Pre-Study of the Important Factors for the Factory Start-Up Abroad

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ABSTRACT

In the past years Väderstad Verken has been developing rapidly and expanding the sales of its machines in new markets, in particular in Eastern Europe. Due to the growing sales and some risks related to possible increases in the import duties on some agricultural equipment the company is considering the possibility of building a factory in the Eastern Europe to serve that market.

For this reason the company was interested in a pre-study on the important factors for the factory start-up in Eastern Europe, in particular, Russia and Ukraine. Thus the scope of the thesis included the research and identification of the factors important particularly for Väderstad Verken as well as identifying some general steps necessary for the factory start-up. In order to identify and analyse location factors critical for Väderstad Verken, literature on location analysis was analysed in order to identify a list of possible factors as well as tools which could be used to evaluate them.

Center of Gravity and Analytic Hierarchy Process (AHP) have been selected to evaluate the performance of several regions on these factors to identify the suitable location of the factory. Expert Choice software was applied in order to simplify the comparison of various factors following the AHP steps.

A specification for the potential factory has been defined given the desired production capacity and requirements. Two factory layouts have been suggested taking into consideration the possibility of the factory expansion.

In some way this master thesis could be used as a guideline for the selection of suitable manufacturing location as well as factory start-up.
CONTENTS

ACKNOWLEDGMENTS ................................................................................................................................. 2

ABSTRACT ....................................................................................................................................................... 3

1 INTRODUCTION ............................................................................................................................................... 6

1.1 Background ................................................................................................................................................ 6
1.2 Purpose ...................................................................................................................................................... 6

2 AIM OF THE PROJECT .................................................................................................................................... 7

3 PROBLEM STATEMENT .................................................................................................................................. 8

4 PROJECT LIMITATIONS .................................................................................................................................. 9

5 THEORETICAL BACKGROUND AND SOLUTIONS METHODS ....................................................................... 10

5.1 Introduction ................................................................................................................................................ 10
5.2 Manufacturing Location Decisions .............................................................................................................. 10
Step 1: Evaluating the Production Capacity .................................................................................................. 10
Step 2: Expansion or a New Facility .................................................................................................................. 10
Step 3: Establish Facility Specification ........................................................................................................... 11
Step 4: Identify Key Location Factors ............................................................................................................ 14
Step 5: Site Selection ...................................................................................................................................... 16
5.3 Defining general area of search ................................................................................................................... 17
5.4 Selecting communities ............................................................................................................................... 18
5.5 Identifying sites ....................................................................................................................................... 19
5.6 Final report .............................................................................................................................................. 21
5.7 Evaluation of alternatives .......................................................................................................................... 21
5.7.1 The centre of gravity technique ............................................................................................................ 22
5.7.2 Economic models ................................................................................................................................. 23
5.7.3 MCDA Methods .................................................................................................................................. 24

6 EMPIRICAL STUDY ......................................................................................................................................... 36

6.1 Reasons for using interview technique ...................................................................................................... 36
6.2 Interview results and comparison ................................................................................................................ 36

7 APPLIED SOLUTIONS PROCEDURE ............................................................................................................. 41

7.1 Facility specification .................................................................................................................................. 41
7.1.1 Capacity planning ................................................................................................................................. 42
7.1.2 Layout .................................................................................................................................................. 43
7.1.3 Organization chart ............................................................................................................................... 43
7.2 Factors ...................................................................................................................................................... 44
7.2.1 Market potential ................................................................................................................................. 45
7.2.2 Labour ................................................................................................................................................ 47
7.2.3 Transportation infrastructure ............................................................................................................. 47
7.3 Site selection stage .................................................................................................................................. 48
7.4 Selecting a macro-region .......................................................................................................................... 49
7.5 Centre of Gravity ................................................................................................................................... 49
7.6 AHP .......................................................................................................................................................... 50
7.6.1 Pairwise comparison ............................................................................................................................. 50
7.6.2 Sensitivity analysis .............................................................................................................................. 52
7.7 Cost calculation ....................................................................................................................................... 58
7.7.1 Packing cost ....................................................................................................................................... 58
7.7.2 Transportation of assembled machines .............................................................................................. 59
7.7.3 Transportation of components ........................................................................................................... 59
7.7.4 Assembly costs .................................................................................................................................. 59
7.7.5 Administration costs ........................................................................................................................... 60
7.7.6 Transportation cost from the new factory to customers ...................................................................... 60
7.7.7 Cost analysis ...................................................................................................................................... 61

8 CONCLUSIONS AND RECOMMENDATIONS ............................................................................................... 62
8.1 Summary ................................................................................................................................................ 62
8.2 Recommendations for the future work ................................................................................................. 63

9 REFERENCES ................................................................................................................................................. 64

10 APPENDICIES ............................................................................................................................................... 66

Appendix A: Site Requirements for a Proposed New Facility (Hack, 1999) ........................................... 66
Appendix B: Results from the Interview with Company A ........................................................................ 68
Appendix C: Results from the Interview with Company B ....................................................................... 71
Appendix D: Factory Layout, 3 250 m² ................................................................................................. 74
Appendix E: Factory Layout, 7 150 m² ................................................................................................. 75
Appendix F: Map of Regions in Ukraine ............................................................................................. 76
Appendix G: Map of Regions in Russia ............................................................................................. 77
Appendix H: Center of Gravity .............................................................................................................. 78
Appendix I: Values for X and Y coordinates ....................................................................................... 79
Appendix J: Salary Breakdown ............................................................................................................. 81
1 INTRODUCTION

1.1 Background

Väderstad Verken is a family firm, named after the Swedish village where it is based. The business was founded in 1962 by Rune and Siw Stark, who began manufacturing farming tools for local farmers in a small engineering workshop on their own farm. At that time their farm had some 30 hectares of arable land.

From this modest start, Väderstad has grown into a company with a staff of more than 600 people working in a very modern factory. At present, the company’s production facilities total 36,000 m², including covered storage areas. The company is still owned by the Stark family.

Väderstad Verken has today about 100 employees which work outside of Sweden at eleven subsidiaries, which are located in England, France, Germany, Poland, Hungary, Estonia, Latvia, Lithuania, Ukraine, Russia and Australia.

The vision of the company is to become a global supplier benefiting farmers, co-workers, society and owners. The Väderstad’s business idea is to provide the modern agriculture with highly effective machines and methods.

Innovation occupies a central position in the corporate culture of Väderstad. The company has a strong track record of trailblazing approach to product development. Customer satisfaction and excellent customer relations are always high priorities at Väderstad. They have their sights set firmly on being one of the true market leaders in cultivation and seed drilling machinery. Väderstad’s role is to produce revolutionary machinery and tillage systems for farmers. Drawing on the experience of their customers as well as their own resources, Väderstad’s mission is to continue to promote the rationalisation of arable farming methods in Europe, through sound design, innovation and invention.

1.2 Purpose

The purpose of this thesis is to recommend a list of factors which are important for the factory establishment abroad. Additionally, suitable areas for the factory start-up should be analysed based on the identified factors.
2 AIM OF THE PROJECT

Väderstad Verken is constantly developing and expanding its operations. In 2006, demand for Väderstad machines has been extremely high, which has led to a growth of over 30% within all markets and all product families. Some of the fastest growing markets were Ukraine and Russia. In 2007, for the first time in Väderstad history, sales in the Swedish market have been outperformed by sales in a single country outside of Sweden. According to the sales results of 2007, Russia became the biggest market for Väderstad Verken.

The Russian market is rather important for Väderstad Verken. In order to have a more strong position at this market as well as reduce risks associated with possible increase in import duties on such agricultural equipment as cultivators and drills management at Väderstad decided to analyse the possibility of starting-up a factory in Eastern Europe.

The aim of this project is to analyse two questions related to the factory start-up abroad. The first question is: What factors should be taken into consideration when establishing a factory in Eastern Europe? The answer to this question should provide a list of factors which are relevant for a factory to be built by Väderstad as well as analysis of the feasible locations for start-up in terms of meeting those factors.

The second question is: How big the factory should be? The answer to this question should specify what operations should be performed, what resources are required to perform those operations, and how should be arranged the plant’s layout and size.

Additionally, in order to get some practical experience the company was interested in interviewing some international companies who already have production operations in Russia or Ukraine.
3 PROBLEM STATEMENT

Introduction of import duties on agricultural machinery by Russia can increase the sales price of Väderstad Verken machines and hence make them less competitive in the growing market. In order to secure its market position in Eastern Europe Väderstad Verken is considering an option of building a factory in Russia or Ukraine. However, the company does not have an experience of starting up production outside of Sweden. Study of the important factors for the factory establishment by Väderstad Verken would give the company a better understanding of this process. Further, analysis of suitable location for the factory would give an understanding for management on that how different location factors could effect the final choice of the factory location.

Below is a short summary of the most important activities during the project:
- Identify important factors for the factory start-up.
- Analyse how the identified factors effect the choice of the suitable area for the factory location.
- Create a specification of the future factory.
- Compare total cost of a machine produced at Väderstad and in Eastern Europe.
4 PROJECT LIMITATIONS

The limitations of the project are presented below.

- We would analyse the optimal location of the future factory only in two countries – Russia and Ukraine.
- The future factory is expected to supply markets in only three countries.
- The location of potential suppliers will not be taken into consideration when analysing the optimal location.
- Optimal location for a factory would be analysed only at the level of macro-region selection and will not include selection of a specific site due to time constraints.
5 THEORETICAL BACKGROUND AND SOLUTIONS METHODS

5.1 Introduction

In the current dynamic environment in which change is the only constant, businesses must analyse the production network. Hence companies must be flexible in order to respond in a timely manner to this dynamic environment. A company may start looking for a new facility location to meet one, several, or multitude of requirements. Among most common requirements, Hack (1999) lists the need for expanded capacity for the development of new products, new markets, or the additional production capacity to satisfy existing markets. In some cases, a new location also may be required to place modernised production equipment, or to obtain higher efficiency and decrease operating costs that exist in the present outdated facility. Other reasons for changing location include taking advantage of unexploited supplies of raw materials or to get out of high labour cost regions. No matter what are the reasons behind the decision to build a new facility, most location studies involve the same critical factors. Consequently, management must have a well-defined plan for its overall location analysis program.

5.2 Manufacturing Location Decisions

Both Schmenner (1982) and Hack (1999) agree on that manufacturing location decision should be subdivided into the following five major steps which are represented below in Figure 1:

![Figure 1: Steps in Manufacturing Location Decisions](chart.png)

Step 1: Evaluating the Production Capacity

Potential production shortfalls could be revealed in various ways and they significantly vary from corporation to corporation. Schmenner (1982) gives an example of that some large US corporations have implemented some formal planning system; one of the system’s purposes is to reveal possible shortfalls or surpluses. In order for the management to realize the first three above-mentioned steps, Hack (1999) recommends implementing a corporate strategic planning procedure. The strategic plan should include several years, usually five, and describe the chronological growth of the company. The plan should be consulted with and included into any location process as an intricate part. This plan will often reveal many issues that might be ignored in the suggested expansion or relocation process.

