is supposed to be located somewhere as the Map 4.1 illustrated, and the nearest post code is NG17 7QR.

Map 4.1 Calculated location in NG17 7QR

However, as the Graph 4.1 illustrated, actually, this place is very close to Notts Golf Club in Hollinwell, and is surrounded by Kirby Forest, where there are no available warehouses or distribution centers near and also is not ideal to construct a new bottling plant. As a result, it is necessary to replace this place by finding the nearest property which is an available industrial unit for warehousing and distributing purpose.

Graph 4.1 Satellite view of the location in NG17 7QR

（Source: Google Maps）

Based on the research in Joneslanglasalle.co.uk (2013), there are 25 available properties for warehouse or distribution centre in the East Midlands area, among which Unit A Millennium Business Park in Mansfield has already been concerned as one candidate location. The other 24 industrial units are listed in Table 4.3, with location details.

Table 4.3 twenty four available industrial units in East Midlands

Number	Address	County	Postcode
1	Unit A Birch Park	Nottinghamshire	NG16 3SU
2	Cirft, Geddington Road	Northamptonshire	NN18 8ET
3	Dirft II, Daventry	Northamptonshire	NN6 7FT
4	Black Swan, Cob Drive	Northamptonshire	NN4 9BB
5	Markham Vale	Derbyshire	S44 5JX
6	Unit 1 Highgrounds Industrial Estate	Nottinghamshire	S80 3AT
7	The Green Giant Markham Vale East	Derbyshire	DE4 5GG
8	North Road	Leicestershire	LE11 1QJ
9	Unit 8 Waterloo Court	Derbyshire	S44 5HY
10	Pintail Close, Victoria Business Park	Nottinghamshire	NG4 2PE
11	Unit 2B Ash Court	Nottinghamshire	NG8 6AR
12	Queen's Bridge Road	Nottinghamshire	NG2 1NB
13	East Road, Sleaford	Lincolnshire	NG34 8SP
14	3 Coombe Road, Moorgreen	Nottinghamshire	NG16 7US
15	Unit 2A Ash Court	Nottinghamshire	NG8 6AR
16	Blenheim Court	Nottinghamshire	NG6 8YP
17	Access Point, Keys Road	Derbyshire	DE55 7FQ
18	Compass Business Park A1	Nottinghamshire	DN22 0QX
19	Hallam Way	Nottinghamshire	NG19 9BG
20	Crossways Park	Leicestershire	LE4 7PD
21	Belgrave Park	leicestershire	LE4 6AR
22	Sherwood Networkcenter	Nottinghamshire	NG22 9FD
23	Castlefirelds Retail Park	Northamptonshire	NN8 2DP
24	G Park Newark	Nottinghamshire	NG24 2ER

By using mapping tool of Batchgeo (2013), the relative location of the calculated location and other available properties can be seen in Map 4.2, where there are five units visually closer to that. Given the distance information and the graphic illustration (where the radius is 5 miles), the industrial unit which is 4.859 mile away from the calculated location marked as N in the graph is finally selected as the fourth candidate location, the postcode of which is NG16 7US. See Table 4.4 and Map 4.3.

Map 4.2Dispersion of twenty four industrial units in East Midlands

(Source: Batchgeo)

Table 4.4Relative distance between the location of nearer industrial units and NG17 7QR

Location	Direct distance (mile) between it and NG17 7QR
NG19 9BG	5.131
DE55 7FQ	6.462
NG16 3SU	4.993
NG16 7US	4.859
NG6 8YP	5.10

Map 4.3 Illustration of the fourth candidate location

4.2.2. Analytical Hierarchy Process

-Problem modelling

In problem modelling, all the four alternatives have been determined, which are shown in Table 4.5. Based on the structure given in the methodology, the whole problems can be fully modelled by AHP.

Table 4.5 Four Alternatives of candidate locations

Alternatives	Address	Postcode
Candidate location 1	Millennium Way East, Phoenix Center, Nottingham	NG8 6AR
Candidate location 2	Unit8 Giltbrook Industrial Park, Nottingham	NG16 2RP
Candidate location 3	3 Coombe Road, Moorgreen	NG16 7US
Candidate location 4	Unit B Enterprise Way, Millennium Business Park, Mansfield	NG19 7JY

-Judgement scaling and pairwise comparison of criteria

Based on the preference ranking of the eight criteria, by following the method mentioned in methodology part, the corresponding pairwise comparison can be enhanced, which is demonstrated in Table 4.6.

Table 4.6 Pairwise comparison of pairs of criteria

Pairwise Comparison	More important criteria	How much more important	Numerical rating
Distance (breweries-bottling plant) -Competition exposure	Distance (breweries-bottling plant)	Equally to Moderately	2
Distance (breweries-bottling plant) -Distance (consolidation point/wholesaling)	Distance (breweries-bottling plant)	Moderately	3
Distance (breweries-bottling plant) -Distance (bottle sourcing)	Distance (breweries-bottling plant)	Moderately to Strongly	4
Distance (breweries-bottling plant) -Accessibility	Distance (breweries-bottling plant)	strongly	5
Distance (breweries-bottling plant) -Facility Features	Distance (breweries-bottling plant)	Strongly to very strongly	6
Distance (breweries-bottling plant) -Employment rate	Distance (breweries-bottling plant)	very strongly	7
Distance (breweries-bottling plant) -Security	Distance (breweries-bottling plant)	very strongly to extremely strongly	8
Competition exposure -Distance(consolidation point/wholesaling)	Competition exposure	Equally to Moderately	2
Competition exposure -Distance (bottling sourcing)	Competition exposure	Moderately	3
Competition exposure -Accessibility	Competition exposure	Moderately to Strongly	4
Competition exposure -Facility Features	Competition exposure	strongly	5
Competition exposure -Employment rate	Competition exposure	Strongly to very strongly	6
Competition exposure -Security	Competition exposure	very strongly	7
Distance(consolidation point/wholesaling)-Distance (bottle sourcing)	Distance(consolidation point/wholesaling)	Equally to Moderately	2
Distance(consolidation point/wholesaling)-Accessibility	Distance(consolidation point/wholesaling)	Moderately	3
Distance(consolidation point/wholesaling)-Facility features	Distance(consolidation point/wholesaling)	Moderately to Strongly	4
Distance(consolidation point/wholesaling)-Employment rate	Distance(consolidation point/wholesaling)	strongly	5
Distance(consolidation point/wholesaling)-Security issues	Distance(consolidation point/wholesaling)	Strongly to very strongly	6
Distance (bottle sourcing) -Accessibility	Distance (bottle sourcing)	Equally to Moderately	2
Distance (bottle sourcing) -Facility Features	Distance (bottle sourcing)	Moderately	3
Distance (bottle sourcing) -Employment rate	Distance (bottle sourcing)	Moderately to Strongly	4
Distance (bottle sourcing) -Security	Distance (bottle sourcing)	strongly	5
Accessibility -Facility features	Accessibility	Equally to Moderately	2
Accessibility -Employment rate	Accessibility	Moderately	3
Accessibility -Security issues	Accessibility	Moderately to Strongly	4
Facility features -Employment rate	Facility features	Equally to Moderately	2
Facility features -Security issues	Facility features	Moderately	3
Employment rate -Security issues	Employment rate	Equally to Moderately	2

The Table 4.7 demonstrates the pairwise matrix translated from the details given above.

Table 4.7 Pairwise comparison matrix of criteria

	Distance from brewery to bottling plant	**Competition exposure**	**Distance from bottling plant to consolidation point/wholesaling**	**Distance referring to bottle sourcing**	**Accessibility**	**Facility features**	**Employment rate**	**Security issues**
Distance from brewery to bottling plant	1	2	3	4	5	6	7	8
Competition exposure	1/2	1	2	3	4	5	6	7
Distance from bottling plant to consolidation point/wholesaling	1/3	1/2	1	2	3	4	5	6
Distance referring to bottle sourcing	1/4	1/3	1/2	1	2	3	4	5
Accessibility	1/5	5 1/4	1/3	1/2	1	2	3	4
Facility features	1/6	1/5	1/4	1/3	1/2	1	2	3
Employment rate	1/7	1/6	1/5	1/4	1/3	1/2	1	2
Security issues	/	/	/	/	/	/	/	/

- Judgement scaling and pairwise comparison of alternatives in each criterion

Next, in order to determine the relative preference between pairs of alternatives in terms of each criterion, relevance analysis should be given in each part.

Criteria analysis

1.Distance from brewery to bottling plant

To determine the numerical rating of the four alternatives, the total distances (the real land distances) should be calculated by adding all the individual distances regarding the one between the candidate bottling plant and each brewery in the list together by using UK Grid Reference Finder. See Table 4.8.

Table 4.8 Real distances from breweries to candidate locations

Brewery N (N=1.2…..,12)	**Postcode**	Real distance (MILE) From Candidate location 1 (NG8 6AT)	Real distance From Candidate location 2 (NG16 2RP)	Real distance From Candidate location 3 (NG16 7US)	Real distance From Candidate location 4 (NG19 7JY)
Raw Brewing Company	S43 3LS	22.786	23.584	19.627	10.693
Nutbrook Brewery	DE7 6LA	9.341	6.341	8.302	23.428
Lincoln Green Brewing Company	NG15 7SZ	4.793	6.177	6.72	10.73
Barlow Brewery	S18 7TR	27.875	28.672	24.716	15.721
Funfair Brewing Company	NG23 5NS	23.698	27.531	29.14	26.138
SPIRE BREWERY	S43 3YF	24.047	24.844	20.887	11.953
Langton Brewery	LE16 7TU	46.853	47.94	49.901	66.249
8 Sail Brewery	NG34 9JW	52.746	56.579	53.004	45.473
Brampton Brewery	S40 2AR	23.482	24.279	20.323	11.329
Pheasantry Brewery	NG22 0SN	29.914	45.404	33.019	20.743
Derventio Brewery Ltd	DE22 1DZ	16.848	17.937	11.885	23.014
Amber Ales	DE5 4AP	11.019	8.034	7.005	14.695
	SUM	**293.402**	**317.322**	**284.529**	**280.166**

Therefore, based on the result, candidate location 4 can be the most preferred one given the shortest total distances, which is nearly equally preferred to candidate location 3 with only 4.363 miles difference. All the mile differences among the pairs of the four alternatives are calculated as follows. See Table 4.9. Then, the mile differences are translate into numerical ratings, by using Table 4.10 as the guideline.

Table 4.9 Mile differences among pairs of alternatives

Pairs	Mile difference
Location 1 to Location 2	23.92
Location 1 to Location 3	8.873
Location 1 to Location 4	13.236
Location 2 to Location 3	32.793
Location 2 to Location 4	37.156
Location 3 to Location 4	4.363

Table 4.10 Guideline of Judgement scaling referring to mile difference in the criteria of distance from bottling plant to breweries

Mile difference	Verbal Judgement	Numerical rating
0-5	Equally preferred	1
5-10	Equally to Moderately preferred	2
10-15	Moderately preferred	3
15-20	Moderately to Strongly preferred	4
20-25	Strongly preferred	5
25-30	Strongly to Very strongly preferred	6
30-35	Very strongly preferred	7
35-40	Very strongly to extremely strongly preferred	8

As a result, the relative preferences among pairs of alternatives can be determined and put into a pairwise matrix, which is illustrated in the Table 4.11.

Table 4.11 Pairwise comparison matrix 1 of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	5	1/2	1/3
Location 2(NG16 2RP)	1/5	1	1/7	1/8
Location 3(NG16 7US)	2	7	1	1
Location 4(NG19 7JY)	3	8	1	1

2.Competition exposure

Basically, the three bottling contractors which have already cooperated with the four respondents mentioned in survey result can be considered as the potential competitors in East Midlands area. Also, Bath Ales which provide contract bottling service can be considered as one of the competitors as well. In addition to the list of bottlers given by Jeremy Avis (See Appendix V) where Edwin Holden's Bottling is one of the bottling contractors referred before, the dispersion of the competitors surrounding the 13 breweries can be illustrated in Map 4.4. In this map, the spots marked in blue are the three bottling contractors plus Bath Ales (the location details can be found in Table 4.12), and the red ones are other potential competitors in that list. In terms of distance, the listed competitors, Cumbrian Bottling and Bath Ales are relatively far away from the cluster of breweries compared to Edwin Holden's Bottling and Leek Brewery. Therefore, these two nearer bottlers are selected as the competitors who the centralized bottling plant will mainly compete with.

Table 4.12 Four main competitors

Name	Address 1	Address 2	Address 3	Address 4	City	County	Postcode
Edwin Holden's Bottling	George Street	Woodsetton	W. Midlands		Dudley		DY1 4LW
Cumbrian Bottling	Unit 12	Derwent Mills	Commercial Park	Cockermouth	Cumbria		CA13 0HT
Leek Brewery	Staffordshire Brewery Ltd	2 Harrison Way	Cheddleton, Leek			Staffordshire	ST13 7EF
Bath Ales Limited	Units 3-7 Caxton Business Park,	Crown Way	Warmley		Bristol		BS30 8XJ

Map 4.4 Geographic illustration of competitors and breweries

Map 4.5 clarifies the overall dispersion of the four candidate bottling facilities, breweries and the competitors. Based on the rationale of Huff's model as mentioned before, in this project the market share is expressed as the number of barrels from customers which the candidate bottling facility tend to serve against the competitors, where each brewery is considered as a customer. The formula of attraction function is used to compare the respective competitiveness of the four candidate locations.

Map 4.5 Geographic illustrations of breweries, candidate locations and two main competitors

(Source: Batchgeo)

Appendix VI gives the required information of breweries which will be used to calculate the market share, where Langton Brewery is not taken into account because it did not give its demand amount for bottling. Therefore, there are only 11 customers will be considered in this part. In addition, the proposed bottling rate of the machine which the centralized bottling plant will utilize is given as 2500 bottles (500ml per bottle), that is 1250 litters per hour. The hourly capacity of Edwin Holden's Bottling is 4000 litters, and Leek Brewery's is 1000 litters. The way to calculate the market share is illustrated by giving the example of the candidate location 1 (NG8 6AR), shown as follows.