Step 2: Expansion or a New Facility

Rather often, the process for identifying the need for a higher production capacity commences when management reveals a discrepancy when comparing production capacity to production goals and sales forecasts. Hence, if it is revealed that forecasts exceed production capacity, the
management has to evaluate different ways to reach the desired capacity in order to stay competitive.

Capacity shortfalls can be met in several ways. The short-term measures to meet the demand can include modification in workforce levels, overtime, additional shifts, inventory policies, modifications in production control, subcontracting, and planned backlogs. Long-term measures – additional floor space, fundamental changes in production technology or process management, and the like.

There are several factors that can effect the decision on whether to expand existing facilities or whether to construct a new factory. Typically, the first option for consideration is whether to expand existing facilities. Only if there are some limitations to or problems with the on-site expansion, management begins to consider start-up of a new factory or relocation of an existing one.

Schmenner (1982) points out that, generally, starting a new factory is favoured if problems obvious at the existing factory include product proliferation, workforce size, and meeting anticipated growth. He also mentions that the company which wants to avoid disorder as the result of too many products in process, or to side-step possible workforce unionization, job bumping, depersonalization in the quality of work life, and so on, or to get a grip of rapid growth through careful management of multi-plant strategy, frequently prefers opening a new factory to expansion. A new factory can take advantage of the latest production technology and the most suitable plant design.

Step 3: Establish Facility Specification

If management decided to build a new factory instead of the on-site expansion, a new suitable location must be found. Before proceeding with the search of a new location it is necessary to create a specification of the future facility. The main determinants of the size and layout of the proposed new facility are the operations that will be carried out at the factory and equipment that will be used during those operations. Thus, based on management’s goals and future plans, specifications for the new facility could be defined.

These specifications are usually stated in great detail. Among the most important specifications, Hack (1999) lists required area of the land plot, the utility requirements, transportation requirements for materials and personnel, waste disposal, water, and utility requirements. The list could be extended with additional factors that are unique to the operation of the proposed new facility.

Facility specification should define what the plant is intended to do. Schmenner (1982) specifies features that should be planned for in start-up, such as:

- products manufactured and output goals for the initial start-up period and beyond;
- plant size and configuration;
- equipment to be used and flow pattern of product within the plant;
- number of workers, sex and age, and skill levels required, in the initial months and as the plant is broken in during the first few years;
- labour training that is required to meet the workforce goals;
- stance toward the adoption of quality of worklife programs, from cross-training to job enlargement to team concepts;
- production scheduling and control systems to be employed;
• how the plant must interact with other plants and/or warehouses, including supplies or products shipped, modes used, personnel borrowed for troubleshooting, and the like;
• overhead functions such as new product engineering, major raw materials purchasing, direct receipt of customer orders, industrial engineering. Which of these will the plant be responsible for, and which functions it can and cannot expect to take over as it grows;
• how the new plant will be expanded subsequently and what will trigger that expansion (sales goals met, new products introduced);
• what it would take to close the plant.”

In order to describe some of the above-mentioned features necessary to create a plant specification a good start would be to identify future plant capacity since it can help in estimating the number of required workers at the factory.

The foundation for estimating long-term capacity needs is forecasts of demand, productivity, competition, and technological changes that extend well into the future. Unfortunately, the farther you look the more chance you have of making an inaccurate forecast.

The demand forecast has to be converted to a number that can be compared directly with the capacity measure being used. Suppose that capacity is expressed as the number of available machines at an operation. When just one product (service) is being processed, the number of machines required, \( M \), is

\[
\text{Number of machines required} = \frac{\text{Processing hours required for year's demand}}{\text{Hours available from one machine per year, after deducting desired cushion}}
\]

\[
M = \frac{D \times p}{N \times (1 - (C/100))}
\]

Formula 1: Capacity Calculation (Krajewski et al., 2002)

where
- \( D \) = number of units (customers) forecast per year
- \( p \) = processing time (in hours per unit or customers)
- \( N \) = total number of hours per year during which the process operates
- \( C \) = desired capacity cushion

The processing time, \( p \), in the numerator depends on the process and methods selected to do the work. Estimates of \( p \) come from established work standards. The dominator is the total number of hours, \( N \), available for the year, multiplied by a proportion that accounts for the desired capacity cushion, \( C \).

Once the number of workers required to perform operations has been identified it is possible to proceed with developing a facility layout. Plant size and layout depends on the products to be produced and operations to be performed at the new factory. There are three general types of layout for a facility: fixed position, process, and product. They are shown in Figure 2. Hybrid methods such as the cellular and modular layouts are becoming rather popular, however, they will not be discussed in this paper. Type of industry significantly influences the final choice of a particular layout.
Stonebraker et al. (1994) define fixed position layout as the layout in which the location of a product or customer is unchanging and materials, equipment and workers are moved to and from the product or customer. This type of layout is typical for industries where the products are very massive or heavy, and it is difficult to move the product. Common examples are shipbuilding, aircraft assembly, rockets, oil drilling, and most construction projects.

In a process, machines with similar functions are positioned together. This type of layout is applied when the volume of the products to be manufactured is not big enough to justify product or cellular layout. The products or customers do not flow according to some predetermined pattern. Some examples of this layout could be found in hospitals, universities, automobile repair shops, tailor shops, department stores, etc.

According to Nahmias (1997) in the product layout, often referred to as production or assembly line, machines are arranged to follow the sequence of operation necessary to manufacture the product. This type of layout is most desirable for high-volume production with standardised products or services. Manufacturing examples are automobile assembly and small appliances assembly.

The more carefully and accurately a company considers how a new plant will be utilised and modified over the years in response to various changes, the better able it will be to design the plant and its manufacturing systems especially for such changes. The plant then will be better
adjusted to the company’s requirements at every point in its useful life. A template which could be used for preparing facility specification is included into Appendix A. For example, defining electricity and water requirements at the future factory is rather critical since access to them could affect the final choice of the location due to that access to power supply could be problematic and expensive both in Russia and Ukraine.

It might be beneficial to include in the project group of people with various expertises, for example, from personnel or marketing departments. In this way more aspects would be taken into consideration during the search of optimal location. This would also ensure that a wider range of expertise and interests is incorporated into the analysis since differences in the importance of the criteria relative to one another can change the results.

**Step 4: Identify Key Location Factors**

The final decision on site selection for a new facility is greatly influenced by the location factors that have been selected and evaluated, as well as by their influence on corporate objectives and operations. There are rather many location factors that have an impact on the final location choice. The extent to which these factors impact the location decision depends on the industry a company is working in. Additionally, the importance of factors varies greatly depending on the stage of the selection process. For example, the importance of factors for selecting certain region differs considerably from those influencing the selection of an individual site.

The location factors could also be addressed not only based on the uniqueness of industry type, but also based on facility type and product life-cycle stage. For example, for labour intensive industries labour related factors such as labour availability, productivity and salary rate are of major importance, whereas for high-tech industries factors that attract highly skilled labour force such as quality of life are of primary importance. The priority of factors for locating a new production facility would differ from that of locating a warehouse. As for the product lifecycle stages, during the product development stage, facilities are rather often located in major science centres where the high cost of facilities is justified by the timely introduction of new products. In contrast, after product reaches the growth stage, it is preferred to locate facilities in proximity to main markets to reduce transportation costs and delivery time.

The priority of location factors also differs at various stages of decision making process. At the beginning of the selection process only few critical factors, such as proximity to customers, availability of labour or quality of infrastructure are taken into consideration. At the stage of selecting specific site, such factors as land price and availability or quality of utilities may have the major influence.

Location factors could also be divided into quantitative and qualitative categories. Jiaqin (1997) defines quantitative factors as those that can be measured in numerical values, such as the average monthly salary or transportation costs. Qualitative factors, such as attitude towards foreign investment, quality of life or business climate, cannot readily be expressed in numerical terms and evaluated by quantitative models. Location selection decisions become more complex when qualitative factors are considered, because subjective judgments must then be adopted.
Many empirical studies and extensive research have been conducted on the relative importance of the various location factors. MacCarthy et al (2003) report findings of a Delphi study on factors affecting international plant location decisions. During the study they analyzed the importance of 13 major factors for international location decisions which are displayed in Table 1. Cost was ranked highest, followed by infrastructure, labour characteristics, government and political factors, and economic factors. The study also showed that the ratings for the top four factors were very close to one another and all were rated relatively high. The two factors which were given the lowest priority were proximity to parent company’s facilities and proximity to competition. Further on MacCarthy et al (2003) investigated the importance of major sub-factors and identified the top ten sub-factors that may strongly influence international location decisions: quality of labour force, existence of modes of transportation, quality and reliability of modes of transportation, availability of labour force, quality and reliability of utilities, wage rates, motivation of workers, telecommunication systems, record of government stability, and industrial relations laws. Additionally, it was mentioned during the study that the importance of factors and sub-factors can vary by geographical region and type of industry, hence, every company should develop own set of priorities.

Table 1: Key Factors Affecting International Location Decisions (MacCarthy et al, 2003)

According to Jiaqin (1997) five primary location factors include: location in relation to markets, material sources, transportation cost and services, availability and cost of utilities, and availability and cost of labour. In his opinion these primary factors often play the major role in determining the general search area, while other secondary factors help to determine a specific site location.

Hack (1999) discusses in great detail various location factors typically important in site selection process and provides information on data sources.

Schmenner (1982) provides an extensive checklist of factors which should be considered by manufacturing location decision makers. The checklist would be most useful for the stage of location search when suitable sites are identified. He also suggests dividing further the listed
factors into “musts” and “wants”. Under “musts” Schmenner (1982) implies those factors which are crucial for the site location, whereas “wants” could also be taken into consideration.

In addition to the extensive checklist of important factors for site selection, Schmenner (1982) points out two considerations that are neglected sometimes during the selection process but which could have a big impact on the final decision. The first consideration is the attractiveness of the new factory location for managers and engineers. During the selection process the primary focus is on costs, labour availability, infrastructure and the like, however, the attractiveness for living in an area is sometimes ignored or taken for granted. So a company can end up in a situation when it is increasingly difficult to persuade managers or engineers to move there. This problem is most often faced by companies moving into small towns.

The second consideration is movement of people and material between facilities. Rather often the cost of interplant movement is ignored during the selection process. This can lead to higher logistics costs or more time spent travelling between plants. As the result, the amount of frequency of travel made to an inconveniently located facility can reduce and it will be left to operate without proper support from the head office or main plant. However, those companies that do take into consideration executive/engineer travel time insist on locating the new facility in the proximity to the airport which has frequent flights to the head office or main plant.