Location 1-

By using the following formula:

$$MS(\alpha,x)=\sum_{i\in I} Wi\frac{attr\ (i,x)}{attr(i,x)+\sum_{f\in CF} attr\ (i,f)}$$

Equals to the sum of the market share (in terms of barrels) gained from the demand of each brewery, where the calculation of the market share from one individualbrewery is expressed by:

weekly production of brewery 1× its percentage for bottling×

$$\frac{\frac{\text{the bottling rate of proposed bottlingplant}}{\text{its distance away from brewery1}}}{\frac{\text{the bottling rate of proposed bottlingplant}}{\text{its distance away from brewery1}}+\left(\frac{\text{the bottling rate of Leek Brewery}}{\text{Leek Brewery's distance away from brewery 1}}+\frac{\text{the bottling rate of Edwin Holden's Bottling}}{\text{Edwin Holden's Bottling's distance away from brewery 1}}\right)}$$

That is,

$$= \quad 16*20\%\ barrels*\frac{1250\ litters/hour\ /\ 22.786\ miles}{\left(1250\frac{litters}{hour}\Big/22.786\ miles\right)+\left(\frac{1000\frac{litters}{hour}}{55.29\ miles}+\frac{4000\ litters/hour}{75.011\ miles}\right)}$$

$$+ \quad 25*30\%\ barrels*\frac{1250\ litters/hour\ /\ 9.341\ miles}{\left(1250\frac{litters}{hour}\Big/9.341\ miles\right)+\left(\frac{1000\frac{litters}{hour}}{35.641\ miles}+\frac{4000\ litters/hour}{55.362\ miles}\right)}$$

$$+ \quad 20*20\%\ barrels*\frac{1250\ litters/hour\ /\ 4.793\ miles}{\left(1250\frac{litters}{hour}\Big/4.793\ miles\right)+\left(\frac{1000\frac{litters}{hour}}{52.175\ miles}+\frac{4000\ litters/hour}{69.424\ miles}\right)}$$

$$+ \quad 3.5*50\%\ barrels*\frac{1250\ litters/hour\ /\ 27.875\ miles}{\left(1250\frac{litters}{hour}\Big/27.875\ miles\right)+\left(\frac{1000\frac{litters}{hour}}{33.790\ miles}+\frac{4000\ litters/hour}{80.100\ miles}\right)}$$

$$+ \quad 50*50\%\ barrels*\frac{1250\ litters/hour\ /\ 23.698\ miles}{\left(1250\frac{litters}{hour}\Big/23.698\ miles\right)+\left(\frac{1000\frac{litters}{hour}}{71.794\ miles}+\frac{4000\ litters/hour}{87.797miles}\right)}$$

$$+30*50\%\ barrels*\frac{1250\ litters/hour\ /\ 24.047\ miles}{\left(1250\frac{litters}{hour}\Big/24.047\ miles\right)+\left(\frac{1000\frac{litters}{hour}}{39.327\ miles}+\frac{4000\ litters/hour}{76.272miles}\right)}$$

$$+ \quad 7 \quad * \quad 20\%\ barrels*\frac{1250\ litters/hour\ /\ 52.746\ miles}{\left(1250\frac{litters}{hour}\Big/52.746\ miles\right)+\left(\frac{1000\frac{litters}{hour}}{100.842\ miles}+\frac{4000\ litters/hour}{116.845miles}\right)}$$

$$+ 25 * 20\%\ barrels * \frac{1250\ litters/hour \big/ 23.482\ miles}{\left(1250\frac{litters}{hour}\Big/ 23.482\ miles\right) + \left(\frac{1000\frac{litters}{hour}}{34.134\ miles} + \frac{\frac{4000\ litters}{hour}}{75.707 miles}\right)}$$

$$+ 15 * 30\%\ barrels * \frac{1250\ litters/hour \big/ 29.914\ miles}{\left(1250\frac{litters}{hour}\Big/ 29.914\ miles\right) + \left(\frac{1000\frac{litters}{hour}}{77.111\ miles} + \frac{\frac{4000\ litters}{hour}}{96.832 miles}\right)}$$

$$+ 15 * 20\%\ barrels * \frac{1250\ litters/hour \big/ 16.848\ miles}{\left(1250\frac{litters}{hour}\Big/ 16.848\ miles\right) + \left(\frac{1000\frac{litters}{hour}}{29.642\ miles} + \frac{\frac{4000\ litters}{hour}}{49.363 miles}\right)}$$

$$+10 * 30\%\ barrels * \frac{1250\ litters/hour \big/ 11.019\ miles}{\left(1250\frac{litters}{hour}\Big/ 11.019\ miles\right) + \left(\frac{1000\frac{litters}{hour}}{38.122\ miles} + \frac{\frac{4000\ litters}{hour}}{57.843 miles}\right)}$$

= **34.37 barrels**

And the entire weekly demand amount is 73.35 barrels from the 11 breweries.

In the same way, the result of market share obtained can be demonstrated in Table 4.13:

Table 4.13 Market share obtained from competition to the candidate sites

Alternatives	Market share (barrels)
Candidate location 1	34.37
Candidate location 2	33.46
Candidate location 3	34.38
Candidate location 4	35.76

To decide the relative preference among the pairs of alternatives, the guideline is followed by:

Table 4.14 Guideline of judgement scaling referring to market share difference

Difference in market share (barrels)	Verbal Judgement	Numerical rating
0-1	Equally preferred	1
1-2	Equally to Moderately preferred	2
2-3	Moderately preferred	3

Based on this, the results can be arranged and put into pairwise comparison matrix, as it is given below in Table 4.15.

Table 4.15 Pairwise comparison matrix 2 of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	1	1	1/2
Location 2(NG16 2RP)	1	1	1	1/3
Location 3(NG16 7US)	1	1	1	1/2
Location 4(NG19 7JY)	2	3	2	1

Besides, in practice, some other issues should be considered in terms of competition. Both competitors have requirements regarding the minimum quantity. Edwin Holden’s Bottling only undertake the volume of production equally to twelve barrels and above. Leek Brewery accept the volume which is more than 1000 litters, that is, approximately 6 barrels. Also, unit price for bottling can be another important factor. When viewing the current pricing strategy of two competitors, given the survey result, Nutbrook Brewery, whose current contract bottler is Leek Brewery, send approximately 7.5 barrels for bottling each time and the unit price of bottling (per 500 ml) is 46-65p. In contrast, Edwin Holden’s Bottling prices it at 46-65p to its customer-Derventio Brewery Ltd, but in terms of the minimum quantity of 12 barrels. Therefore, apart from the distance considerations, to more aggressively capture market share, it is better to deliver reasonable price advantage catering to customers’ expectations and provide flexibility referring to the minimum volume.

3.Distance from bottling plant to consolidation point

Firstly, the ten addresses of freight forwarder which provide full services of container consolidation, further storage, freight forwarding near Derby are selected from Yell.com (2013) based on the destination the service goes which should cover Asia especially China. See Table 4.16.

Table 4.16 Freight forwarders near Derby

No.	Name	Address	Postcode
1	Wells&Root	135 Parker Drive Leicester Leicestershire	LE4 0JP
2	Cargolink, Express	Cargo Link Express 3 Cygnus Court, Beverley Road East Midlands Airport, Derby	DE74 2SA
3	Meachers Global Logistics	East Side Park East Service Road Raynesway Spondon Derby	DE21 7BF
4	Global Forwarding (2723)-C.H. Robinson	Unit 2, Sycamore Road Trent Lane Industrial Estate, Castle Donington Derby	DE74 2NP
5	Kintetsu World Express (UK) Ltd	WarkeFlatt Unit 7b, Willow Farm Business Park	DE74 2UD
6	Agility Logistics	Hawthorne Rd, Derby	DE74 2QR
7	Evolution Time Critical Ltd	Building 101, East Midlands Airport, Derby	DE74 2SA
8	Trans Atlantic Shipping Ltd	Churchill House 9-11 Nottingham Road Eastwood Nottinghamshire	NG16 3AP
9	Eastwest Cargo Services Ltd	Building 59, East Midlands Airport, Derby	DE74 2SA
10	Logwin Air & Ocean UK Ltd	Stanhope House, Harrington Mills, Leopold St, Nottingham	NG10 4QE

Trans Atlantic Shipping Ltd is relatively closer to the four candidate locations (blue spots) when mapping the ten addresses, which can potentially be selected as the partner to forward the cargos. See Map 4.6.

Map 4.6 Geographic illustrations of freight forwarders and candidate locations

The Table 4.17 gives the real distance between this address and each candidate location.

Table 4.17 Real distances measured from candidate locations to Trans Atlantic Shipping Ltd

Alternative	Real distance (miles) away from Trans Atlantic Shipping Ltd
Candidate location 1	5.281
Candidate location 2	1.964
Candidate location 3	1.455
Candidate location 4	19.899

Therefore, based on that, the final pair-wise comparison (See Table 4.19) can be derived by following the guideline shown below in Table 4.18.

Table 4.18 Guideline of judgement scaling referring to mile difference in the criteria of distance from bottling plant to consolidation point

Pairs	Mile difference	Mile difference classification	More preferred alternative	Verbal judgement	Numerical Rating
Location 1 to Location 2	3.317	0-5	Location 2	Equally preferred	1
Location 1 to Location 3	3.826	0-5	Location 3	Equally preferred	1
Location 1 to Location 4	14.618	10-15	Location 1	Moderately preferred	3
Location 2 to Location 3	0.509	0-5	Location 3	Equally preferred	1
Location 2 to Location 4	17.935	15-20	Location 2	Moderately to Strongly preferred	4
Location 3 to Location 4	18.444	15-20	Location 3	Moderately to Strongly preferred	4

Table 4.19 Pairwise comparison matrix 3 of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	1	1	3
Location 2(NG16 2RP)	1	1	1	4
Location 3(NG16 7US)	1	1	1	4
Location 4(NG19 7JY)	1/3	1/4	1/4	1

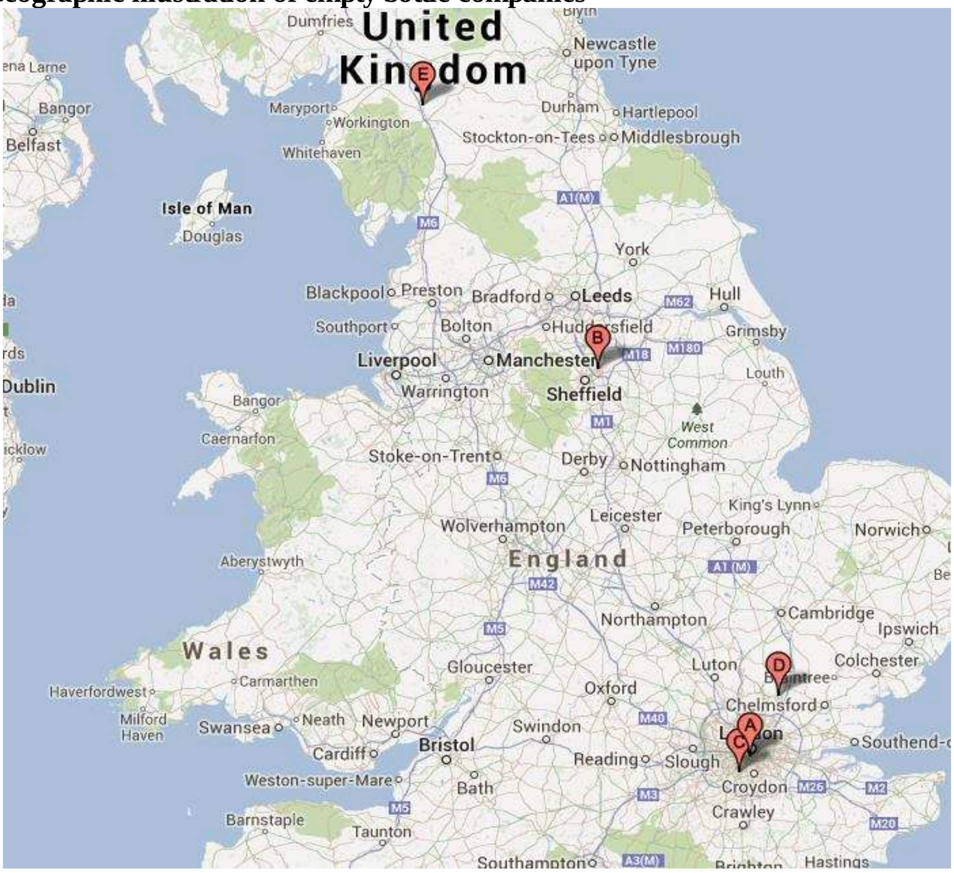
4.Distance referring to bottle sourcing

Firstly, consulting the list provided by SIBA Local Beer (siba.CO.UK, 2013), there are five bottle manufacturers which can be considered in UK. Their locations can be illustrated in Map 4.7, based on the physical addresses and postcodes listed in Table 4.20.

Table 4.20 Empty bottle companies

Name	Address	Postcode
A E Chapman and Son Ltd	Timbermill Way, Gauden Road, Clapham, London	SW4 6LY
Beatson Clark Ltd	The Glass Works, Greasbrough Road, Rotherham, South Yorkshire,	S60 1TZ
Croxsons	Alpha Place, Garth Road, Morden, Surrey	SM4 4LX
O-I Sales & Distribution UK Ltd	Edinburgh Way, Harlow, Essex	CM20 2UG
VetreriaEtrusca Ltd	16 Beckside, Plumpton, Penrith, Cumbria	CA11 9PD

Map 4.7 Geographic illustration of empty bottle companies



(Source: Batchgeo)

Therefore, Beatson Clarke Ltd, which is marked as B in the map and located relatively central in East Midlands area, can be selected as the ideal bottle supplier.

The distances between each candidate location and this bottle supplier are calculated in Table 4.21.

Table 4.21 Real distance between candidate locations and BeatsonClaarke Ltd

Alternative	Real distance (miles) away from Beatson Clarke Ltd
Candidate location 1	37.243
Candidate location 2	38.575
Candidate location 3	34.652
Candidate location 4	25.292

Based on the rule that the shorter the distance is the preferable the alternative should be,the numerical ratings of each pair of alternatives are presented in Table 4.22.

Table 4.22 Guideline of judgement scaling referring to mile difference in the criteria of distance referring to bottle sourcing

Pairs	Mile difference	Mile difference classification	More preferred alternative	Verbal judgement	Numerical Rating
Location 1 to Location 2	1.332	0-5	Location 1	Equally preferred	1
Location 1 to Location 3	2.591	0-5	Location 3	Equally preferred	1
Location 1 to Location 4	11.951	10-15	Location 4	Moderately preferred	3
Location 2 to Location 3	3.923	0-5	Location 4	Equally preferred	1
Location 2 to Location 4	13.283	10-15	Location 4	Moderately preferred	3
Location 3 to Location 4	9.360	5-10	Location 4	Equally to Moderately preferred	2

According to the numerical ratings given above, the pairwise comparison matrix can be filled. See Table 4.23.

Table 4. 23Pairwise comparison matrix 4 of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	1	1	1/3
Location 2(NG16 2RP)	1	1	1	1/3
Location 3(NG16 7US)	1	1	1	1/2
Location 4(NG19 7JY)	3	3	2	1

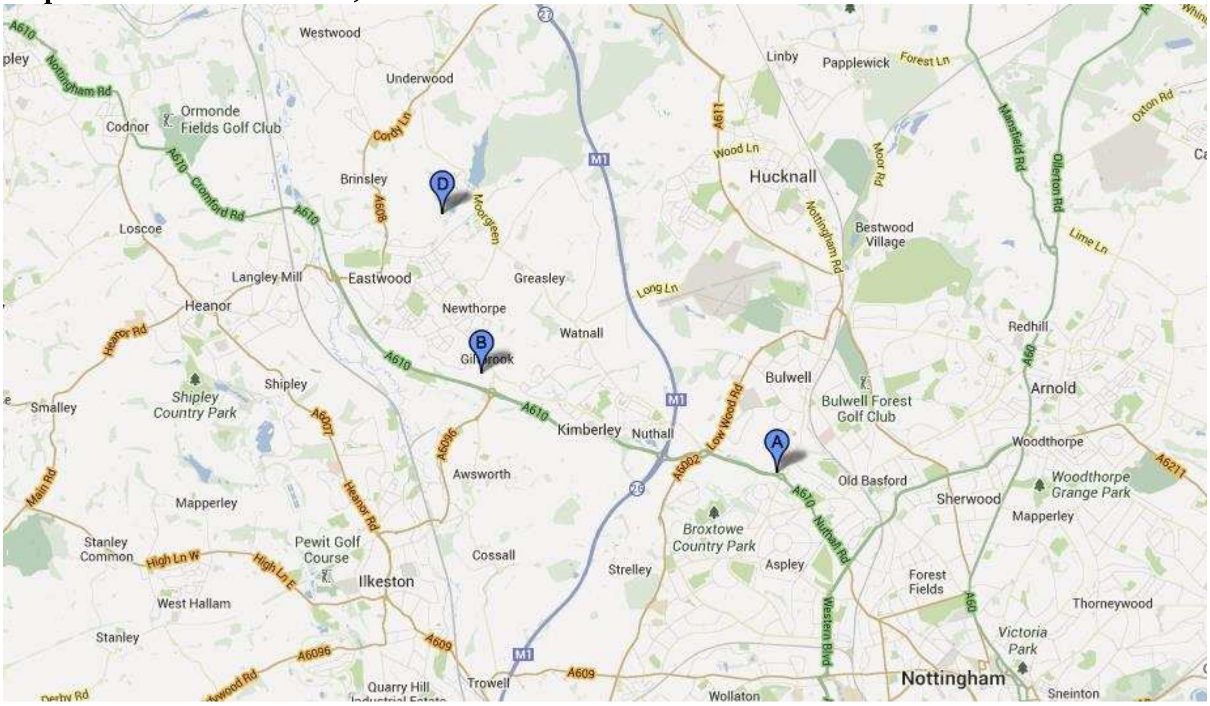
5.Accessibility

Accessibility can be regarded as the ability of reaching required destinations, services, goods or activities. Land-use accessibility can be one significant aspect, the performance indicators of which include density, network connectivity, convenient proximity, land use mix, non-motorized condition, roadway access, walkability (Litman, 2013). In this project, only density, roadway access and walkability are selected for performance measurement.

Firstly, density is measured in terms of number of people per land unit given that more people in one unit of land is supposed to increase possibility of common endpoints. Basically, the population of Nottingham and Mansfield are 305,700 and 99,600 respectively(Mansfield District Council, 2013; Nottingham Insight, 2012). The total land areas of them are 74.61 and 78 km^2 correspondingly (UK Online,2013; Nottingham Insight, 2012). According to this, the density of Nottingham is 4,097.3 people per km^2, and that of Mansfield is 1,276.9 people per km^2.

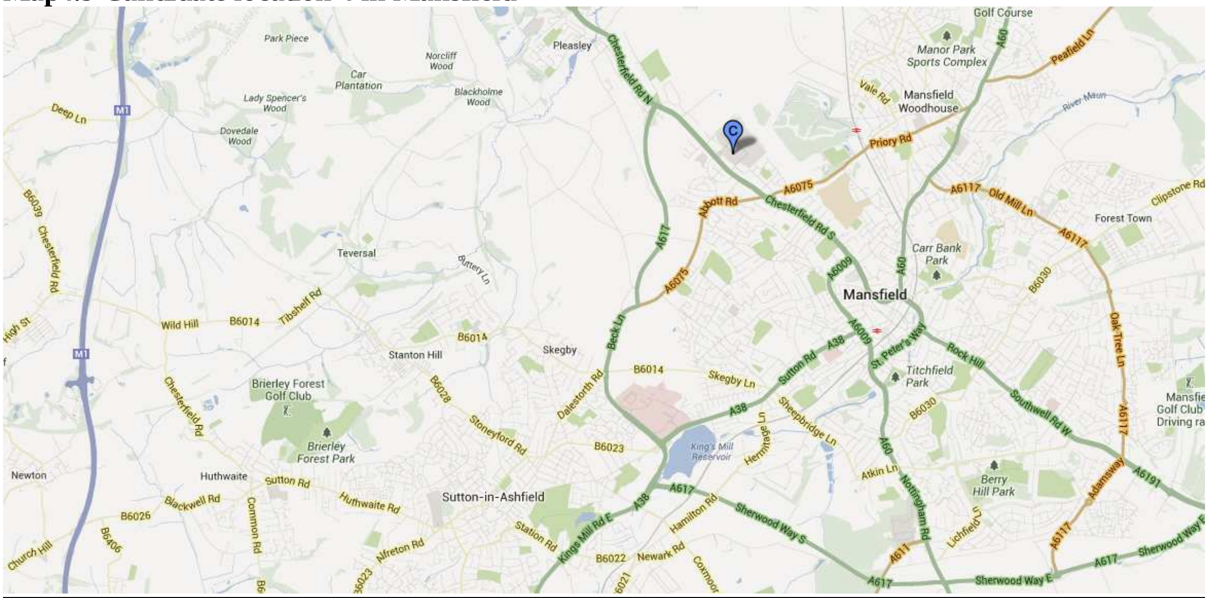
Secondly, to roadway access, Candidate location 1 and 2 can be close to main road-A610 and motorway M1, also with local routes surrounded. In comparison, the location 3 is relatively farther way from the main road, but close to several local roadways. The one in Mansfield is far away from motorway M1, but very close to the network of A roads, especially A617 and A6075. See Map4.8 and Map 4.9.

Map4.8 Candidate location 1, 2 and 3



(Source: Google Maps)

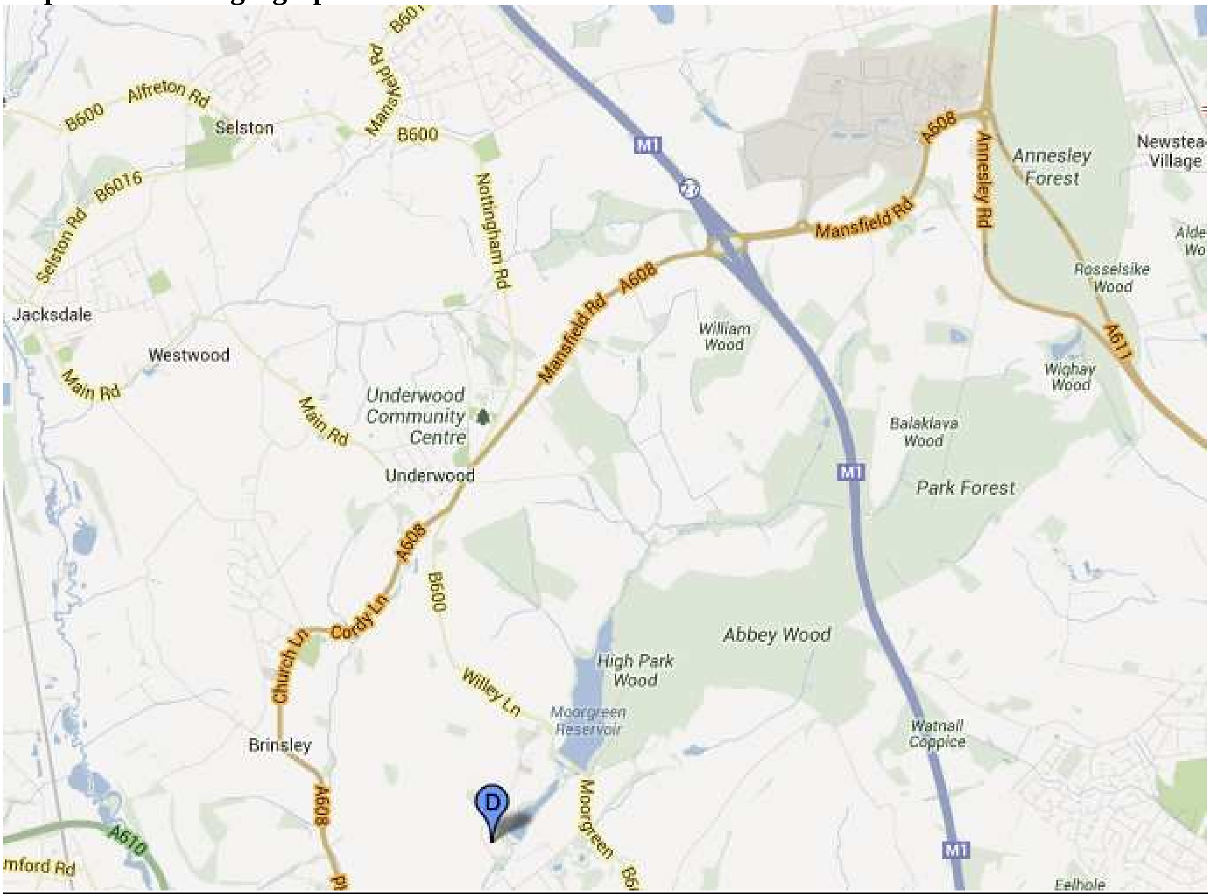
Map4.9 Candidate location 4 in Mansfield



(Source: Google Maps)

Thirdly, only geographic attributes will be considered to measure walkability. Location 3, compared to the other three locations, can be less preferred due to the fact that there is a series of forest between it and the main roads and motorway, as it is presented in the Map 4.10. Other three alternatives are mainly located in build-up areas.

Map 4.10 General geographic conditions around Location 3



(Source: Google Maps)

Therefore, to aggregate all the analysis, location 4 is slightly more favoured than location 1 and 2, and these two locations are preferred than location 3. The Table 4.24 below gives the ratings of preferences in the pairwise comparison matrix.

Table 4.24Pairwise comparison matrix 5 of alternatives

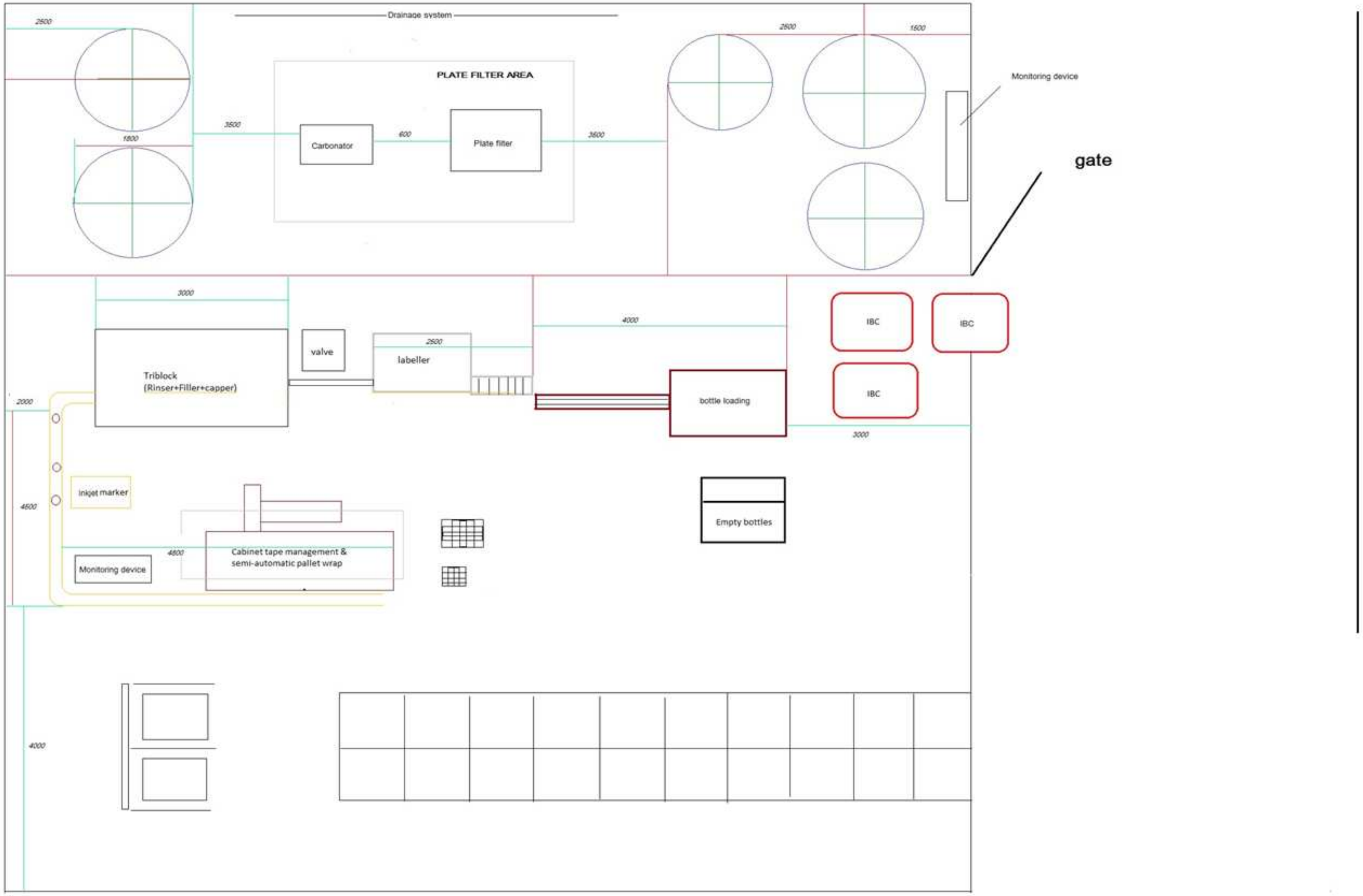
	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	1	2	1/2
Location 2(NG16 2RP)	1	1	2	1/2
Location 3(NG16 7US)	1/2	1/2	1	1/4
Location 4(NG19 7JY)	2	2	4	1

6.Facility features

Firstly, according to the investor's expectation, the property should only be used for bottling plant and the bonded warehouse in the current stage, but will include brewing part in the future. Therefore, currently, the selection should be mainly based on how feasible the required equipment and facilities can fit into the four candidate properties.