**Step 5: Site Selection**

The previous paragraph shows that the amount of location factors that should be analysed could be overwhelming and different levels of site selection decisions are dominated by structurally different types of location factors. In order to simplify the complexity of location problem it is common to decompose it into several stages.

Many studies have been conducted to identify the necessary extent of location problem decomposition. Hack (1999), Vinh (2005), MacCormack(1994), Schmenner (1982), Hubner (2007), MacCarthy et al (1995) and Jiaqin (1997) mention in their works that problem should be broken down into three or four major levels. These levels are graphically summarised in Figure 3, which also shows major location factors relevant for each level.
At the level of selecting a country such factors as market potential, transportation costs, infrastructure and labour can dominate the decision. Selection of a community and physical site are mainly determined by quantitative factors such as site infrastructure and openness of local authorities, and to a certain extent local cost differences and site-specific investment requirements also effect the decision. As the site search proceeds, the number of alternatives is becoming smaller whereas level of detail about each alternative is increasing.

The amount of major steps for analysis depends on the area that the company is considering for site location. For example, if a company is considering a plant construction for its global operations that at first it will have to identify an economic region such as Eastern Europe, Western Europe, Asia-Pacific, or the like. However, if the company is planning to build a new factory in order to serve the domestic market, then it is possible to skip the first stage and start with the identification of macro-region.

Hack (1999) mentions that many location analyses do not require all major phases described in Figure 3 because the choice of the region, state or even community may be predetermined or based on many obvious factors.

5.3 Defining general area of search

The first stage of site selection is to define a general area of search. Size of this area maybe as large as an entire economic region, such as Middle East or Western Europe, or it may be as small as a few square kilometres or a single metropolitan area. Therefore, the more narrowly defined is the search area before beginning any field investigations, the more beneficial it is for the company because it can save both time and resources.
There is no rule of thumb for deciding on the optimum size of the general search area to be studied. According to Hack (1999) the following characteristics of the individual company would effect the size that should be investigated:

- the company’s markets and where their sources of supply are located;
- which costs are geographically variable, and to what extent;
- and whether or not there are any unusual community or site requirements which could eliminate many areas, and so on.

Hack (1999) recommends using Center of gravity approach (which would be described later in the paper) or least-cost distribution point method to identify the general area of search.

As it was previously mentioned, Schmenner (1982) recommends creating a list of factors, “musts” list, which are critical for site selection. He also suggests that this list should be used as the standard against which alternatives for general area of search are evaluated. The list of possible factors at this stage is represented in Table 2.

<table>
<thead>
<tr>
<th>Major factors for selection of general search area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location in relation to markets</td>
</tr>
<tr>
<td>Location in relation to material sources</td>
</tr>
<tr>
<td>Transportation cost</td>
</tr>
<tr>
<td>Availability and cost of utilities</td>
</tr>
</tbody>
</table>

Table 2: Major Factors for the Selection of Economic Area/Macro-Region (Hack, 1999)

By weighing the known characteristics of particular alternatives against this list, those alternatives which are appropriate for the location of the proposed facility can be detected and supported. For example, if market potential is vital and 55% of the market growth is forecasted to be concentrated in Eastern Europe with the remaining 45% spread out over the rest of the world, it is more logical for the company to search for a new location in Eastern Europe.

The market factor is usually of primary importance in the location process. However, it should not be assumed that the principal factors will be the only determinants in the selection of the general search area. A number of secondary considerations may enter into process.

In addition to academic publications, publications directed primarily at practitioners faced with location decisions are available. Hack (1999) provides a comprehensive step-by-step approach to site selection. He proposes a planning process including an evaluation process based on a simple scoring model. Additionally, the appendix contains several checklists and survey questionnaires. Based on comprehensive empirical analysis Schmenner (1982) provides guidance on how to conduct location decisions for industry but also gives advice to states and localities on how to attract industry.

5.4 Selecting communities

After the optimal general search area is determined, it is possible to proceed with the site selection of communities within that area. The procedures and methods for the selection of communities will vary from one company to another. Hack (1999) lists common steps for selecting a community:

- put together a list of communities in the search area;
- find data on location factors for each community;
• eliminate communities obviously not suited;
• investigate and evaluate remaining candidate communities;
• select three or four final candidate communities that meet company’s requirements.

The next step would be a more detailed analysis and examination of individual communities in the area of search that were previously identified. The basic objective in any location process is to select the specific community that will either maximize profits and/or minimize the cost of the product delivered to customers.

The choice of the final candidate communities for the location of a new factory can be effected by many different economic factors. It is impossible to create a single list of factors which would fit all situations. The factors which enter into this choice and their importance will vary from one company to another. Nevertheless, Hack (1999) proposes a list of some factors which could be applicable to many situations and businesses. These factors are listed in Table 3.

<table>
<thead>
<tr>
<th>Community location factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local labor supply</td>
</tr>
<tr>
<td>Local labor costs</td>
</tr>
<tr>
<td>Labor management relations</td>
</tr>
<tr>
<td>Labor training programs</td>
</tr>
<tr>
<td>Transportation facilities and services</td>
</tr>
<tr>
<td>Cost and reliability of electric power</td>
</tr>
<tr>
<td>State and local taxes</td>
</tr>
<tr>
<td>Telecommunication services</td>
</tr>
<tr>
<td>Adequacy of streets and highways</td>
</tr>
<tr>
<td>Police protection</td>
</tr>
<tr>
<td>Fire protection</td>
</tr>
<tr>
<td>Recreation, parks, and civic facilities</td>
</tr>
<tr>
<td>Natural gas cost and service</td>
</tr>
<tr>
<td>Cost and reliability of water service</td>
</tr>
<tr>
<td>Adequacy of sewer system</td>
</tr>
<tr>
<td>Waste disposal</td>
</tr>
<tr>
<td>Health and medical services and facilities</td>
</tr>
</tbody>
</table>

Table 3: Major Factors for the Selection of Community (Hack, 1999)

The information about each community on every factor should be gathered with great care because it is critical for the evaluation process.

Hack (1999) recommends reducing the number of alternative communities through a preliminary screening which could be conducted in the company’s office with the help of published statistics. The number of qualifying communities could be significantly reduced if a company has location requirements of an unusual nature, for example, the need to locate near a university which offers certain type of degree; stable electricity supply; proximity to sea or river ports, etc.

5.5 Identifying sites

After several candidate communities have been identified, it is necessary to proceed with finding specific sites within those communities on which to construct the facility. The number of sites that are thoroughly investigated normally depends on time, cost, and inclination.
Schmenner (1982) advises to analyse thoroughly not more than 25 sites. He also mentions that it is common to have less than 10 sites for detailed evaluation. The list of particular sites within the communities could be refined through contacts with local development agencies, industrial realtors, developers, or similar people.

After filtering out unsuitable sites and identifying the most promising ones, it is possible to investigate the remaining sites even deeper. This would normally require putting together even more data about these sites, checking it, and combining it into a form which can be used to compare one site against another. Additionally, at this point in the process, site visits are usually made. Since quite much data is already available for each candidate location, the site visit is mainly a way to collect qualitative and subjective information and impressions about each location and to verify the data already collected.

Hack (1999) points out that there is a large amount of overlap for factors influencing the choice of a community and those used for the evaluation and selection of a site. Some factors are relevant mainly for choosing a physical site, whereas others are used in different ways, depending on whether a site or a community is being evaluated. The list of typical factors for site selection is presented in Table 4.

<table>
<thead>
<tr>
<th>Factors of site investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size and shape of site</td>
</tr>
<tr>
<td>Topographic considerations</td>
</tr>
<tr>
<td>Availability and cost of utilities</td>
</tr>
<tr>
<td>Water supply</td>
</tr>
<tr>
<td>Sewer facilities</td>
</tr>
<tr>
<td>Drainage and flooding</td>
</tr>
<tr>
<td>Soil conditions</td>
</tr>
<tr>
<td>Cost of development</td>
</tr>
<tr>
<td>Location in community</td>
</tr>
<tr>
<td>Transportation facilities</td>
</tr>
<tr>
<td>Fire and police protection</td>
</tr>
<tr>
<td>Taxes and insurance</td>
</tr>
<tr>
<td>Zoning and other legal aspects</td>
</tr>
<tr>
<td>Suitability of existing building</td>
</tr>
<tr>
<td>Land costs and options</td>
</tr>
</tbody>
</table>

Table 4: Major Factors for the Location of Site (Hack, 1999)

Usually one or two sites will be found in a community that meets the company’s requirements. The number of potential sites should be reduced even further, to a first choice and an alternate. Hack (1999) summarises all steps for the evaluation of alternative sites in the following way:
- review the site requirements and identify the primary and secondary characteristics;
- find information on each requirement;
- evaluate the data for sites, determining where additional information is needed;
- remove from the list sites that do not meet preliminary screening requirements;
- make a second visit to the remaining sites to check specific problems and/or to address any questions;
- review and evaluate all information, then select two or three sites that best meet the company’s needs;
- obtain options on selected sites.
As the result, the number of potential sites is narrowed down to a first choice and an alternative.

5.6 Final report

The recommendations and the final report to management normally conclude the site selection process. The final report should include information on the selection and recommendation of the communities and sites that best meet the company’s requirements.

5.7 Evaluation of alternatives

Once all important factors for site selection have been identified, it is necessary to analyse them in some way. The analysis process could be complicated by that some factors are of qualitative nature while others are of quantitative. Additionally, some factors are of higher importance than others and this difference should also be taken into consideration during the analysis process.

Various location decision models have been developed to conduct comparative evaluation of potential location sites through examining related location factors and site requirements. In addition to traditional mathematical models (e.g. mixed integer programming and decision analysis), new solution methodologies have been applied in recent facility location research. Evaluation methods applied in the context of site selection can be generally grouped into optimization, Multiple Criteria Decision Analyses (MCDA), simulation and investment appraisal calculations. The suitability of these methods can depend on the stage of site selection, type of location factors (i.e. quantitative or qualitative), number of facilities under consideration, time horizon, etc.

In a word, the techniques used in the determination of the area of search are as numerous as there are location studies. However, as Jiaqin (1997) mentions, there are also limitations in the current location decision model literature. First, there are very few examples of application-oriented solution procedures that are convenient to handle large real-world problems. Second, the majority of reported location decision models do not take into consideration qualitative factors which could be critical for the location selection, especially at the site selection level. Finally, most reported location decision models are deterministic in nature and thus lack the dynamic solution capability necessary to deal with the fast changes in today’s location decision problems. In particular, the present location decision model literature lacks a framework that can present and structure all related location factors (both quantitative and qualitative) into a solution model and analyze these location factors with specific site requirements.