Basically, the Graph 4.2 generally illustrates the layout of the bottling part of the premises. The space required is used to accommodate several different sizes of vessels for containing different volume of each single type of beer, plate filter and carbonator for filtering and carbonating the beer, the triblock (rinser, filler and capper), inkjet marker, at least two monitoring and controlling equipment, one packaging device for cabinet tape management, one semi-automatic pallet wrapper, one tray for loading empty bottles and some necessary connexion tools, shelves for holding purposes. Also, in the bottling plant, there should be spare space for holding incoming IBCs, pallets of empty glasses for weekly uses (approximately 52 pallets, 60,000 bottles per week), material handling (i.e. for empty bottle, with forklift movement), and other installations such as drainage system. Since this bottling plant is supposed to use the line at a rate of 2500 bph, the estimation of the floor area is by consulting the layout of the bottling plant of Cairngorrn Brewery (see Appendix VII) from Jeremy Avis and Bath Ales, the bottling rate of which are 2500 bph and 2200 bph. The graph gives the details of the space estimation with the dimension of millimetre. Based on that, the floor area of the bottling plant required approximately 230 sq metre (16 m×14 m).

Graph 4.2 Layout of bottling plant



Secondly, the space of the bonded warehouse should depend on several factors: the return rate (bottles required back to original breweries), stocks of empty bottles (approximate 20 days' stock), numbers held for wholesaling and exporting, and packaging activities.

According to the Table 4.25 derived from questionnaire (neglecting Langton brewery and Hardley's), using the formula below, the required bottles to be returned can be calculated referring to the table. Therefore, it estimates that there are 10,548 bottles of beer needed to be returned, just in terms of the 11 breweries.

1 barrel = 36 gallons

1 gallon = 4.546 litres

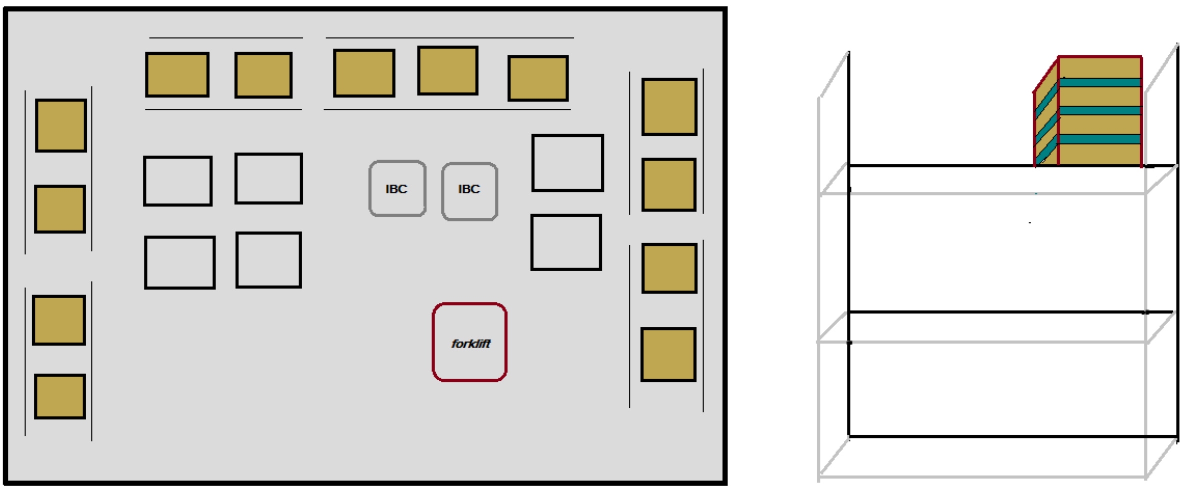
1 litre=2 bottles (500 ml/ bottle)

Table 4.25 Required information referring to return rate

Brewery Name	**Average weekly production (brls)**	**Approximately what percentage of your production might you outsource for bottling?**	**Number of barrels to expected to be bottled**	**How much would you expect to come back**	**Number of bottles required to be returned**
Funfair Brewing Company	40-60	Between 40%-60%	25	20% Some	1637
SPIRE BREWERY	30	Between 40%-60%	15	50% Half	2455
Nutbrook Brewery	25	Between 20%-40%	7.5	80% Most	1964
Brampton Brewery	25	Less than 20%	5	80% Most	1309.24
Lincoln Green Brewing Company	20	Less than 20%	4	20% Some	262
Raw Brewing Company	16	Less than 20%	3.2	100% All	1047
Pheasantry Brewery	15	Between 20%-40%	4.5	50% Half	736
Derventio Brewery Ltd	15	Less than 20%	3	20% Some	196
Amber Ales	10	Between 20%-40%	3	20% Some	196
8 Sail Brewery	7	Less than 20%	1.4	100% All	458
Barlow Brewery	3.5	Between 40%-60%	1.75	50% Half	286
SUM			73.35		**10,548**

By assuming the same packing way of empty glasses in Bath Ales (247 Bottles/ Pack; 5 Packs/Pallet), the warehouse requires to hold at least 9 pallets of bottled beer. If 20 days' stock of empty glasses are assumed to be approximately 180,000 bottles (considering 60,000 bottles per week), which should be around145 pallets. One pallet is 120 cm (length)×100cm (width) × ×110 cm (height) (Nationalpallets.co.uk, 2013). Therefore, there are 154 pallets should be stored, where the already bottled beer can be regarded as fast-moving items which can put on the floor instead of shelves for quick collections. If three-storey shelves are to be used, the floor space still requires 120cm× 100cm ×145÷3= 58 sq metre, without any spare space for material handling. Given the wholesaling and exporting volume which assumes to be 5% of total volume received (73.35 brls in Figure), it could be only around 600 bottles. However, the amount which is held should be accumulated until reaching certain number of pallets, which can be estimated to be say, at most 10 pallets. Thus, if some IBCs which wait for filling the line are also included, the total floor area should be 120 to 180 sq. metres to allow forklift and staff to handle the pallet and also to count some more potential clients (not just 11 breweries). See Graph 4.3 with illustrations of warehouse layout and the shelf.

Graph 4.3 Illustrations of warehouse



As a result, the total floor area of the property should at least 450 sq. metres. And the height is better to be higher than 330 cm.

Based on the analysis and the basic property information provided is listed in Table 4.26 and Table 4.27 from JohnLangLasalle.co.uk (2013), the factors of facility structures, available facilities and equipment, external spacing and rent are considered to compare each pair of the properties.

Table 4.26 Some basic information of the four properties

Location	Floor Area (m^2)	Eaves Height (m)	Lease Terms (Rateable value)	Other information
NG8 6AR	473	2.5	£27,500 per annum plus VAT	/
NG16 2RP	280	6.5	On application	/
NG16 7US	635.4	2.5	£29,750 per annum	/
NG19 7JY	1,012.921 (=10,903 sqft)	7.1	£32,000 per annum	With a two-storey office block

Table 4.27 Available facilities, equipment and parking situations of four sites

Location	Available facilities and equipment	Parking
NG8 6AR	-New fire alarm system; -Kitchenette -WC facility; -office	Large parking area
NG16 2RP	-WC's installed -glazing for later retro -office installation in the 1st floor -signage and on-site CCTV	189 car parking space on site
NG16 7US	-Internal office accommodation, (with perimeter trunking, carpeted floor , suspended ceiling, air-conditioning); -Alarm system -external CCTV -lighting -gated vehicular access.	External large yard area for parking;
NG19 7JY	-Three-phase power supply, -Two gas-blow heaters, sodium bay lighting and an electric roller shutter door. - Chiller and freezer - Accommodation for a reception area, - Two offices - A kitchenette - W.C.	two distinct yards outside the warehouse (one providing approximate 20 vehicles' car parking and another further security).

Basically, in terms of the facility structure, the property in NG16 2RP can be less favourable compared to other three due to the narrow floor space. Both the properties in NG16 7US and NG19 7JY can be good choices if consider future expansion and also the inclusion of retailing element, especially that in NG19 7JY, which has clarified borders for three parts. But that property has a two-storey block for two independent offices, which could be a bit waste of space since for the first five years, it may only require a maximum of 10 people. In contrast, for the ones in NG8 6AR and NG16 7US, the space can be better utilized in floor one to install a simple office both for inspection and staff rest, enhancing operation productivities as well. Appendix VIII gives the overview of the premises structures.

Furthermore, referring to existing facilities and equipment, it seems the one in NG16 7US is relatively preferred except the lack of WC facility. In contrast, those in first two properties can be comparatively simpler without some fundamental installations such as lighting and alarm system. And the one in NG19 7JY has some redundant facilities and installations such as chiller and freezer, gas-blow heater, an extra office.

In terms of external spacing, it can make no differences for the four options given that all of those properties have enough space for parking plus the space for vehicle movement.

Based on the qualitative analysis above, the Table 4.28 gives the estimation of the relative preferences.

Table 4.28 Pairwise comparison matrix 6 of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	2	1/3	1/2
Location 2(NG16 2RP)	1/2	1	1/6	1/4
Location 3(NG16 7US)	3	6	1	1/2
Location 4(NG19 7JY)	2	4	2	1

7.Unemployment rate

Among the four candidate locations, three are located in the city of Nottingham and the other (the candidate location 4) is located in Mansfield. Those three alternatives will be treated equally given the same unemployment rate of Nottingham which is 6.1% recorded until the end of 2012 (Nottingham City Council, 2012). In contrast, Mansfield where the fourth alternative is located has much higher unemployment rate, that is, approximately 10% (Fitzsimons, 2012). The establishment of the new centralized bottling plant is supposed to favour the region which has higher unemployment rate, given which more current unemployed people can fill vacancies in it. Therefore, candidate location 4 can be moderately preferred rated at 3 compared to the other three alternatives in this criterion. As a result, the pairwise comparison matrix is illustrated in Table 4.29.

Table 4.29Pairwise comparison matrix 7of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	1	1	1/3
Location 2(NG16 2RP)	1	1	1	1/3
Location 3(NG16 7US)	1	1	1	1/3
Location 4(NG19 7JY)	3	3	3	1

8.Security issues

Basically, crime rate can be one indicator, concerning one mile away from the centre where the alternatives are located in. Based on the statistics from Police.co.uk (2013), within the whole month of July of 2013, all crime is summarized in Table 4.30. Generally, location 3 seems to be the ideal one with the lowest crime rate almost in each category (just one more record than location 2 in public order and vehicle crime). In comparison, location 1 is the worst one with the highest crime rate in every crime category, especially anti-social behaviour where the recorded crime number is far more than the other three alternatives. Location 2 and Location 4 have similar record in almost all categories, except the record in violence and sexual offences of Location 4 is almost doubled and similarly criminal damage and arson was recorded much worse in location 2. The crime rates in both these two locations are a little worse than Location 3, mainly referring to the record of anti-social behaviour.

Table 4.30 Crime rate in the surrounded area of four candidate locations

Crime category	NG8 6AR	NG16 2RP	NG16 7US	NG19 7JY
Anti-social behaviour	217	26	17	33
Bicycle theft	15	2	2	1
Burglary	30	7	2	3
Criminal damage and arson	46	11	1	5
Drugs	18	4	0	2
Other theft	34	2	1	4
Possession of weapons	5	0	0	0
Public Order	12	0	1	2
Robbery	5	0	0	2
Shoplifting	20	5	1	1
Theft from the person	1	0	0	1
Vehicle crime	21	1	2	0
violence and sexual offences	86	6	3	13
other crime	3	2	0	0

Secondly, it can be important to measure the proximity to police station and fire station, due to the frequent interaction of flammable alcohol and containers or metal equipment and possible theft of expensive machines. Table 4.31 gives the details about the nearest police station and fire station to each candidate location, as well as the referred distances(using Google Maps). In terms of this, Location 1(NG8 6AR) seems to be the optimal one.

Table 4.31 Distance information of nearest police stations and fire stations

	NG8 6AR	NG16 2RP	NG16 7US	NG19 7JY
Nearest Police station	Bullwell Police Station	South Division Kimberley Police Station	Derbyshire Constabulary	Mansfield Woodhouse Police
	1.2 miles	0.9 miles	2.5 miles	1.9 miles
Nearest Fire station	Stockhill fire station	Eastwood fire station	Eastwood fire station	Nottinghamshire Fire and Rescue Service
	0.8 miles	1.4 miles	1.2 miles	1.5 miles

To determine the relative preference, there can be distinct difference referring to the crime rate among alternatives which is supposed to be more significant than the proximity to police and fire station where the differences of the distance can be neglected.

Based on the qualitative analysis given before, the result of pairwise comparison can be estimated, shown in Table 4.32.

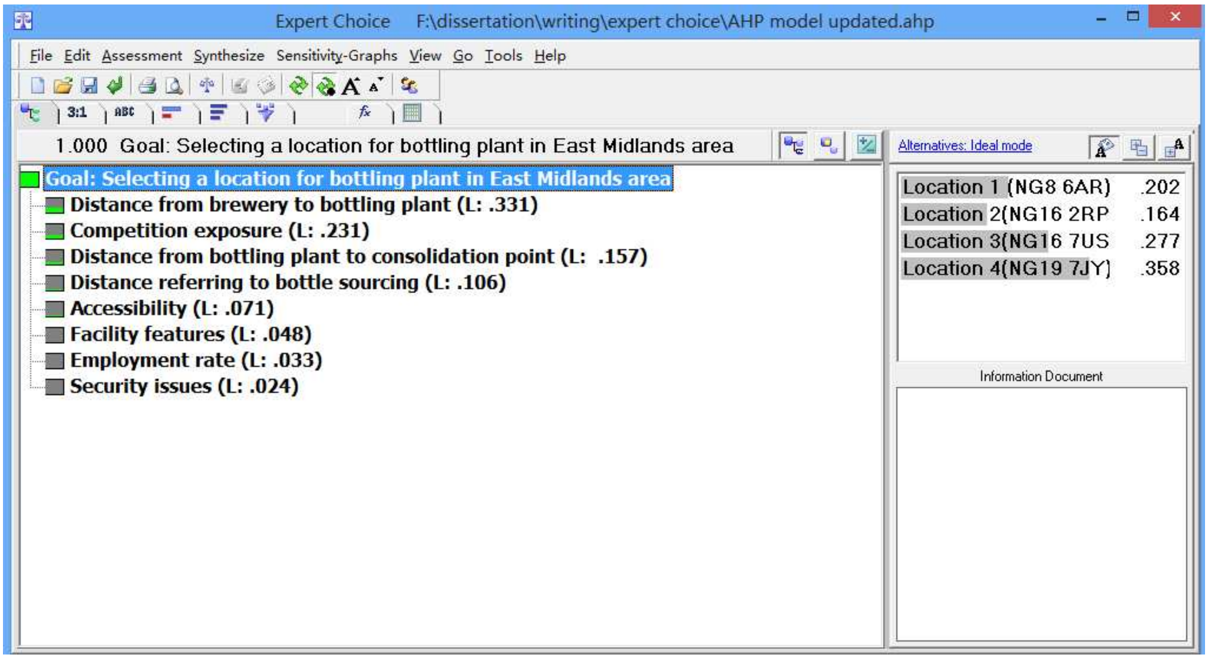
Table 4.32 Pairwise comparison matrix 7of alternatives

	Location 1	Location 2	Location 3	Location 4
Location 1((NG8 6AR)	1	1/8	1/9	1/8
Location 2(NG16 2RP)	8	1	1	1
Location 3(NG16 7US)	9	9	1	1
Location 4(NG19 7JY)	8	1	1	1

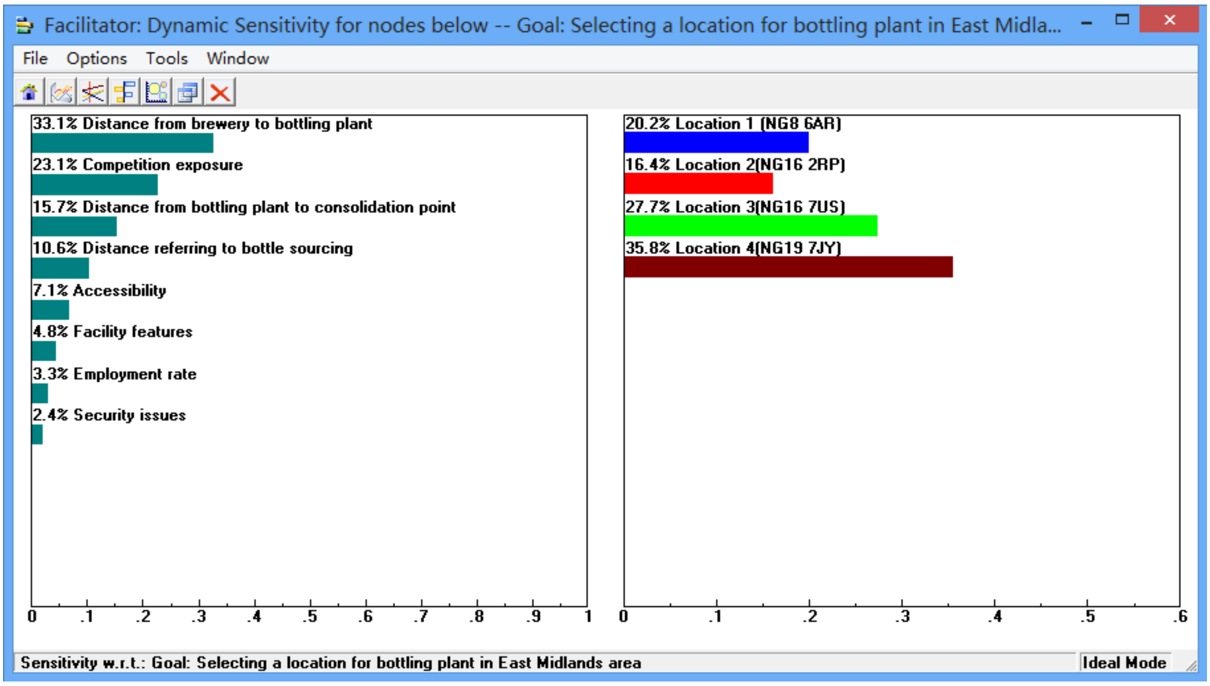
- Result and sensitivity analysis

Whenputting all the pairwise matrices (1 for pairs of criteria; 8 for alternatives in each criteria) into Export Choice (as it is illustrated in Screenshot 4.1.), it generates the result which gives the weight of each criteria (from 33.1% to 2.4%) and also the final ranking of the four candidate locations (shown as percentage). See Screenshot 4.2.

Screenshot 4.1 Overview of the problem modelling of AHP in Expert Choice

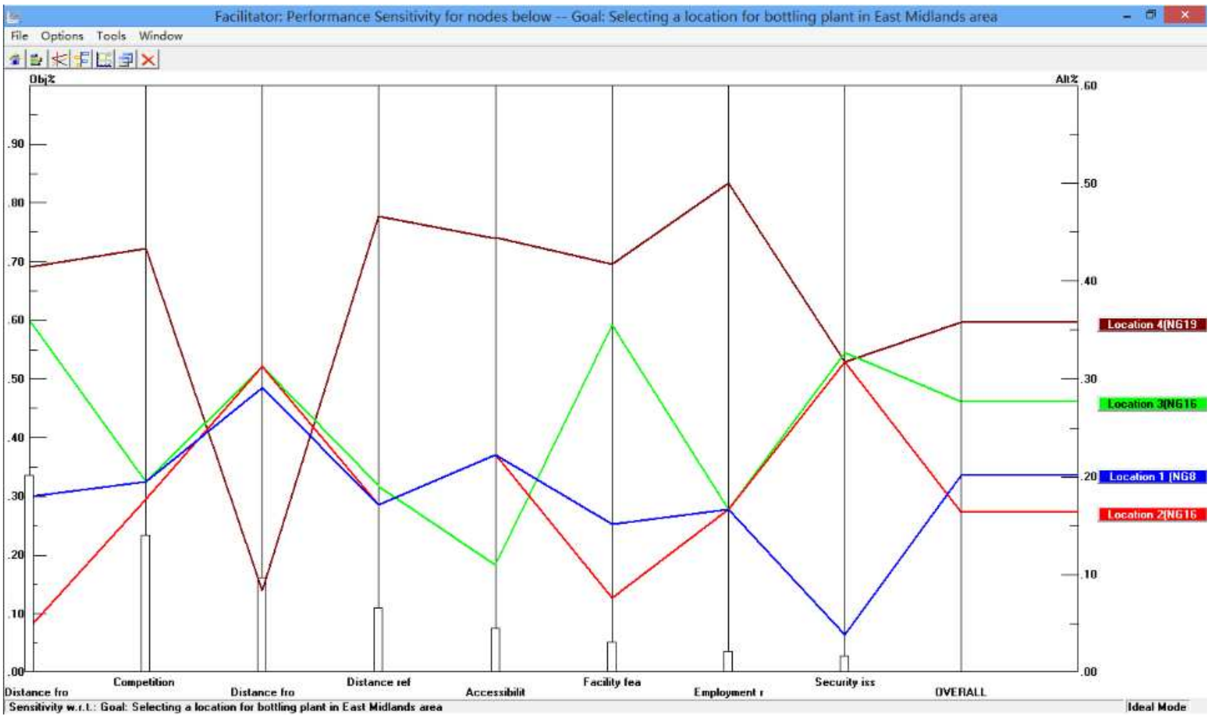


Screenshot 4.2 The result of AHP



Expert choice selects Location 4 as the optimal site for the goal of ‘selecting a location for bottling plant in East Midlands’, which is presented as 35.8%. In comparison, Location 3 is the second best choice with 27.7%. And Location 1 and 2 have a weight of 20.2% and 16.4%, positioned in third and fourth place.

Screenshot 4.3 Performance sensitivity graph of the result



Screenshot 4.3 presents a performance sensitivity graph which gives a clear view of the way each alternative positions in terms of each criterion and also their interactions which give the final result. Table4.33gives an overview about how each alternative is valued in terms of each criterion.

Table 4.33 Overview of the valuations of each candidate location in each criterion

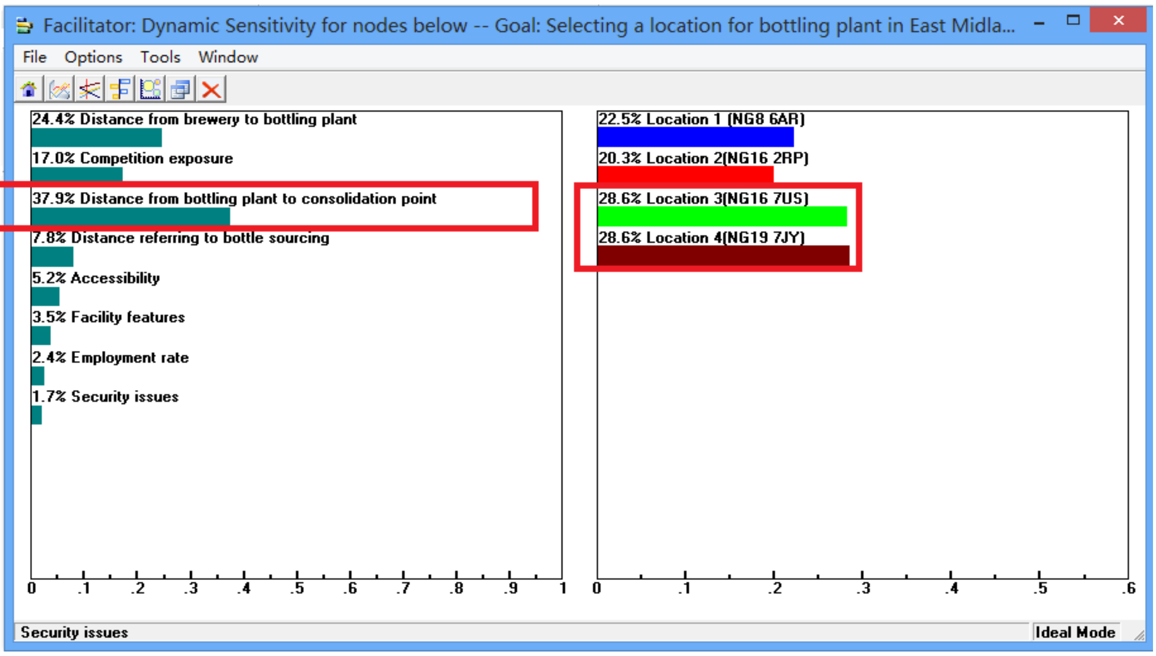
Criterion	Alternative	Weight
Distance from brewery to bottling plant	Location 1(NG8 6AR)	0.180
	Location 2 (NG16 2RP)	0.046
	Location 3 (NG16 7US)	0.359
	Location 4 (NG19 7JY)	0.415
Competition exposure	Location 1(NG8 6AR)	0.195
	Location 2 (NG16 2RP)	0.177
	Location 3 (NG16 7US)	0.195
	Location 4 (NG19 7JY)	0.434
Distance from bottling plant to consolidation point	Location 1(NG8 6AR)	0.291
	Location 2 (NG16 2RP)	0.312
	Location 3 (NG16 7US)	0.312
	Location 4 (NG19 7JY)	0.084
Distance referring to bottle sourcing	Location 1(NG8 6AR)	0.171
	Location 2 (NG16 2RP)	0.171
	Location 3 (NG16 7US)	0.191
	Location 4 (NG19 7JY)	0.467
Accessibility	Location 1(NG8 6AR)	0.222
	Location 2 (NG16 2RP)	0.222
	Location 3 (NG16 7US)	0.111
	Location 4 (NG19 7JY)	0.444
Facility features	Location 1(NG8 6AR)	0.152
	Location 2 (NG16 2RP)	0.076
	Location 3 (NG16 7US)	0.355
	Location 4 (NG19 7JY)	0.417
Employment rate	Location 1(NG8 6AR)	0.167
	Location 2 (NG16 2RP)	0.167
	Location 3 (NG16 7US)	0.167
	Location 4 (NG19 7JY)	0.500
Security issues	Location 1(NG8 6AR)	0.039
	Location 2 (NG16 2RP)	0.317
	Location 3 (NG16 7US)	0.327
	Location 4 (NG19 7JY)	0.317

It is clear that Location 4 positions much higher than the other three alternatives in five criteria: distance from brewery to bottling plant, competition exposure, distance referring to bottle sourcing, accessibility and facility feature. When increasing the weight of any of those five criteria, the valuation of Location 4 will be increased in each case. Therefore, basically, if any of those five criteria can carry a relative big weight compared to others, the position of Location 4 should be remained as the best choice. But to the other three criteria, the weight of the criterion and Location 4's final judgement (the weight it carries in final result) can be negatively correlated. And the Table 4.34 can illustrate the correlation between the weight changes of criteria and the changes of final judgements of alternatives by presenting each pair. Even based on this, Location 4's first place can be only replaced if the weight of 'Distance from bottling plant to consolidation point' and 'Security issues' changed. In detail, when the weight of 'Distance from bottling plant to consolidation point' reaches to 37.9% and higher, Location 3 starts to occupy the position of the first place which values 28.6%, when Location 4 values the same percentage. See Screenshot 4.4. Similarly, to 'Security issues', if its weight is higher than approximately 89.7%, the position of Location 3 will catch up with Location 4 given the judgement of 32.2%. It is demonstrated in Screenshot 4.5.