In this chapter I am going to present the techniques which in my opinion are both practical and comprehensive for the site selection. In particular, I am going to consider more thoroughly such location analysis methods as center of gravity technique, some economic models, simple additive weighting, simple scoring, fuzzy logic, and Analytic Hierarchy Process (AHP). Some of these methods are more applicable at a particular location analysis stage, for example, center of gravity technique is most suitable for identifying general search area and economic models could be used to compare particular sites. Other methods such as fuzzy logic or AHP could be applied at all levels. The strengths and weaknesses of all models are analysed as well.
5.7.1 The centre of gravity technique

The centre of gravity approach, sometimes referred to as centre of market approach, is rather common to use methods that analyse transportation costs and services in order to identify the general search area. The result of such an analysis could be either the geographic centre of distribution or the point at which transportation costs would be minimized. The group in charge of location selection process should investigate the cost of both inbound and outbound transportation, with some companies limiting their analysis to market distribution only. The latter situation usually is rather typical when shipment tariffs and total transportation costs are considerably higher for the final product than for the raw materials and components that are used to manufacture it.

This approach is rather valuable tool. However, companies using this simple technique in the identification of a general location should do it with care since the technique is intended as a rough guide rather than a precise tool.

The process of determining the center of gravity could be broken down into the following steps.

1. On a map draw a graph-type grid of an arbitrary scale. Place existing and/or future destinations of outbound and/or inbound transportation on a coordinate grid.
2. Prepare a table that has columns for (1) city/town name; (2) $x$-coordinates of a location on a map; (3) $y$-coordinates of a location on a map; (4) tonnage weights/quantity of shipments; (5) $x$ units multiplied by tonnage weights; and (6) $y$ units multiplied by the tonnage weights. Input relevant data into the corresponding column.
3. Based on the information provided for every location point, calculate the centre of gravity. The centre of gravity’s $x$-coordinate, denoted $x^*$, is found by multiplying each point’s $x$-coordinate ($x_i$) by its load ($l_i$), summing these products ($\sum x_i l_i$), and then dividing by the sum of loads ($\sum l_i$). The $y$-coordinate, denoted $y^*$, is found the same way, with the $y$-coordinates used in the numerator. The formulas are

$$x^* = \frac{\sum_i x_i l_i}{\sum_i l_i}, \quad y^* = \frac{\sum_i y_i l_i}{\sum_i l_i}$$

4. At this point locate the “optimal” distribution point on the map using weighted average $x$ and $y$ coordinates obtained in the 3rd step.
5. Hack suggests drawing a circle around the “optimal” location point to indicate general area of search. The size of such circle can vary, but in most cases a radius of 200 kilometres is appropriate. However, a smaller or larger area of search can be identified, depending on the amount of territory the location team believes it must explore in order to find the community that meets all of the company’s specifications.

**Strengths**

- Krajewski (2002) notes that the location point obtained though center of gravity approach is not the optimal one for the Euclidean or rectilinear distance measures, but it could be anyway an excellent starting point.
- It is a simple method which does not require additional training.
The technique assumes cost is directly proportional to distance and volume shipped. In its simplest form, this method assumes that inbound and outbound transportation costs are equal, and does not include special shipping costs for less than full load. The centre of gravity method of location planning is accurate only when the quantities to be shipped to each location are equal.

5.7.2 Economic models

Some location problems could be solved by using traditional economic models such as payback, rate of return and benefit/cost ratio. These models are most applicable at the site selection stage because mainly at that level cost and benefits associated with each site could be identified.

**Payback period**

The payback method is commonly used to determine the relative attractiveness of investment at each site. The goal of this technique is to calculate how many periods are required to return an initial investment, that is cumulative benefits would equal cumulative costs. Costs and benefits are normally expressed as cash flows or discounted present values of cash flows. Once it has been determined for all site alternatives under consideration, a comparison is made on the basis of corresponding payback periods. The smaller the payback (period), the more preferred is the site.

Geng (2004) provides the following formula for the calculation of (undiscounted) payback of value \( N^* \):

\[
P = \sum_{j=1}^{N^*} A_j
\]

where \( P \) is the initial investment and \( A_j \) is the cash flow in period \( j \). Discounted payback, which is used less often, is calculated as follows:

\[
P = \sum_{j=1}^{N^*} A_j (1 + i)^{-j}
\]

**Strengths**

- Payback is a useful tool to obtain some indication of how long time it might take to recover the initial investment. It is a helpful supplementary measure of the attractiveness of the investment, but it should never be used as the sole measure of quality.

**Criticism**

- The main drawback of the payback is that all cash flow beyond the end of the payback periods is ignored.

**Rate of return method**

The internal rate of return (IRR), or the rate of return (RoR), is the interest rate \( i^* \) at which the present value of all expenditures are equal to the present value of all earnings. One mathematical definition of the IRR, given by Geng (2004), is the rate \( i^* \) that satisfies the equation

\[
\sum_{j=0}^{N} A_j (1 + i^*)^{-j} = 0
\]
This formula assumes discrete cash flows $A_j$ and end-of-period discounting in periods $j = 1, 2, \ldots, N$.

The discount rate used in present value calculation is the opportunity cost – a measure of the return that could be earned on capital if it were invested in other projects. Thus a given site candidate should be economically attractive if and only if its IRR exceeds the cost of opportunities forgone as measured by the firm’s minimum attractive rate of return (MARR).

Geng (2004) notes that mutually exclusive projects may not be rank-ordered on the basis of their respective IRRs. Rather, an incremental procedure must be implemented. That is, alternatives must be compared pairwise, with decisions made about the attractiveness of each increment of investment.

**Benefit/cost ratio**

In the benefit-cost ratio method present value of benefits and present value of costs are calculated and compared. An investment is justified only if the benefits $B$ resulting from it exceed the resulting cost $C$. Obviously, all benefits and costs must be expressed in equivalent terms, measured at the same point(s) in time. Geng (2004) mentions that usually, both benefits and costs are expressed stated as “present value” or are “annualized” by using compound interest factors as appropriate. Thus,

$$B : C = \frac{\text{PW (or AW) of all "benefits"}}{\text{PW (or AW) of all "cost"}}$$

The site that has the highest ratio should be selected. However, Geng (2004) warns that like the rate of return method, the proper use of the benefit-cost ratio method requires incremental analysis. Mutually exclusive alternatives should not be rank-ordered on the basis of benefit-cost ratios. Pairwise comparisons are necessary to test whether increments of costs are justified by increments of benefits.

Even though these methods are simple and practical to use, however they have some drawbacks when it comes to comparing various location alternatives. The major drawback of these economic models is that they take into consideration only factors which could be measured in terms of money. However, some important qualitative factors, such as proximity to highway or attitude of the local authorities, are ignored even though they could be rather critical for the location decision. The solution for this drawback could be to apply economic models together with some other models (further described in this paper) which take into consideration qualitative factors.

**5.7.3 MCDA Methods**

As it was previously discussed the number and diversity of sometimes conflicting location factors that have to be considered when selecting production site could be overwhelming. This situation makes obvious the need to apply a systematic decision support tool. Studies in the subject of Multiple Criteria Decision Analysis (MCDA) aim at providing tools that guide decision makers in identifying their most preferred solution to such a decision problem. Hubner (2007) notes that the evaluation of potential sites is part of Multiple Attribute Decision Analysis (MADA), which is one of the two types of multiple criteria decision
situations. In this paper we are going to cover several MADA methods: simple additive weighting, fuzzy logic, and analytic hierarchy process.

**Simple additive weighting and simple scoring**

Simple additive weighting and simple scoring are probably the most widespread MADA methods in practice. Application of simple additive weighting/simple scoring requires five steps which are shown in Figure 4:

![Figure 4: Simple Additive Weighting/Simple Scoring Steps](image)

The two methods only differ in the third step. Simple scoring uses a standardized interval scale (e.g., 0-100) for evaluation of all objectives. At first decision makers rate each of the major factors from 0 to 100 relative to its importance, and then they directly rate the performance of each individual location with respect to each factor on this scale. Simple additive weighting, on the other hand, uses direct rating on a standardized scale only in case of purely qualitative attributes. For numerical attributes scores are calculated by normalizing observed attribute values to match the standardized scale.

<table>
<thead>
<tr>
<th>Location factor</th>
<th>Weight</th>
<th>Location X</th>
<th>Location Y</th>
<th>Location Z</th>
<th>Weight x Factor score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to market</td>
<td>40</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>360 400 320</td>
</tr>
<tr>
<td>Availability of labour</td>
<td>30</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>150 240 300</td>
</tr>
<tr>
<td>Proximity to suppliers</td>
<td>20</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>120 180 180</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>8</td>
<td>100 70 80</td>
</tr>
<tr>
<td><strong>Total weighted score</strong></td>
<td>730</td>
<td>890</td>
<td>880</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Simple Additive Weighting

Location Y in Table 5 has the highest total weighted score and therefore should be selected. However, in this example two best sites, locations Y and Z, have rather small difference in scores (10 points) so it might be necessary to have further investigation. For example, additional location factors could be included for further evaluation of these two sites.

Alternatives could be compared using two different types of scales: local and global. Hubner (2007) describes that a local scale is outlined with the best and worst existing alternatives forming the reference point for the bounds of the scale while a global scale is outlined relative to absolute values for the best and worst performance. He points out that local scales are easier to express whereas global scales allow the decision maker to define objective weights independent of observed attribute values.

It is obvious that the scoring received by this method is largely subjective because when the factors are evaluated, they express a decision maker’s feelings that are measured in terms of assigned weights. It is quite possible that different decision makers might choose varying scores for the same physical conditions, leading to entirely different site selections. To avoid
such variations in judgment Sule (2001) recommends using certain minimum requirements to eliminate non-qualifying location and then apply economic models for the comparison of remaining sites. He claims that it is possible to apply economic models because most factors such as land, labour, utility, and taxes could be quantified in monetary terms.

Hubner (2007) mentions another extension to the basic model. He suggests constructing an explicit value function to convert observed attributes into preferences values, instead of directly scoring alternatives on a normalized scale or assuming a linear correlation between attribute values and decision makers’ preferences.

**Strengths**
- The key advantages of simple weighting/scoring are simplicity of application and understandability. The rating procedure requires numerical rating values as an input from the evaluators and then a simple sum or arithmetic mean is all that is needed for assigning the final ranking.
- No previous training is required to conduct the decision making process. A decision-maker can simply use personal judgment and the knowledge of the problem to come to a conclusion.
- The evaluation itself does not require special software packages but can be performed with standard spreadsheet software.