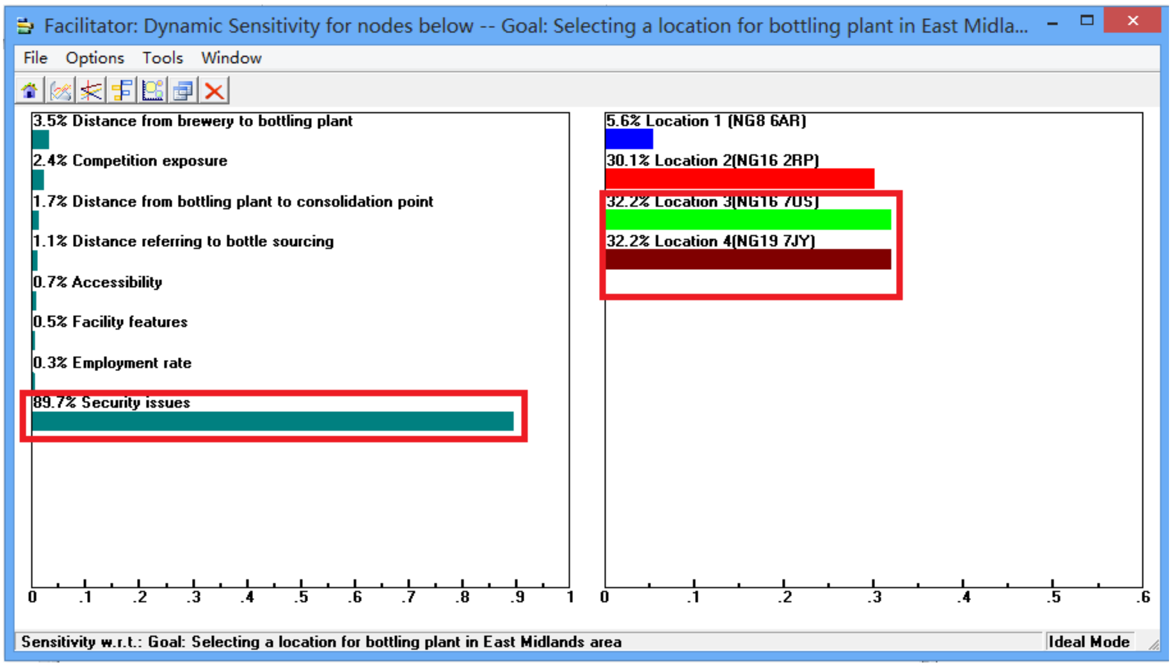
Table 4.34 Correlations between the weight increase of specific criterion and final valuation of specific alternative

Criterion	Alternative	Referred correlation
Distance from brewery to bottling plant	Location 1(NG8 6AR)	Negative
	Location 2 (NG16 2RP)	Negative
	Location 3 (NG16 7US)	Positive
	Location 4 (NG19 7JY)	Positive
Competition exposure	Location 1(NG8 6AR)	Negative
	Location 2 (NG16 2RP)	Positive
	Location 3 (NG16 7US)	Negative
	Location 4 (NG19 7JY)	Positive
Distance from bottling plant to consolidation point	Location 1(NG8 6AR)	Positive
	Location 2 (NG16 2RP)	Positive
	Location 3 (NG16 7US)	Positive
	Location 4 (NG19 7JY)	Negative
Distance referring to bottle sourcing	Location 1(NG8 6AR)	Negative
	Location 2 (NG16 2RP)	Negative
	Location 3 (NG16 7US)	Negative
	Location 4 (NG19 7JY)	Positive
Accessibility	Location 1(NG8 6AR)	Positive
	Location 2 (NG16 2RP)	Positive
	Location 3 (NG16 7US)	Negative
	Location 4 (NG19 7JY)	Positive
Facility features	Location 1(NG8 6AR)	Negative
	Location 2 (NG16 2RP)	Negative
	Location 3 (NG16 7US)	Positive
	Location 4 (NG19 7JY)	Negative
Employment rate	Location 1(NG8 6AR)	Negative
	Location 2 (NG16 2RP)	Positive
	Location 3 (NG16 7US)	Negative
	Location 4 (NG19 7JY)	Positive
Security issues	Location 1(NG8 6AR)	Negative
	Location 2 (NG16 2RP)	Positive
	Location 3 (NG16 7US)	Positive
	Location 4 (NG19 7JY)	Negative

Screenshot 4.4 AHP result with the weight change of the criteria-Distance from bottling to consolidation point



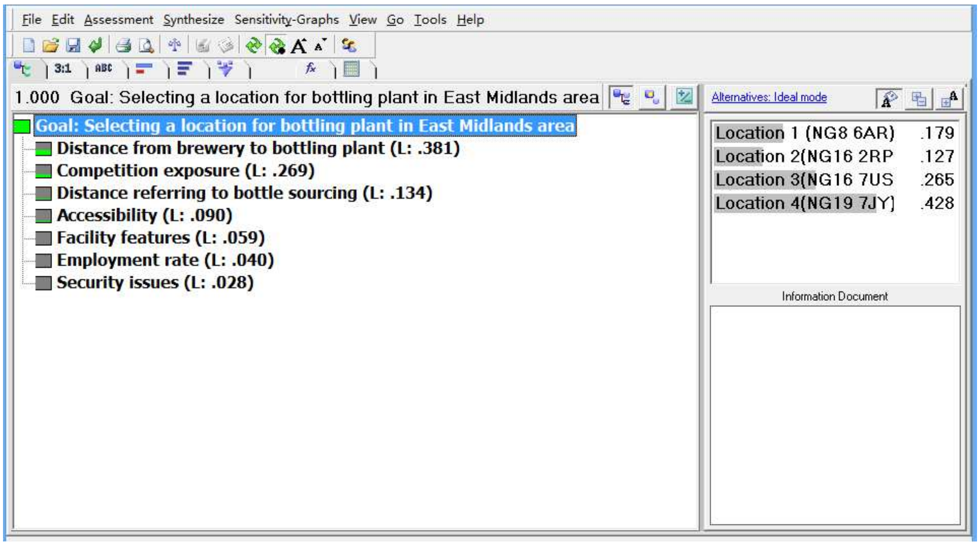
Screenshot 4.5AHP result with the weight change of the criteria-Security issues



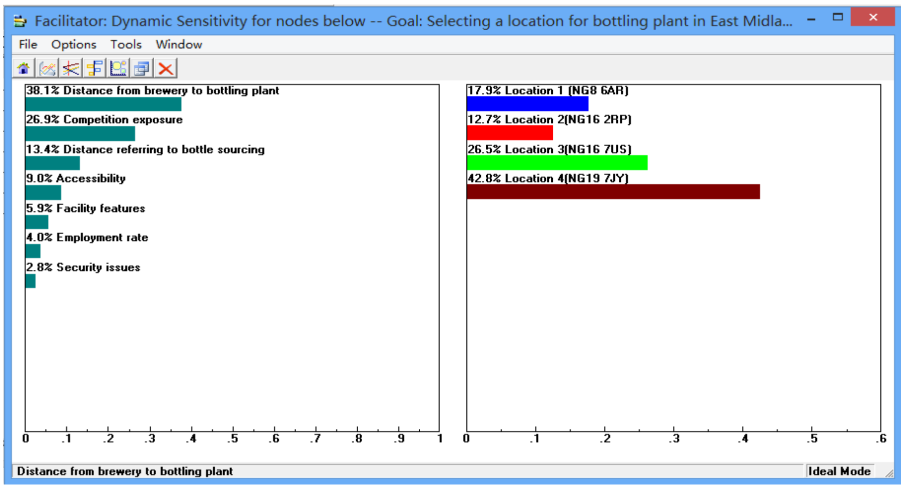
But some alternatives are not sensitive to the weight changes of some criteria. The final valuation of Location 1 will not change very obviously when 'Distance from breweries to bottling plant' weigh much more or less. The judgement of Location 2 is not so sensitive to the weight variations of both 'Competition exposure' and 'Distance referring to bottle sourcing'. For Location 3 and Location 4, their final valuation will not easily affected by 'Employment rate' and 'Facility features' respectively.

In addition, removing the criterion of 'Distance from bottling plant to consolidation point' can be another 'what-if' scenario in this decision making, because it may not be necessarily consider if the freight forwarders charge the cargo on load basis instead of certain distances. The Screenshot 4.6 and 4.7show another result based on this situation, where Location 4 is still the best choice and also being valued more (that is, 42.8%).

Screenshot 4.6 Overview of the problem modelling of AHP (modified version)in Expert Choice



Screenshot 4.7 The result of AHP (modified)



4.3. Summary

In this chapter, firstly it summarizes the findings from survey, observations and meetings which proceeded during the project period. Secondly, the theoretically optimal location is found in NG16 7US by explaining how the collected data is used in centre-of-gravity method and the way final location is found with an available property. Thirdly, it gives full explanations of Analytical Hierarchy Process, in which each criterion is analysed in detail, which gives in total 8 pair-wise comparison matrices for pairs of alternatives. Then, final result of AHP is given that NG19 7JY is the most optimal one, following with its sensitivity analysis.

Chapter 5: Conclusion

In conclusion, in this project, an appropriate location (NG19 7JY) of a beer bottling plant is found in East Midlands area based on the two steps of finding a theoretical site first and then selection, by using centre of gravity method and Analytical Hierarchy Process. This project-based facility location problem is identified based on previous studies, the first part of which should be a minisum problem, whereas, the second part of which is classified as a multi-criteriaproblem. This location is out of the expectation by which the location can be close to Junction 26 and Motorway 1. However,this final result is completely relying on the current responses from only thirteen breweries. As the fact indicates, there can possibly be more potential clients out of over 100 microbreweries in East Midlands area in the first five years. Therefore, the theoretical site derived by considering the total weighted distances from those 13 microbreweries can be inaccurate, so as the criteria analysis in AHP, especially the ones of distance from breweries to bottling plant and competition exposure. Besides, there are only eight aspects have been considered in this moment, which are not sufficient under investment background.

Nevertheless, the methodology used in this facility location problem is still feasible if more clients are to be counted or more criteria to be accommodated. Also, this paper might be helpful for future study of facility location problem under investment. Even, it can fill the gap in the specific geographic area of UK in facility location problem to some extent. Especially, the structure of the problem modelling even the whole methodology can be a good example for researchers who are interested in multi-criteria location problem of bottling facility with certain features to besingle-facility, discrete, static, uncapacitated, and competitive environment.

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Appendix I:

List of 88 breweries in East Midlands area

Brewery Name	Weekly production (brls)	Address 1	Address 2	Address 3	Address 4	City	County	Postcode
MrGrundys Brewery	8	MrGrundys Tavern	Ashbourne Road			Derby	Derbyshire	DE22 3AD
Tollgate Brewery	6	Unit 1	Southwood House Farm	Staunton Lane	Calke	Ashby-de-la-Zouch	Derbyshire	DE11 7EH
Black Iris Brewery	6	The Flowerpot	23-25 King Street				Derbyshire	DE1 3DZ
Hartshorns Brewery	6	Unit 4	Tomlinsons Industrial Estate	Alfreton Road			Derbyshire	DE21 4ED
Haywood Bad Ram Brewery	6	Callow Top Holiday Park	Buxton Road	Sandybrook		Asbourne	Derbyshire	DE6 2AQ
North Star Brewing Company Ltd	6	Unit 6	Gallows Industrial Estate	Furness Road		Ilkeston	Derbyshire	DE7 5EP
Wentwell Brewery	6	15 Wingfield Drive				Chaddesden	Derbyshire	DE21 4PW
J Thompsons Brewing Co	6	Ingleby				Melbourne	Derbyshire	DE73 7HW
Leadmill Brewery Ltd	6	Unit 3	Small Business Centre	Adams Close	Heanor Gate Industrial Estate	Heanor	Derbyshire	DE75 7SW
Tap House Brewery	6	The tap House	Annwell Road	Smisby		Ashby-de-la-Zouch	Derbyshire	LE65 2TA
Townes	6	Speedwell	Lowgates	Staveley		Chesterfield	Derbyshire	S43 3TT

		Inn						
Peak Ales	35	The Barn Brewery	Cunnery Barn	Chatsworth		Bakewell	Derbyshire	DE45 1EX
Spire Brewery	30	Unit 4	Deepdate Close	Hartington Industrial Estate	Staveley	Chesterfield	Derbyshire	S43 3YF
Shardlow Brewing Co Ltd	25	The Old Brewery	Stables	British Waterways Yard		Shardlow	Derbyshire	DE72 2HL
Raw Brewing Company	11	Unit 3 & 4	Silver House	Adelphi Way	Staveley	Chesterfield	Derbyshire	S43 3LS
Muirhouse Brewery	10	Unit 1	Enterprise Court	Mariners Avenue	Mariners Industrial Estate	Ilkeston	Derbyshire	DE7 8EW
Nutbrook Brewery Ltd	10	6 Hallam Way			West Hallam	Ilkeston	Derbyshire	DE7 6LA
Shottle Farm Brewery	10	School House Farm	Lodge Lane			Shottle	Derbyshire	DE56 2DS
Taddington Brewery	10	Blackwell Hall	Blackwell			Buxton	Derbyshire	SK17 9TQ
Whim Ales	10	Whim Farm	Hartlington			Buxton	Derbyshire	SK17 oAX
Dancing Duck Brewery	7.5	Unit 1	John Cooper Buildings	Payne Street			Derbyshire	DE22 3AZ
Buxton Brewery Company Ltd	7	Units 7 D & E	Staden Business Park			Buxton	Derbyshire	SK17 9RZ
Brunswick Brewery Ltd	6	1 Railway Terrace				Derby	Derbyshire	DE1 2RU
Derby Brewing Company Ltd	40	Masons Place Business Park	Nottingham Road			Derby	Derbyshire	DE21 6AQ
Leatherbritches Brewery	40	The Tap House	5 Annwell Lane	Smisby		Ashby-de-la-Zouch	Derbyshire	LE65 2TA

Derventio Brewery Ltd	30	Long Mill	Abbey Mills			Darley Abbey	Derbyshire	DE22 1DZ
Brampton Brewery Ltd	25	Unit 5	Chatsworth Business Park	Chatsworth Road		Chesterfield	Derbyshire	S40 2AR
The Brunswick Brewery Ltd	20	Railway Terrace					Derbyshire	DE1 2RU
Howard Town Brewery	16	Hawkeshead Mill	Hope Street			Glossop	Derbyshire	SK13 7SS
Wild Walker Brewing Co Ltd	15	Unit 7D&E	Staden Lane			Buxton	Derbyshire	SK17 9RZ
Ashover Brewery	10	1 Butts Road	Ashover			Chesterfield	Derbyshire	S45 0EW
Bottle Brook Brewery	10	Church Street	Kilburn			Belper	Derbyshire	DE56 0LU
Coppice Side Brewery	10	Unit 3	Small Business Centre	Adams Close	Heanor Gate Industrial Estate	Heanor	Derbyshire	DE75 7SW
Falstaff Brewery	10	24 Society Place					Derbyshire	DE23 6UH
Amber Ales Ltd	15	PO Box 7277				Ripley	Derbyshire	DE5 4AP
Golden Duck Brewery	6	Unit 2	Redhill Farm	Top Street		Appleby Magna	Leicestershire	DE12 7AH
Dow Bridge Brewery	6	2-3 Rugby Road	Catthorpe			Lutterworth	Leicestershire	LE17 6DA
Parish Brewery	25	6 Main Street				Burrough on the Hill	Leicestershire	LE14 2JQ
Belvoir Brewery & Sample Cellar	15	Crown Business Park	Station Road			Old Darby	Leicestershire	LE14 3NQ
Hoskin Brothers	10	The Ale Wagon	27 Rutland Street				Leicestershire	LE1 1RE

Langton Brewery	10	Grange Farm	Welham Road	Thorpe Langton		Market Harborough	Leicestershire	LE16 7TU
Riverside Brewery	8	Bees Farm	Brewster Lane	Wainfleet		Skegness	Lincolnshire	PE24 4LX
Poachers Brewery	7.5	439 Newark Road				North Hykeman	Lincolnshire	LN6 9SP
Sleaford Brewery Hop Me Up Ltd	6	21 Pride Court	Enterprise Park			Sleaford	Lincolnshire	NG34 8GL
Willys Brewery Ltd	6	17 High Cuff Road				Cleethorpes	Lincolnshire	DN35 8RQ
Newby Wyke Brewery	40	Unit 24	Limesquare Business Park	Alma Park Road		Grantham	Lincolnshire	NG31 9SN
Oldershaw Brewery	27	12 Harrow Hall Estate	Harrowby			Grantham	Lincolnshire	NG31 9HB
Swanton Brewery	20	North End Farm	High Street	Swanton		Sleaford	Lincolnshire	NG34 OJP
Fulstow Brewery	8	Unit 13	Thames Street			Louth	Lincolnshire	LN11 7AD
Grafters Brewery	8	The Half Moon Public House	23 High Street	Willingha-by-Stow		nr Gainsborough	Lincolnshire	DN21 5JZ
Blue Bell Brewery Ltd	6	Blue Bell Inn	Cranesgate South Whaplode	St Catherine		Spalding	Lincolnshire	PE12 6SN
Hopshackle Brewery Ltd	6	Unit F Blenheim Business Park	Blenhiem Way	Northfields Industrial Estate		Market Deeping	Lincolnshire	PE6 8LD
Brewster's	25	5 Burnside	Turnpike			Grantham	Lincolnshire	NG31 7XU

Brewing Co Ltd			Close					
8 Sail Brewery	16	Heckington Windmill	Hale Road	Heckington		Sleaford	Lincolnshire	NG34 9JW
Hart Family Brewers Ltd	8	The 1833 Brewery	Unit 21	Nene Court	27 The Embankment	Wellingborough	Northamptonshire	NN8 1LD
Silverstone Brewing co Ltd	8	Kingshill Farm	Syresham				Northamptonshire	NN13 5TH
Tom Smith Ales Ltd	8	15 Lindsey Street				Kettering	Northamptonshire	NN16 8RG
Gun Dog Ales Ltd	6	5b Great Centre Way	Woodford Halse			Daventry	Northamptonshire	NN11 3PZ
Whittlebury Brewery	6	Stable Store	Home Farm Yard	Church Way	Whittlebury	Towcester	Northamptonshire	NN12 8XS
Julian Church Brewing Co	6	38 Nunnery Avenue				Rotherwell	Northamptonshire	NN14 6JJ
Nobbys Brewery	45	c/o The Ward Arms	High Street			Guilsborough	Northamptonshire	NN6 8PY
Frog Island Brewery	25	The Maltings	Westbridge St James Road			Northampton	Northamptonshire	NN5 5HS
Great Oakley Brewery	21	Ark Farm	High Street	South Tiffield		Towcester	Northamptonshire	NN12 8AB
Digfield Ales	17.5	North Lodge Farm				Barnwell	Northamptonshire	PE8 5RJ
Hoggleys Brewery	12	c/o 30 Mill Lane				Kislingbury	Northamptonshire	NN7 4BD
Potbelly Brewery	10	c/o Corium Leather Co Ltd	25-31 Durban Road			Kettering	Northamptonshire	NN16 0JA
Castle Rock Brewery	90	Queensbridge Road				Nottingham	Nottinghamshire	NG2 1NB

Copthorne Brewery	6	Majors Farm	Woodcotes Lane	Darlton		Newark	Nottinghamshire	NG22 0TL
Nottingham Brewery Ltd	50	17 St Peters Street			Radford	Nottingham	Nottinghamshire	NG7 3EN
Springhead Fine Ales Ltd	50	Main Street	Laneham			Retford	Nottinghamshire	DN22 0NA
Mallard Brewery	6	c/o 81 Church Street				Southwell	Nottinghamshire	NG25 0HQ
Maypole Brewery	6	North Laithes Farm			Kneesall	Newark	Nottinghamshire	NG22 0AN
Milestone Brewing Co	45	Great North Road	Cromwell			Newark	Nottinghamshire	NG23 6JE
Blue Monkey Brewing Ltd	30	10 Pentrich Road	Giltbrook Industrial Park			Giltbrook	Nottinghamshire	NG16 2UZ
Grafton Brewing Co	20	c/o 8 Oak Close				Worksop	Nottinghamshire	S80 1BH
Navigation Brewery Ltd	20	Trent Navigation Inn	Meadow Lane			Nottingham	Nottinghamshire	NG2 3HS
Full Mash Brewery	16	17 Lower Park Street	Stapleford			Nottingham	Nottinghamshire	NG9 8EW
Caythorpe Brewery Ltd	14	Trentham Cottage	Boat Lane			Hoveringham	Nottinghamshire	NG14 7JP
Flipside Brewery	11	The Brewhouse	East Link Trade Centre	Private Road No. 2	Colwick	Nottingham	Nottinghamshire	NG4 2JR
Lincoln Green Brewing Company Ltd	10e	Unit 5	Enterprise Parkk	Wigwam Lane		Hucknall	Nottinghamshire	NG15 7SZ
Magpie Brewery	10	4 Ashling Court	Iremonger Road			Nottingham	Nottinghamshire	NG2 3JA

Pheasantry Brewery	10	High Brecks Farm	Lincoln Road			East Markham	Nottinghamshire	NG22 0SN
Priors Well Brewery	10	The Old Kennels	Hardwick Village	Clumber Park Estate		Worksop	Nottinghamshire	S80 3PB
Welbeck Abbey Brewery	10	Lower Motor Yard		Welbeck		Worksop	Nottinghamshire	S80 3LR
Newark Brewery	8	77 William Street			Newark	Newark	Nottinghamshire	NG24 1QU
Dukeries Brewery	6	Unit 6 Peppers Warehouse	Blythe Road			Worksop	Nottinghamshire	S81 0TP
Funfair Brewery	6	Chequers Inn	Toad Lane	Elston		Newark	Nottinghamshire	NG23 5NS
Davis'es Brewing Co Ltd	15	Station Approach	Oakham				Rutland	LE15 6RE

Appendix II:

The Online survey:

Page 1 of 5

Bottling Facility Survey

The purpose of this survey is to determine the number of microbreweries willing to use a central bottling facility and the volume of beer they would like to bottle in the facility. This survey will form part of a project to determine the most appropriate location for a potential plant and to consider issues such a capacity scheduling and transportation. Your contact details will not be passed to any third party without your permission.

Add item

After page 1 Continue to next page

Company Information

Brewery Name

Contact name

Contact e-mail

On average, approximately how many barrels do you produce weekly?

What is your maximum weekly capacity?

Would you expand your capacity in the near future?

Do you send any beer for contract bottling?

If you outsource bottling, who do you use for the majority of contract bottling?

If you are bottling in-house, how many bottles per hour do you produce?

What volume do you send for contract bottling at one time?

- ◯ 5 - 10 brl
- ◯ 11 – 20 brl
- ◯ More than 20 brl

Approximately how much do you pay per 500ml bottle (excluding transport , delivery and VAT)

- ◯ Less than 15p
- ◯ 16p to 25p
- ◯ 26p to 35p
- ◯ 36p to 45p
- ◯ 46 to 65p

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Outsource Bottling Process

How likely are you to use a contract bottling service?

	1	2	3	4	5	
Very unlikely	◯	◯	◯	◯	◯	Very likely

When might you use a contract bottling service?

- ◯ Already use
- ◯ Within 6 months
- ◯ Within 1 year
- ◯ 1 to 2 years
- ◯ More than 2 years

Add item

Outsource Bottling Facility

Approximately what percentage of your production might you outsource for bottling?

How often might you send beer for contract bottling?

Beer could be stored (ex duty) at a bonded warehouse and called off back to the brewery or sent directly to retail outlets, wholesalers or export. How much would you want to come back to the brewery?

If beer is brought back to the brewery from the contract bottlers then how quickly would you need it back?

What would you consider to be a reasonable but competitive price for contract bottling the following volumes (per 500ml bottle excluding transport , delivery ex VAT) ?
a) Bottling 5 brls

What would you consider to be a reasonable but competitive price for contract bottling the following volumes (per 500ml bottle excluding transport , delivery ex VAT) ?
b) Bottling 6 - 10 brls

What would you consider to be a reasonable but competitive price for contract bottling the following volumes (per 500ml bottle excluding transport , delivery ex VAT) ?
c) Bottling 11 - 20 brls

Add item

After page 4 Continue to next page

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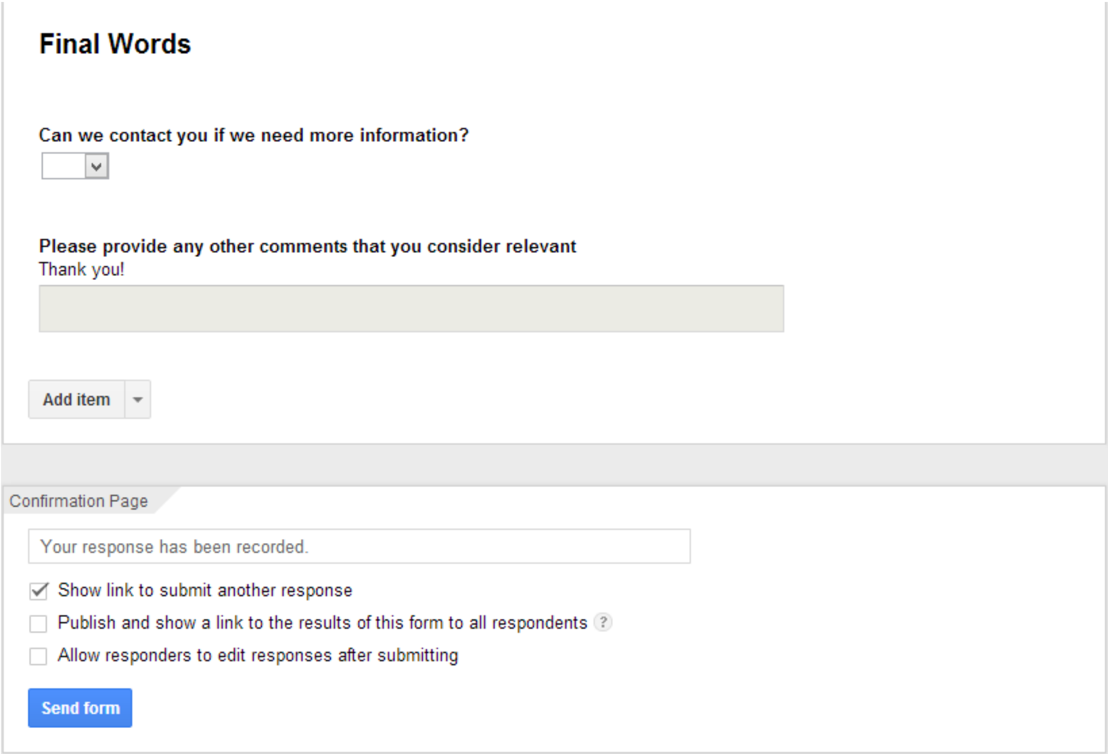

Final Words

Can we contact you if we need more information?

Please provide any other comments that you consider relevant
Thank you!

Add item

Confirmation Page

Your response has been recorded.

- [x] Show link to submit another response
- [ ] Publish and show a link to the results of this form to all respondents ?
- [ ] Allow responders to edit responses after submitting

Send form

Appendix III

Result from the online questionnaire:

	Brewery Name	Average weekly production	Maximum weekly capacity	Whether to expand capacity or not	Current contract bottler	What volume do you send for contract bottling at one time?
1	Funfair Brewing Company	40-60	120	Yes		
2	SPIRE BREWERY	30	40	Yes		
3	Nutbrook Brewery	25	36	Yes	**Leek Brewery**	5 - 10 brl
4	Brampton Brewery	25	30	Yes	**Bottled In Cumbria**	5 - 10 brl
5	Lincoln Green Brewing Company	20	20	Yes		
6	Raw Brewing Company	16	22	Yes	**Cumbrian Bottling**	5 - 10 brl
7	Pheasantry Brewery	15	40	**No**		
8	Derventio Brewery Ltd	15	20	Yes	**Holdens Bottling**	5 - 10 brl
9	Langton Brewery	12	12	Yes		
10	Amber Ales	10	25	Yes		
11	8 Sail Brewery	7	11	**No**		
12	Barlow Brewery	3.5	5	Yes		
13	Handley's	0.5	1	**No**		

	Brewery Name	How likely are you to use a contract bottling service?	When might you use a contract bottling service?	Approximately what percentage of your production might you outsource for bottling?	How often might you send beer for contract bottling?	How much would you expect to come back	How quickly would you need bottled beer back
1	Funfair Brewing Company	5 (STRONGLY LIKELY)	Within 6 months	Between 40%-60%	Twice a month	20% Some	1 - 2 weeks (from bottling)
2	SPIRE BREWERY	1 (STRONGLY UNLIKELY)	Within 6 months	Between 40%-60%	Twice a month	50% Half	1 - 2 weeks
3	Nutbrook Brewery	5	Already use	Between 20%-40%	Once a month	80% Most	1 - 2 weeks
4	Brampton Brewery	5	Already use	Less than 20%	Twice a month	80% Most	3 – 7 days
5	Lincoln Green Brewing Company	5	Within 1 year	Less than 20%	Once a month	20% Some	3 – 7 days
6	Raw Brewing Company	4	Already use	Less than 20%	Twice a month	100% All	1 - 2 weeks
7	Pheasantry Brewery	2	Within 6 months	Between 20%-40%	Once a month	50% Half	1 - 2 weeks
8	Derventio Brewery Ltd	5	Already use	Less than 20%	Less than once a month	20% Some	2 – 4 weeks
9	Langton Brewery	1	More than 2 years	NIL			
10	Amber Ales	5	Within 6 months	Between 20%-40%	Twice a month	20% Some	1 - 2 weeks
11	8 Sail Brewery	3	Within 1 year	Less than 20%	Less than once a month	100% All	1 - 2 weeks
12	Barlow Brewery	4	Within 6 months	Between 40%-60%	Once a month	50% Half	3 – 7 days
13	Handley's	1		NIL	NIL		