**Criticism**
- The scoring rating model is rather basic and subjective and can solve only those problems that are direct and simple.
- The method can not accurately measure the relations between factors, if there are too many subjective factors involved.
- It is not possible to perform consistency check on the decision maker’s inputs. The ability to check consistency is especially critical if there is more than one decision maker involved in the scoring process.
- Sometimes, there might be some outliers in ranking, and such judgment might be critical. In this method, there is no means to include or measure these outliers because only the mean value is of importance.

Besides the general criticism of additive aggregation models Hubner (2007) mentions that the most criticized aspects about these simple methods are the fact that the direct scoring of alternatives and direct estimation of weights often lead to results that lack an argumentative justification and the resulting preference values lack an economic interpretation.

**Fuzzy logic**
Location analysis could also be conducted with the help of fuzzy set theory. As it was previously described many factors should be analysed when selecting a location for a new facility. Sule (2001) divides these factors into three classes: critical, objective, and subjective. The factors that each location must meet for further evaluation belong to the critical criteria. The objective factors can be expressed in monetary terms such as the investment cost, labour cost, and land cost. The subjective factors such as, for example, climatic conditions and availability of skilled labour, are qualitative.

It is not difficult to evaluate objective factors since they can be easily expressed in terms of numbers. Subjective factors, on the other hand, are expressed in qualitative terms and hence
they are more difficult to analyse. It is possible to convert these qualitative evaluations into quantitative ones using the fuzzy set theory. After the conversion it is possible to evaluate the contributions of the subjective factors in an effective way.

Sule (2001) notes that the subjective criteria are generally expressed in terms of “very low”, “low”, “good”, “very good”, “medium”, “high”, and the like. With the fuzzy set theory, these are converted to quantifiable evaluations that generally take a triangle or a trapezoidal shape with different weights, which are provided in Figure 1 and Table 6.

For example, from Table 6, “high rating” has 0-0.5 weight in decision making. So if four payoff values for the high rating are 600, 650, 700, and 850 then in trapezoidal terms it is interpreted as, high of 600 with the weight of 0.5, first midpoint of 650 with the weight of 0.7, the second midpoint with the payoff 700 with the weight of 0.7, and the maximum payoff of 850 with the weight of 1. It is easy to interpret the trapezoidal fuzzy set numbers. For example, “approximately equal to $600” may be represented as (595, 600, 600, 605), “approximately between $600 and $650” may be represented as (595, 600, 650, 655), and the non-fuzzy numbers such as $700 can be represented as (700, 700, 700, 700). Thus, in linguistic description, each attribute – such as “high rating” – has a four-point trapezoidal distribution. The weight distribution is 0.5, 0.7, 0.7, and 1. A composite trapezoidal distribution should be developed for all subjective factors.

In applying the fuzzy logic technique, the first step is to divide the criteria (denoted by \( C_i \)) into subjective and objective categories. The next step is to assign weight: very high (VH),
high (H), medium (M), low (L), or very low (VL) to each site criteria. If there is more than one decision maker involved then each decision maker (denoted by D1, D2, D3, and D4) is asked to assign a linguistic rating to each factor, both subjective and objective factors, and to display their subjective and objective factors, and to display their subjective evaluation of importance of each factor. The linguistic rating from each decision maker is aggregated for each criterion.

Next, the decision makers should evaluate each criterion, relative to each possible location. Note that it is possible to give a rating in between two major weights such as BP and VP meaning between poor and very poor. The categories and associated four-point numeric values are shown in Table 7.

<table>
<thead>
<tr>
<th>Linguistic attribute</th>
<th>Numerical weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>(0, 0, 0, 0.2)</td>
</tr>
<tr>
<td>Between low and very low</td>
<td>(0, 0.2, 0.2, 0.4)</td>
</tr>
<tr>
<td>Low</td>
<td>(0, 0.2, 0.2, 0.4)</td>
</tr>
<tr>
<td>Between medium and low</td>
<td>(0, 0.2, 0.5, 0.7)</td>
</tr>
<tr>
<td>Medium</td>
<td>(0.3, 0.5, 0.5, 0.7)</td>
</tr>
<tr>
<td>Between high and medium</td>
<td>(0.3, 0.5, 0.8, 1)</td>
</tr>
<tr>
<td>High</td>
<td>(0.6, 0.8, 0.8, 1)</td>
</tr>
<tr>
<td>Between very high and high</td>
<td>(0.6, 0.8, 0.8, 1)</td>
</tr>
<tr>
<td>Very high</td>
<td>(0.8, 1, 1, 1)</td>
</tr>
</tbody>
</table>

Table 7: Weights for the Extended Fuzzy Set Rating (Sule, 2001)

Following the same procedures as before, the lower, mid-two, and upper bound-weight values for each location and for each associated criterion are determined.

The next step should be evaluation of objective criteria such as, for example, cost. It is not necessary to involve decision makers into evaluation of different costs because they could be obtained through market research. Just as we did with the subjective criteria, we should obtain four cost estimates in terms of their numeric value for each site. It is advisable to convert the total cost into a dimensionless form so that the objective criteria becomes consistent with the subjective criteria. The evaluation is needed in terms of cost distribution for each site and comparing the sites with each other. It should be kept in mind that the alternative with the lowest cost should get the highest rating, since the lower the cost the more attractive is the alternative. To accomplish this objective Sule (2001) recommends to converse the data for each site $i$ in the following way.

$$ R_i = \left\{ t_1 \times \left[ t_1^{-1} + t_2^{-1} + \cdots + t_m^{-1} \right]^{-1} \right\} $$

where $t_1, t_2, t_3$ are the cost of factors, 1, 2, 3, each with four estimates, and $t_i$ is the sum of the costs for the factors at appropriate levels.

Since when $R_i$, relative total cost, is calculated we converse each sum in the same way, the relative weights between the sums will not change. However, since the cost should be transformed into relative ranking, the site with the highest cost would get a worse rank than the site with the lower cost. Hence, a random number that is greater than the largest number in the cost distribution is picked and then it is divided by each cost. As the result we will obtain a ranking in which the alternative with the highest value is the best option.
Sule (2001) writes that “to find fuzzy suitability index \( F_i \) for site \( i \) the average of the product of weight for each criterion times the relative weight of that criterion for site \( i \) should be found. This is given by:

\[
F_i = \frac{1}{k} \times \left[ \left( S_{i1} \times w_1 \right) + \left( S_{i2} \times w_2 \right) + \left( S_{i3} \times w_3 \right) + \ldots + \left( S_{in} \times w_n \right) \right]
\]

where \( k \) is the number of factors that are being evaluated”.

Sule (2001) summarizes steps in fuzzy analysis as follows:

1. Identify criteria and candidates for site selection.
2. Select preference ratings for criteria weight.
3. Select preference ratings for alternative sites for both subjective and objective criteria.
4. Chart the weighing of subjective criteria and group them to obtain the aggregate weight, for each criterion.
5. Compute the fuzzy ratings of alternative sites for subjective criteria.
6. Compute the fuzzy ratings of alternative sites for objective criteria.
7. Aggregate the weightings of criteria and fuzzy ratings of alternatives relative to all criteria and obtain the fuzzy suitability indices.
8. Compute the ranking value of each alternative and choose the alternative which obtained the highest rank.

Sule (2001) argues that “fuzzy set theory is capable of handling situations that involve decision criteria that are of an intangible nature. The concepts of fuzzy numbers and logistic variables are used to evaluate objective and sub-objective factors in such a manner that the viewpoints of an entire decision-making body can be expressed without any constraints. The fuzzy set of decision algorithm used for site selection can also be computerised to make the implementation a little easier”.

**Strengths**

- The amount of factors that could be analysed is not limited since the amount of factors does not greatly influence the difficulty of the analysis.
- There are many words that could be used to define the exact rating feeling of an alternative so it gives the decision maker a large range of scales from which to choose the description of subjective criteria.
- The concept of membership sets allows a large amount of information to be represented in a single construct for logical or algebraic manipulation.

**Criticism**

- It is not possible to identify inconsistency in the judgment.
- If there is more than one decision maker involved, the individual inconsistencies would contribute toward the total inconsistency, which is the geometric function of individual consistencies.
- In order to use fuzzy set theory for solving a problem, however simple, it is necessary to have a complete understanding of the theory itself. This overshadows the capability of the theory to solve complex problems, because an evaluator or decision maker must be trained to use this method.
- Even though it is possible to develop an algorithm for the fuzzy set problem and then computerize it, this could be sometimes rather expensive.
The assessment process has to lead to a rank ordering of the alternative sites and a recommendation of where to locate the plant. Once the alternatives have been assessed, again management has to select the preferred site and approve the implementation project.

Analytic Hierarchy Process
The Analytic Hierarchy Process, developed by Saaty, is one of the most widespread MADA tools. Case examples reporting the use of AHP in (plant) location decisions can, for example, be found in Min and Melachrinoudis (1999), Yang and Lee (1997), Kathawala and Gholamnezhad (1987), Yoon and Hwang (1985b) or Wu and Wu (1984).

Jiaqin (1997), Hubner (2007), and Badri (1998) mention that the application of AHP should be conducted at several stages.

Figure 6 represents the major AHP steps that have been described by the aforementioned researchers.

**Figure 6: Major AHP Steps**

Step 1: Hierarchical break-down of the decision problem
The first step of the AHP is to analyze a decision problem by hierarchically breaking it down into several components and identifying the alternatives that are to be evaluated. Hence, the hierarchy would consist of the overall goal, objectives and one or more levels of sub-objectives. The alternatives that will be evaluated are listed at the lowest level of the hierarchy. In order to understand better the overall problem, it is recommended to draw a graphical representation of the hierarchy similar to the one presented in Figure 7 below. The final figure would vary depending on the amount of objectives, sub-objectives and alternatives to be considered. The first level of the hierarchy depicts the overall goal; the second level represents the objectives that would contribute to the achievement of the overall goal, and at the last level each alternative would contribute to each objective in a unique way.
According to Saaty (1980) the maximum amount of elements in a cluster should not be more than 7 because results from psychological tests show that 7+/−2 are the maximum number of elements a person can effectively compare simultaneously.