	Brewery Name	Approximately how much do you pay per 500ml bottle (excluding transport , delivery and VAT)	What would you consider to be a reasonable but competitive price for contract bottling less than 5 barrels (per 500ml bottle excluding transport, delivery ex VAT)?	What would you consider to be a reasonable but competitive price for contract bottling 6-10 barrels (per 500ml bottle excluding transport, delivery ex VAT)?	What would you consider to be a reasonable but competitive price for contract bottling 11-20 barrels (per 500ml bottle excluding transport, delivery ex VAT)?
1	Funfair Brewing Company		16p to 25p	16p to 25p	Less than 15p
2	SPIRE BREWERY	16p to 25p	36p to 45p	26p to 35p	
3	Nutbrook Brewery	46 to 65p	36p to 45p		26p to 35p
4	Brampton Brewery	36p to 45p	36p to 45p	26p to 35p	16p to 25p
5	Lincoln Green Brewing Company	Less than 15p		36p to 45p	26p to 35p
6	Raw Brewing Company	46 to 65p	46 to 65p	36p to 45p	36p to 45p
7	Pheasantry Brewery	16p to 25p	16p to 25p	16p to 25p	Less than 15p
8	Derventio Brewery Ltd	46 to 65p	46 to 65p	36p to 45p	26p to 35p
9	Langton Brewery	16p to 25p			
10	Amber Ales	16p to 25p	16p to 25p		
11	8 Sail Brewery	26p to 35p	Less than 15p	Less than 15p	Less than 15p
12	Barlow Brewery	Less than 15p	26p to 35p		
13	Handley's				

Appendix IV:

Questions and answers in Meeting:

Q1. **How many employees are supposed to be hired in the first five years? And what are their**
occupations? (i.e. how many security, administration personnel, HR staffs required)

A1: We can discuss this but I think the following are likely over the course of 5 years:

Packaging operatives	5
Warehouse operative	1
Supervisor	1
Administration	1
Finance	0.5
Retailing	1.5
Manager	1

Q2. Does the whole area of the facility only for the bottling plant and warehouse? Should there
be a spare space left for other purposes in the future (i.e. brewing)?

A2: Yes future expansion should be possible into brewing– c. 1000 sqmetres

Q3. **Should there be a kind of barrier to separate the bottling part and the warehouse to make them independent?**

A3: They don’ t need to be independent but we may need a physical barrier to entry if some beer is held in duty suspension i.e. the beer is bottled and stored but duty has not been paid.

Q4. Is the facility expected to have souvenir store to do retailing (or wholesaling) for its clients? About wholesaling, is this bottling plant willing to do the wholesaling where the 3rd party transportation agent will be responsible to pick up the beer? The same question for exporting. (because Bath Ales put the bottled beer in its warehouse, waiting for further distribution both to wholesaling and exporting)

A4: There is likely to be a retailing element to the facility– maybe within 2 years. The bottling facility will act as a wholesale depot for its clients– in such a case a third party will pick up beer from the facility– this will apply to exporting also.

Q5. How about the supposed size of the bottling plant? Should it be similar compared to Bath Ales, whose bottling rate is around 2200 bph (not so much difference to this bottling facility under investment where the bottling rate is around 2500 bph)?

A5: The final size of the bottling plant will depend on the most economical solution with respect to a capital investment. However, you can assume that the rate will be the same as for Bath (2200 bph) all the plant that we have looked at are about this size and the next step up is double this which would be too big.

Q6. Also, is the facility supposed to have a Mezzanine for the office, staff rest room, inspection room, or required an independent second-floor area (maybe partially)?

A6: This depends on the most appropriate facility that is available. Some area will need to be double height so a mezzanine floor is possible but not mandatory.

Q7. Normally, how much space required in front of the plant for big vehicles which carry IBCs?

A7: IBCs would be loaded / unloaded outside– ask Gonzalo what space would be needed for unloading and vehicle movement.

Q8. Should the size and number of vessels required be based on the result from Otsile in the moment? Or there are some expectations?

A8: Base these on Otsiles work at the moment

.

Appendix V:

The NEAREST contract bottlers:

Branded Drinks
The Bottling Works, Unit 1, The Business Park, Tufthorn Avenue, Coleford, GL16 8PN
T: 01594 810261
F: 01594 810372
E: jon.calver@brandeddrinks.co.uk
W: www.brandeddrinks.co.uk
Contact: Jonathan Calver
We are able to offer a comprehensive bottling service to the highest quality standards as demanded by the brewing industry. We can bottle a minimum of 5BB upto 60BB or larger if required. In addition to this we can offer sales through to the supermarket sector.

The Celt Experience
Unit 2E Hills Court, PontygwindyInd Estate, Caerphilly, CF83 3HU
T: 02920 867707
E: becky@theceltexperience.co.uk
W: www.theceltexperience.co.uk
Contact: Becky Newman
Minimum run/quantity: 20 barrels
Maximum run/quantity: 40 barrels

Country Life Brewery Ltd
The Big Sheep, Abbotsham, N. Devon, EX39 5AP.
T: 01237 420808
E: simon@countrylifebrewery.com
Contact: Simon
Minimum run/quantity: 1 x 18g
Maximum run/quantity: 8 barrels

Edwin Holden's Bottling Co. Ltd.
Hopden Brewery, George Street, Woodsetton, Dudley, W. Midlands, DY14LW
T: 01902880051
F: 01902665473
E: enquiries@holdensbottling.co.uk
W: www.holdensbottling.co.uk
Contact: Mark Hammond
Minimum run/quantity: 10 barrels
Maximum run/quantity: 100+ barrels

Hambleton Ales
Melmerby Green Road, Melmerby, Ripon HG4 5NB
T: 01765 640108
E: admin@hambletonales.co.uk
W: www.hambletonales.co.uk

Contact: Hannah Stafford
Minimum run/quantity: 164 litres
Maximum run/quantity: 3000 litres per day

The Hurns Brewing Co Ltd
3 Century Park, Valley Way, Swansea Enterprise Park, Swansea, SA6 8RP
T: 01792 797321
E: phillparry@tomoswatkin.co.uk
W: www.tomoswatkin.com
Contact: Phill Parry
Minimum run/quantity: 10 barrels
Maximum run/quantity: 80 barrels

Keltek Brewery
Cardrew Industrial Estate, Redruth, Cornwall. TR15 1SS.
T: 01209 313620
F: 01209 215197
E: sales@keltekbrewery.co.uk
W: www.keltekbrewery.co.uk
Contact: Stuart Heath
Minimum run/quantity: 1000 litres
Maximum run/quantity: 16,000 litres

North Yorkshire Brewing co.
Pinchinthorpe Hall, Guisborough, North Yorkshire, TS14 8HG
T: 01287 630200
E: georgepinchinthorpe@hotmail.co.uk
W: www.nybrewery.co.uk
Contact: George Tinsley
Minimum run/quantity: 2 barrels
Maximum run/quantity: -

Red Rock Brewery
Higher Humber Farm, Humber, Teignmouth TQ14 9TD
T: 01626 879738
E: redrockbrewery@gmail.com
W: www.redrockbrewery.co.uk
Contact: John Parkes
Minimum run/quantity: 500 bottles
Maximum run/quantity: 1500 bottles

St Austell Brewery Co Ltd
63 Trevarthian Road, St Austell, Cornwall, PL25 4BY
T: 01726 74444
F: 01726 68965
E: info@staustellbrewery.co.uk

W: www.staustellbrewery.co.uk
Contact: Roger Ryman
Minimum run/quantity: 60 barrels
Maximum run/quantity: 170 barrels

Thames Distillers Ltd
Timbermill Distillery, Timbermill Way, Gauden Road, London SW4 6LY
T: 020 7720 4747
F: 020 7622 7780
E: info@thamesdistillers.co.uk
W: www.thamesdistillers.co.uk
Contact: Charles Maxwell
Thames Distillers Ltd now offers a filtering and bottling service for beer to SIBA members for runs of between 10 to 30 barrels.Thames is a fully customs bonded independent company with many years of experience in the contract bottling business.

WBC (Norfolk) Ltd. T/A Wolf Brewery
Unit 1 Rookery Farm, Silver Street, Besthorpe, Attleborough, NR17 2LD.
T: 01953 457775
F: 01953 457776
E: john@wolfbrewery.com
W: www.wolfbrewery.com
Contact: John Edwards
Minimum run/quantity: 5 barrels/1000 litres.
Maximum run/quantity: 6 to 10 pallets per day,

Williams Bros. Brewing Co.
New Alloa Brewery Kelliebank, Alloa, FK10 1NU UK
T: 01259 725 511
E: S.williams@williamsbrosbrew.com
W: www.williamsbrosbrew.com
Contact: Scott Williams
Minimum run/quantity: 20 barrels
Maximum run/quantity: 150 barrels

Wooden Hand Brewery
Unit 3 Grampound Road IndEst Nr Truro Cornwall TR2 4TB
T: 01726 884596
F: 01726 884579
E: chris@woodenhand.co.uk
W: www.woodenhand.co.uk
Contact: Chris O’Brien
Minimum run/quantity: 15 barrels
Maximum run/quantity: 95 barrels

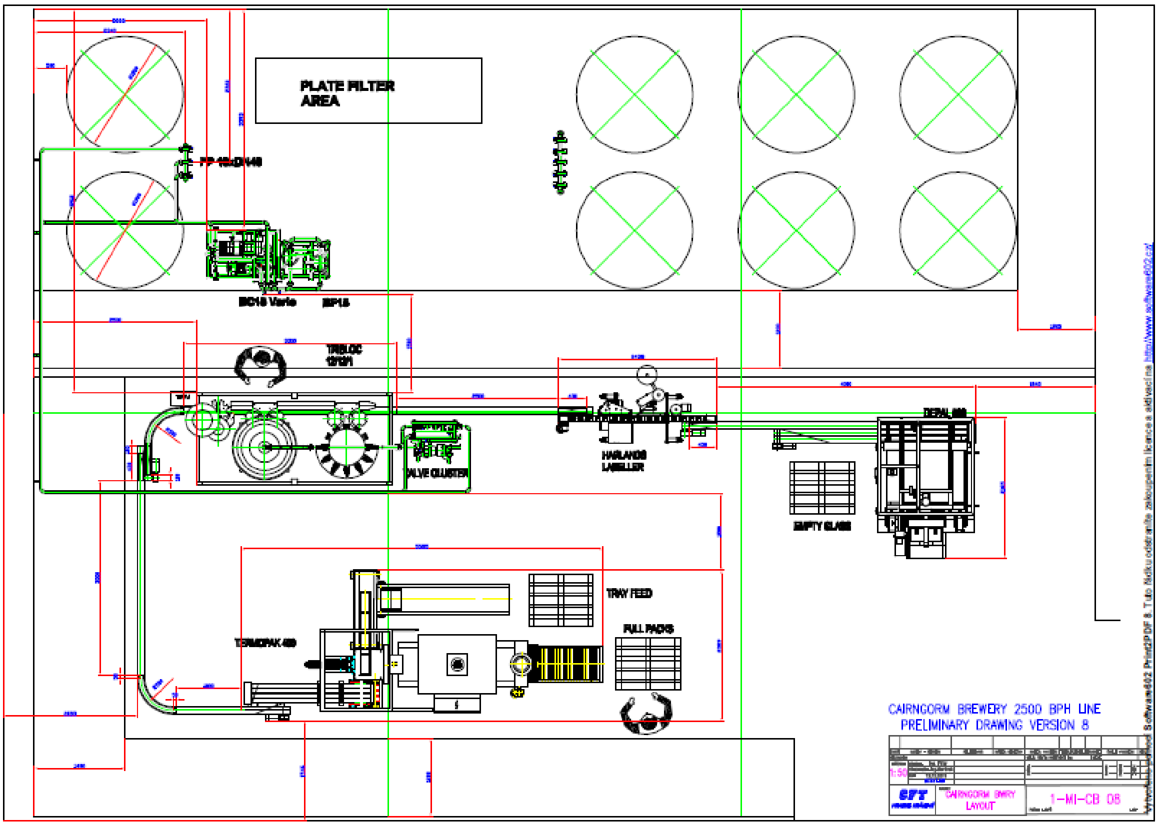
Appendix VI:

Information required for the calculations of market share:

Name	**Weekly production**	**Percentage required for bottling**	**Real distance from location 1 to**	**Real distance from location 2 to**	**Real distance from location 3 to**	**Real distance from location 4 to**	**Real distance from Leek Brewery to**	**Real distance from Edwin Holden's to**
Raw Brewing Company	16	20%	22.786	23.584	19.627	10.693	55.29	75.011
Nutbrook Brewery	25	30%	9.341	6.341	8.302	23.428	35.641	55.362
Lincoln Green Brewing Company	20	20%	4.793	6.177	6.72	10.73	52.175	69.424
Barlow Brewery	3.5	50%	27.875	28.672	24.716	15.721	33.790	80.100
Funfair Brewing Company	40-60	50%	23.698	27.531	29.14	26.138	71.794	87.797
SPIRE BREWERY	30	50%	24.047	24.844	20.887	11.953	39.327	76.272
8 Sail Brewery	7	20%	52.746	56.579	53.004	45.473	100.842	116.845
Brampton Brewery	25	20%	23.482	24.279	20.323	11.329	34.134	75.707
Pheasantry Brewery	15	30%	29.914	45.404	33.019	20.743	77.111	96.832
Derventio Brewery Ltd	15	20%	16.848	17.937	11.885	23.014	29.642	49.363
Amber Ales	10	30%	11.019	8.034	7.005	14.695	38.122	57.843

Appendix VII:

Layout of Cairngorrn Brewery:



Appendix VIII:

Overall structure of the four properties:

NG16 7US

NG19 7JY

NG16 2RP Unit 8

NG8 6AR