Step 2: Comparative analysis of objectives and alternatives

Comparative analysis should be conducted in the second step. Forman et al (2001) recommends evaluating the performance of the alternatives with respect to the objectives before evaluating the priorities of the objectives. In his opinion, by applying this “bottom up” approach a decision maker can get a better understanding of the alternatives in case his/her judgments about the importance of the objectives are dependent on the alternatives. Each alternative should be compared against other alternatives with respect to one particular decision objective at a time. Since one assumption of the AHP is that the evaluations are reciprocal and since all elements will always rank equally when compared to themselves, it is required to perform \( \frac{1}{2}n(n-1) \) comparisons to make the full set of pairwise judgments for \( n \) criteria or alternatives. Hence, a typical comparison might look in the following way:

\[
\begin{bmatrix}
1 & 5 & 9 \\
\frac{1}{5} & 1 & 3 \\
\frac{1}{9} & \frac{1}{3} & 1
\end{bmatrix}
\]

Forman et al (2001) mentions that research has shown that pairwise comparison can generate correct, ratio scale priorities from what are basically rough, ordinal judgments, given that redundant judgments are included in the calculations. In his opinion, redundancy helps to minimise the average effect of errors in a manner analogous to the way that taking the average of a sample of measurements will produce an estimate of the mean that is likely to be closer to the true mean than only one judgment (i.e. no redundancy). Table 8 represents a 9-point ratio scale that Saaty has developed for the pairwise comparison.
Table 8: The Fundamental AHP Scale (Saaty, 1996)

Because the highest ration scale is 9, elements to be compared should be from a homogenous group (i.e., be comparable within one order of magnitude). If this is not the case, Forman et al. (2001) recommends reorganising the elements in different groups because the judgments beyond an order of magnitude rather often lead to lower accuracy and higher inconsistency.

Each judgment expresses the ratio of one element compared to another element. When comparing alternatives for objectives that cannot be quantified, i.e. social, psychological, or political, Forman et al. (2001) recommends using the verbal comparison mode. Verbal judgments are easier to make, and for qualitative and value driven comparisons, easier to justify. When making comparison of the factors which could be measured, then it is preferable to use the numerical or graphical comparison modes, though it is not an absolute requirement.

Step 3: Synthesis of priorities
After all elements have been compared, the next step is to synthesise priorities. At this step the priority weights of elements at all levels should be calculated with the help of eigenvector or least square analysis.

The procedure for synthesizing judgments requires quite complex calculations and includes three steps:
1. Calculate the geometric mean of each row in the matrix.
2. Total the geometric means.
3. Normalize each of the geometric means by dividing the total just computed.

This could be clarified by the example presented in Table 9:

<table>
<thead>
<tr>
<th>Intensity of importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>2</td>
<td>Weak</td>
<td>Experience and judgment slightly favor one activity over another</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance</td>
<td>Experience and judgment strongly favor one activity over another</td>
</tr>
<tr>
<td>4</td>
<td>Moderate plus</td>
<td>An activity is favored very strongly over another; its dominance demonstrated in practice</td>
</tr>
<tr>
<td>5</td>
<td>Strong importance</td>
<td>The evidence favoring one activity over another is of the highest possible order of affirmation</td>
</tr>
<tr>
<td>6</td>
<td>Strong plus</td>
<td>The evidence favoring one activity over another is</td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated importance</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Very, very strong</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Example of Synthesizing Judgements (Forman et al., 2001)
The three steps described above should be repeated for each level of the hierarchy until a decision is finally achieved by overall composite weights. The result of the synthesis would be a report, which places the alternatives in relation to the overall goal. This report contains a detailed ranking which presents the performance alternative with respect to each objective.

After synthesis has been completed, it is necessary to reveal inconsistencies in the pairwise comparisons. Inconsistencies could be estimated by applying the following procedure described by Anderson (1997):

1. “Multiply each value in the first column of the pairwise comparison matrix by the relative priority of the first item considered; multiply each value in the second column of the matrix by the relative priority of the second item considered; multiply each value in the third column of the matrix by the relative priority of the third item being considered. Sum the values across the rows to obtain a vector of values labelled “weighted sum”.
2. Divide the elements of the vector of weighted sums obtained in step 1 by the corresponding priority value.
3. Compute the average of the values found in step 2; this average is denoted $\lambda_{\text{max}}$.
4. Compute the consistency index ($CI$), which is defined as

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1}$$

where $n$ = the number of items being compared
5. Compute the consistency ratio ($CR$), which is defined as

$$CR = \frac{CI}{RI}$$

where $RI$, the random index, is the consistency index of a randomly generated pairwise comparison matrix. The $RI$, which depends on the number of elements being compared, takes on the values” given in Table 10:

<table>
<thead>
<tr>
<th>$N$</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$RI$</td>
<td>0,58</td>
<td>0,9</td>
<td>1,12</td>
<td>1,24</td>
<td>1,32</td>
<td>1,41</td>
</tr>
</tbody>
</table>

Table 10: Random Index Values (Anderson, 1997)

Even though it is preferred to achieve absolute consistency during the comparison process, it is not always possible to get it. Nevertheless, a certain level of consistency is required to obtain meaningful results. Badri (1998) states that the acceptable consistency ratio should not exceed 0.10. However, as Forman et al (2001) points out a low inconsistency should not become the main goal of the decision-making process since it is more important to be accurate than consistent.

Step 4: Sensitivity analysis of results
The final step of the AHP is sensitivity analysis. It is important to conduct sensitivity analysis in order to identify how sensitive the obtained preference ranking of the alternatives is to modifications in objective weights. This step is particularly relevant considering the limitations of weight elicitation previously discussed. If during the sensitivity analysis it is revealed that the preference order changes with small weight modifications the weights should be double-checked.
Strengths

Hubner (2007) mentions that the major advantage of AHP is its usefulness and flexibility which is demonstrated by very many practical examples described in literature. Some other strengths of AHP are:

- The application of pairwise comparisons makes easier to evaluate alternatives by focusing on two alternatives or objectives at a time.
- It is possible to check for inconsistencies in judgements because of the redundancy resulting from having more than the minimum number of comparisons.
- The pairwise comparison matrixes require only one-half of the judgment values as input data. The other half is the reciprocal of these inputs. This reduces the work of a decision maker.
- It is possible to evaluate both subjective and objective factors with the help of AHP.
- The application of AHP does not require much training for a decision maker since it is necessary to compare only two factors at a time.
- Another important advantage of the AHP is the availability of the software Expert Choice, which offers not only the basic AHP functionality but also supports a wide range of additional features.

Criticism

Despite the abovementioned strengths, decision analysts have criticized several aspects of AHP. The biggest concern about AHP is the observed phenomenon of rank reversal. The essence of rank reversal is that if an irrelevant alternative is added or removed from the set of alternatives, a reversal of ranks can happen. Jiaqin (1997) lists three steps that have been identified in terms of ranking preservation in order to overcome rank reversal:

1. allow rank to reverse by using the distributive model of the relative measurement approach;
2. preserve rank by using the ideal mode (in case of irrelevant alternatives); and
3. preserve rank absolutely by using the absolute measurement mode.

Moreover, it has been indicated that the rank reversal should no be a problematic issue in practice because it is not very common to come across two alternatives with very similar parameters, or some preventative measures (i.e. grouping similar alternatives) can easily be applied to avoid any rank reversal.

Another criticised aspect of AHP is the eigenvalue method because of its perceived lack of transparency. Hubner (2007) mentions that several researchers have recommended to use logarithmic least squares instead of eigenvalue method. Saaty however strongly opposes changes of such type and defends the eigenvalue method because of the way it deals with inconsistent judgments.

Hubner (2007) indicates that the 9-point scale used in the AHP has been criticized for being bounded, lacking theoretical validation for the verbal equivalents used and especially the ratio scale property. It has been noticed that in real world situations the values between 7 and 9 are used rarely because of perceived lack of difference to the values of 5 and 6. Leskinen (2000) and Pöhönen and Hämäläinen (1998) give examples of alternative ratio scales and their performance compared to the traditional AHP scale. Additionally, Schoner and Wedley (1989) recommend using the magnitude estimation method instead.
**Expert Choice**

Expert Choice is a software for analyzing multi-objective problems and is based on the analytic hierarchy process (AHP) developed by Saaty. According to Fernandez (1996) “Expert Choice Pro helps a decision maker examine and resolve problems involving multiple evaluation criteria. The software uses the AHP methodology to model a decision problem and evaluate the relative desirability of alternatives”.

Expert Choice has a clear interface which allows aids in solving the AHP on a computer. With the software it is possible to generate a graphical representation of the hierarchy in easy and comprehensible way. In addition to providing the overall priorities for the decision alternatives, Expert Choice is capable of performing sensitivity analyses, whereby the decision maker can begin to learn how the overall priorities for the decision alternatives are affected by changes in the preference input data.

Expert Choice will be further described in the applied part of this paper. For more description on various functions of the software and its application consult Fernandez (1996), Anderson (1997), Kotter, and Forman et al (2001).
6 EMPIRICAL STUDY

In order to get some practical experience the company was interested in interviewing some international companies who already have production operations in Russia or Ukraine. We managed to set up a meeting with two companies which have production operations in Russia.

The first interview we conducted with an international manufacturing company, further on referred as Company A, with the people who where responsible for the start-up of a factory in Southern Russia. The second interview we had with a Swedish manufacturing company, further on referred as Company B, with the person responsible for the factory start-up in Northern Russia.

6.1 Reasons for using interview technique

We used the interview technique as opposed to conducting a survey for empirical study for a number of reasons. First of all with the given short time limitation, doing survey is more time consuming. Secondly, two companies are a too small sample size to produce results representative of the whole market. Thirdly, by interviewing specific companies we could get more practical and in-depth information about start-up activities since this process is rather unique. Additionally, by having a personal interview, we could gather more accurate information than if we distributed a questionnaire to the companies because during the interview the respondents need to formulate answer before giving it. It also allows us to observe the nonverbal communication of the respondents rather than just having their written answers. Moreover, with open-ended questions, we can get additional ideas by asking for further information in some specific area which we would like to have a clarification at the time of the interview.

6.2 Interview results and comparison

Both companies have production operations in Russia. Company A started it operations from scratch, by building a new factory, whereas Company B purchased the majority shares in the existing factory and then modernised it. The results of the interviews could be found in Appendix B and Appendix C.

Even though Companies A and B work in different industries, both of them named customer potential as the major factor for the location selection. Additionally, Company A mentioned such factors as availability of industrial infrastructure and wealth in the region, which also defines the customer potential. In the Company B’s opinion, availability of energy supply is one of the most important factors in site selection decision in Russia especially for power consuming industries.

When we asked companies why they chose the regions in which they have production now we received rather conflicting answers. Company B chose Northern Russia because a factory owner in that city was willing to cooperate with them, even though Company B’s major customers are located in Siberia and Ural area which are lying 2,000 km away from Northern Russia. Company A chose Southern Russia for the factory location because of its enormous agricultural potential, even though it is not the most developed industrial area. Additionally,
Company A mentioned support of local administration as one of the factors influencing their decision. The answers given by the companies about important location factors comply with the study conducted by MacCarthy et al (2003) in which infrastructure, government and political factors, proximity to markets, and characteristics of a specific location were listed among 13 key factors affecting international location decisions.

On the question of major difficulties experienced during the start-up process we obtained rather unexpected answer from Company A. They mentioned customer attitude as the major start-up problem. Russians have a belief that products manufactured in Russia cannot have a good quality. It took Company A about 1.5 year to show and convince customers that Russian produced machines have very high quality and were as good, or maybe even better, as the ones manufactured in western Europe. Company B also mentioned that they faced the same problem and it took them about 3 years to convince in high quality standards. Even though the products they manufacture in Russia are as good as the ones produced in Sweden, they still have to sell Russian made products at a lower price then the ones imported from Sweden. The biggest difficulty for Company B during the start-up was to understand and accept the local system.

Another question that we were interested in was related to the production operations that were performed at the factories in Russia. Company A at the moment has only pure assembly operations. They recommend starting production in several phases rather than implementing all production operations at the same time. Company B performs all production steps at its factory in Northern Russia. Company B was in a different situation than Company A during the start-up because they bought an existing factory with all employees. So they had to change the existing production processes rather than implement them from scratch which turned out to be rather difficult.

Regarding local sourcing of materials we received the same answer from two companies. Both Company A and Company B mentioned that the quality of locally produced components is very poor and not consistent. For example, Company A could not find any local suppliers that were able to meet their quality demands, so instead they decided to find suppliers that were willing to cooperate and cooperate with them now on creating components of the satisfactory quality. For this reason at the moment they are sending all components for the assembly from Western Europe. Company B on the other hand has local suppliers for some components, however, the quality of the supplied material is not consistent and this in turn effects the quality of Company B’s products. The answers of both companies show that the process of finding suppliers is rather difficult and can take a long time.

It appears that both companies supply or plan to supply the same markets from the factory in Russia. For example, for Company B the major market is Russia, however, they also export to Ukraine, Belarus, and Kazakhstan. Company A sells the assembled machines only in Russia for now, but they plan to export Russian-assembled machines to Ukraine, Belarus, and Kazakhstan.

We were also interested to know about the experience of companies in terms personnel. At the start-up stage both companies have/had expatriates working at the factory. For example, Company A has four expatriate managers who work at the factory now. Company B had several expatriates during the start-up but now they have only one Swedish person in the company who is a member of board of directors. Both companies agreed on that it is
necessary to have expatriates at the start-up stage in order to be able to implement western values and work methods as well as corporate culture at a factory.
<table>
<thead>
<tr>
<th>Question</th>
<th>Company B</th>
<th>Company A</th>
</tr>
</thead>
</table>
| **What factors did you consider when analysing the suitable production location?** | Availability of the energy supply is an important factor during site selection. The electricity does not cost so much but it could be very expensive to add additional power supply/capacity to the factory. | · Customer potential  
· Industrial infrastructure  
· How much money the region has. Company A was looking for rich regions.  
 |
| **Which regions did you consider for establishment of the production? Why did you choose the one you are located in now?** | Company B selected Northern Russia for factory location, because the factory’s owner was open for cooperation and foreign investment. Otherwise, the optimal factory location would have been probably near Chelyabinsk (eastern part of Ural Mountains). | Company A wanted to be in the centre of agricultural area. At that time their products were used in 15 regions: from south of Moscow to East Ural and up to Altai.  
Southern Russia was selected as the result of site selection.  
Southern Russia is not the most industrially developed, but:  
· it occupies just 3% of Russia’s area and produces 10% of country’s grain  
· it has high yield and chernozemic soils  
· it has the biggest agricultural university in Russia  
· support from local administration  
· Company A had a possibility to buy land  
 |
| **What where the major difficulties that you experienced during the start up? When the factory is running?** | One of the biggest problems that they experienced was to understand and accept the system; in particular accounting and reporting that should be done according to the local standards. In general, it is difficult to start up with the things but later on as all procedures are worked through things go easier. | The major difficulty was sales of the combiners. Russians have a belief that if something is produced in Russia then it cannot have a good quality. Company A had to show their customers that Russian-produced machines are as good as the ones produced in western Europe. Now, after 1-1.5, year customers started to get convinced that the quality is high.  
 |
| **What production steps do you perform at the factory?** | At Company B they perform all production steps for the production of their products. | Company A started with pure assembly. Advice from them is to do everything in phases.  
 |
| **What kind of material do you buy locally now and plan to buy in the future?** | Company B buys certain components locally (i.e. powder, steel), however, the quality of the products delivered by suppliers is not consistent and can vary. This in turn affects the quality of the final products produced by Company B. | Currently all materials and components are shipped from western Europe or directly from company’s suppliers.  
The localization of supplied materials is a big problem. One of the major bottlenecks is painting. All components are painted in western Europe. Company A finds suppliers who are willing to cooperate and teaches them how to produce quality materials.  
<p>|</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Company B</th>
<th>Company A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What markets are you supplying with the products produced in Russia?</strong></td>
<td>40% of their market is in Siberia (oil companies) and Ural area. They also export to Ukraine, Kazakhstan, and Belarus. There are no duties for exporting to Belarus. Maybe some fees for export to Ukraine and Kazakhstan. A big problem is VAT (value added tax) refund. The VAT in Russia is 18%. The time it takes to get VAT refund depends on the tax authorities the company works with.</td>
<td>Right now they produce machines only for the Russian market; however, they have plans to export to Ukraine, Belarus, and Kazakhstan. So far they’ve produced about 1,000 machines and all of them were sold in Russia. There is a problem with VAT refund. Company A sold a machine to Belarus about 2 years ago and still did not get the tax refund.</td>
</tr>
<tr>
<td><strong>How difficult was it to find management staff in the area of production in Russia?</strong></td>
<td>Right now the management at the factory is Russian. In the board of directors they have one Swedish person who was working as a production manager for one year during start-up. If a company works the Swedish way in terms of attitude to people, than it would be easier to attract employees to the company. For example, Company B regularly pays the salaries, all salary is official, employees get medical insurance, etc. It was difficult to change employee’s attitude since they were used to work the old way. In their opinion it is easier to buy old building and hire new people than to take over an existing factory with all employees. If to start up production in Russia then it is necessary to have some Swedish person working permanently at that factory for several years. At the start up stage a lot of people came from Sweden to help with it.</td>
<td>At Company A in Southern Russia there are working four expatriates who fluently speak Russian and hold management positions. In Company A’ opinion it is a good solution because they can trust these employees and at the same time these employees talk the same language as local authorities which makes it is easier to deal with them. Also the employees know the peculiarities of local culture.</td>
</tr>
<tr>
<td><strong>What is the salary level?</strong></td>
<td>Salary increase is the same as inflation. The average salary at the factory in Nothern Russia is about 700 EUR. This is for the positions that require some previous education with process industry and do not require special skills. In Moscow the salary would be 15-20% more than in Nothern Russia, whereas in areas which are located further from Moscow they would be 50% lower (i.e. Southern Russia).</td>
<td>The monthly salary is 300-400 EUR including all taxes. The salary is growing 10+% every year.</td>
</tr>
</tbody>
</table>

Table 11: Comparison of Interview Results
7 APPLIED SOLUTIONS PROCEDURE

As it was previously described, the first two steps in location decision are estimation of production capacity and analysis of possibilities for capacity expansion. It has been previously estimated by the management at Väderstad Verken that the current capacity at the factory in Väderstad, Sweden, would not satisfy the growing demand for their products. The capacity at the factory was increased in various ways.

For example, to meet the increasing demand, the factory has been extended by 6000 m² during the past year. A robot system for welding was installed in autumn 2007. The new robot system is rather big; it consists of four welding robots and occupies approximately 900 m² floor space. The new welding robot would increase current welding capacity at the factory in Väderstad. With this new welding robot plant, it is possible to increase production of e.g. Top Down cultivators, which have found a large market in a number of countries. The constantly increasing production of Rapid seed drills means that the existing welding system is fully occupied and additional welding capacity is required in order to continue increasing production. The new robot system is expected to be in full production by the end of the year. In addition to the robot system, a new line for the assembly of seed drills was added at the new production area in order to increase capacity. Apart from that, additional shifts have been added at some lines.

Additionally, during the past year demand for Väderstad machines has been extremely high, which has led to a growth of over 30% within all markets and all product families.

Since the need for a new facility has been previously recognised by the management, we do not have to investigate the first two steps of manufacturing location decision and can go directly to the stage of new facility selection.

7.1 Facility specification

Following the outlined steps in location decisions, the next step is to establish facility specification. Based on the information provided by the marketing department it was decided to create a specification for a factory which would produce two different products at the start-up stage with possible expansion over time. The annual volume of products A and B would be 400 units each.

During the interview with Company A we were recommended that it is better to introduce the full production cycle in phases. For example, Company A started with pure assembly at the factory in Southern Russia using the components which are shipped from outside of Russia. However, now they have started to look for local suppliers. Additionally, several companies, for example Volkswagen in Kaluga, that recently opened their factories in Russia also began with only assembly operations.

Hence, we decided to consider the production start-up in several stages. The first stage would be assembly of machines from the components sent from Väderstad Verken in Sweden and its suppliers in Europe. After the assembly operations are set up and run according to Väderstad Verken standards it would be possible to consider expanding operations at the factory. Some
of the considered expansion options are starting welding and painting operations and adding more products at the new factory.

7.1.1 Capacity planning

As it was mentioned in Formula 1 in order to calculate the required capacity we would need the figures on demand forecast, processing time, total number of hours per year during which the process operates, and desired capacity cushion.

We already mentioned that it is planned to produce products A and B, 800 in total.

The total time required to assemble a machine we would base on the information for the time it takes to assemble Product X at the factory in Sweden.

<table>
<thead>
<tr>
<th>Product X</th>
<th>Amount of hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the operation</td>
<td></td>
</tr>
<tr>
<td>Painting</td>
<td>4.2</td>
</tr>
<tr>
<td>Assembly</td>
<td>6.3</td>
</tr>
<tr>
<td>Production of hose</td>
<td>2.38</td>
</tr>
<tr>
<td>Hub, wheel, haul</td>
<td>3.97</td>
</tr>
<tr>
<td>Assembly, leveling out</td>
<td>3.97</td>
</tr>
<tr>
<td>Wing, right</td>
<td>3.97</td>
</tr>
<tr>
<td>Wing, left</td>
<td>3.97</td>
</tr>
<tr>
<td>Middle section</td>
<td>3.97</td>
</tr>
<tr>
<td>Frame, left</td>
<td>3.97</td>
</tr>
<tr>
<td>Frame, right</td>
<td>3.97</td>
</tr>
<tr>
<td>Dockning middle, wings</td>
<td>3.97</td>
</tr>
<tr>
<td>Final assembly</td>
<td>3.97</td>
</tr>
<tr>
<td><strong>Total assembly time</strong></td>
<td><strong>42,03</strong></td>
</tr>
</tbody>
</table>

Table 12: Assembly Time for Product X

In order to calculate total number of hours per year during which the process operates we would be guided by the Russian and Ukrainian labour legislations.

<table>
<thead>
<tr>
<th>Country</th>
<th>Working hours, per day</th>
<th>Holidays, per year</th>
<th>Vacation days, per year</th>
<th>Total number of hours, per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>8</td>
<td>12</td>
<td>28</td>
<td>1 768</td>
</tr>
<tr>
<td>Ukraine</td>
<td>8</td>
<td>11</td>
<td>24</td>
<td>1 808</td>
</tr>
</tbody>
</table>

Table 13: Working Hours in Ukraine and Russia

At the new factory there will not be similar equipment for the assembly so the processing time would be higher than the one in Sweden. Additionally, we believe that the productivity in Russia and Ukraine is lower than that of in Sweden. In order to compensate for these losses in the processing time we would like to secure a cushion of 35%.

Thus the required amount of people at the production line would be calculated as follows:

\[
M_{\text{Russia}} = \left( \frac{400 \times 42.03}{1768 \times (1 - 35/100)} \right) = 14.62
\]
Thus the amount of workers required at each production line in Ukraine or Russia is 15 people.

7.1.2 Layout

It was decided to arrange work following the product layout since the products to be manufactured at the factory are rather standardised and volume would be high enough. There were designed two layouts for two implementation stages. Figure in Appendix D shows layout for the start-up stage when only assembly operations would be carried out at the factory. The factory layout includes area for unloading containers, warehouse for 750 pallets, 2 production lines, area for storage of ready machines, and office area of 340 m². The layout was designed in such a way that it will be possible to expand operations without breaking the production flow. For example, it is possible to add additional assembly lines above the existing ones.

The layout in Appendix E was designed to include such operations as painting and welding. It shows that it is possible to expand the original layout without violating the production flow. Welding and painting operations are added to the left of the assembly lines. Layout 2 is designed for the factory of 7,150 m² which has area for intake of incoming goods, warehouse for 1,200 pallets, painting, welding, 2 assembly lines, storage of ready machines, and an office space of 340 m².

7.1.3 Organization chart

Since no factory cannot run only with assembly staff, it is necessary to identify supporting functions necessary at the factory. The organization chart in Figure 8 was created based on the experience of Väderstad Verken and taking into consideration local peculiarities in Russia and Ukraine. The total number of employees is estimated to be 62 people, including 38 people in production, 9 in logistics, and 15 in administration.
Once the major features of facility specification have been identified, it is possible to move to the next step, that is identification of key location factors.

### 7.2 Factors

During the analysis of the factors which could be important for the location of a Väderstad plant, we identified that market potential, labour, and transportation infrastructure are of primary importance. Further on, we subdivided these three factors into sub-objectives. We decided that the sub-objectives defining market potential should be area of cultivated land, amount of sold machines, and yield. Labour could be further sub-divided into availability of welders, average salary for a welder, average salary in a region, and salary increase. Transportation infrastructure consists of availability of roads, availability of railroad, and availability of airports. The location factors were clustered in a decision hierarchy presented in Figure 9.
7.2.1 Market potential

It is rather important for Väderstad Verken to have its factory close to the customers in order to provide them with timely delivery and reduce transportation costs. So in order to better analyze the market potential we decided to consider the above mentioned sub-objectives.

The machines produced at Väderstad Verken could be used to plant different kind of grains, corn, sun seeds, rapeseed, etc. Hence, the areas in which these types of crops are cultivated represent the potential market. For every macro-region we collected the information on the size of the area in which corn, grain, and sun seeds are cultivated. It is summarised in Table 14.
The location of the existing clients can influence the future sales and also indicates the areas in which there is a demand for Väderstad Verken machines. Hence, we decided to use the amount of sold machines since it is a good indicator of the location of current customers. The information was obtained from the Sales and Marketing department and is represented in Table 15.

<table>
<thead>
<tr>
<th>Macro-region</th>
<th>Amount of sold machines (as of 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Ukraine</td>
<td>39</td>
</tr>
<tr>
<td>Eastern Ukraine</td>
<td>23</td>
</tr>
<tr>
<td>Western Ukraine</td>
<td>60</td>
</tr>
<tr>
<td>Volga Russia</td>
<td>56</td>
</tr>
<tr>
<td>Southern Russia</td>
<td>21</td>
</tr>
<tr>
<td>Central Russia</td>
<td>188</td>
</tr>
<tr>
<td>North-western Russia</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 15: Amount of Sold Machines for Each Macro-Region

Farms that have higher yield of the crops are more profitable and hence they are more likely to be able to afford Väderstad Verken machines. We used data from Table 16 on the wheat yield since it is the most common crop cultivated in the area.

<table>
<thead>
<tr>
<th>Macro-region</th>
<th>Yield, 100 kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Ukraine</td>
<td>20,7</td>
</tr>
<tr>
<td>Eastern Ukraine</td>
<td>19,4</td>
</tr>
<tr>
<td>Western Ukraine</td>
<td>25,0</td>
</tr>
<tr>
<td>Volga Russia</td>
<td>18,7</td>
</tr>
<tr>
<td>Southern Russia</td>
<td>21,4</td>
</tr>
<tr>
<td>Central Russia</td>
<td>22,8</td>
</tr>
<tr>
<td>North-western Russia</td>
<td>16,2</td>
</tr>
</tbody>
</table>

Table 16: Yield for Major Macro-Regions

---

1 Information on Ukraine has been taken from State Statistics Committee of Ukraine (2007) and on Russia from The Institute for the Economy in Transition (2003)
7.2.2 Labour

We decided to evaluate the availability and cost of labour during the selection of the macro-region because the production of Väderstad Verken machines is rather labour intensive.

Two labour intensive production steps include welding and assembly of the machines. While the assembly operations could be performed by unskilled labour, the welding operations require staff with previous welding education and experience. Hence, the company has a special labour requirement for welders and regions with an existing concentration of welders are of particular interest. It was not possible to find information on the amount of vocational school graduates with the training in welding, so we were trying to identify industrial areas. Typically areas with a high percentage of labour force employed in machine-building industry would have a higher concentration of welders.

To analyze the labour cost we were looking at three factors: average (monthly) salary for a welder, average (monthly) salary in a region, and (yearly) salary increase. The information on the average salary for a welder was collected from the classifieds section of electronic version of newspapers in Russia and Ukraine. To the figures on average salaries we added employment tax which equals 26.2% in Russia and 37.16% in Ukraine.

To see the general situation with salary rates in regions we used the data on average salary in a region which is provided by national statistics bureaus of Ukraine and Russia. Additionally, it should be mentioned that in Russia and Ukraine a high percentage of the economy is in shadow. For example, according to some estimates more than 40% of the Ukraine’s economy is in shadow (Панченко, 2007). So the statistics on the average salary in a region might not reveal true labour rates, however, it can indicate general trend and differences among regions.

The summary of salary situation in each macro-region is presented in Table 17.

<table>
<thead>
<tr>
<th>Macro-Region</th>
<th>Average salary for a welder, per month, EUR</th>
<th>Average salary in a region, per month, EUR (2006)</th>
<th>Salary increase, per year, EUR (2006 vs. 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Ukraine</td>
<td>413</td>
<td>114</td>
<td>26</td>
</tr>
<tr>
<td>Central Ukraine</td>
<td>504</td>
<td>140</td>
<td>31</td>
</tr>
<tr>
<td>Eastern Ukraine</td>
<td>418</td>
<td>138</td>
<td>28</td>
</tr>
<tr>
<td>Volga Russia</td>
<td>644</td>
<td>228</td>
<td>46</td>
</tr>
<tr>
<td>North-western Russia</td>
<td>500</td>
<td>333</td>
<td>66</td>
</tr>
<tr>
<td>Central Russia</td>
<td>496</td>
<td>340</td>
<td>70</td>
</tr>
<tr>
<td>Southern Russia</td>
<td>640</td>
<td>203</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 17: Salary Specifications for Major Macro-Regions

7.2.3 Transportation infrastructure

In order to move personnel, equipment, raw materials, and products to and from the plant a good transportation infrastructure is required. It was decided that the machines produced at the factory would be delivered either by truck or railway; hence, we were evaluating the road and railroad networks in every macro-region. We used road and railroad densities in each macro-region, represented in Table 18, to compare the transportation infrastructure.

---

2 Information on Ukraine has been taken from State Statistics Committee of Ukraine (2007) and on Russia from The Federal State Statistics Service (2006)
<table>
<thead>
<tr>
<th>Region</th>
<th>Density of roads, km/1000 sq. km</th>
<th>Density of railroad, km/1000 sq. km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Ukraine</td>
<td>264</td>
<td>32</td>
</tr>
<tr>
<td>Eastern Ukraine</td>
<td>262</td>
<td>43</td>
</tr>
<tr>
<td>Western Ukraine</td>
<td>321</td>
<td>44</td>
</tr>
<tr>
<td>Volga Russia</td>
<td>137</td>
<td>14</td>
</tr>
<tr>
<td>Southern Russia</td>
<td>91</td>
<td>26</td>
</tr>
<tr>
<td>Central Russia</td>
<td>209</td>
<td>33</td>
</tr>
<tr>
<td>North-western Russia</td>
<td>53</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 18: Density of Motorways and Railroads for Major Regions

Additionally, we evaluated the availability of airports because during the start-up stage and when the factory is running it will be necessary to provide the factory with management and technical support from the head-office. Hence, there will be frequent travelling between the head-office and the factory and in order to reduce the total travel time, proximity to an airport should be evaluated.

7.3 Site selection stage

As it was previously mentioned, the final step of the location decisions is the selection of the facility for the new factory. Currently Väderstad Verken sells its products through daughter companies in 12 countries and importers all over the world. The sales breakdown for major markets is presented in Figure 10.

![Figure 10: Sales Breakdown for Major Markets](image)

Some of the fastest growing markets were Ukraine and Russia. Additionally, these markets have a great potential due to enormous area of cultivated land.

The management decided that the geographical region that should be considered for the start-up of new factory should be Eastern Europe, in particular Russia and Ukraine.
7.4 Selecting a macro-region

Since the geographical region was already predetermined, we could start directly with the phase of selecting a macro-region.

The territories of Russia and Ukraine have been divided into 4 and 3 macro-regions, respectively, as they are illustrated on the maps in Appendix F and Appendix G. These 7 macro regions have to be compared in terms of performance on all factors. They are as follows:
- Ukraine west
- Ukraine central
- Ukraine east
- Russia north
- Russia central
- Russia south
- Russia Volga

We did not consider all parts of Russia due to their remote location which could complicate the delivery of the final product to the customers. Additionally, the center of gravity approach suggested that the optimal location should be lying in the European part of Russia.

After thorough evaluation of various location analysis methods, we decided to use two methods to select the appropriate macro-region: Centre of Gravity approach and Analytic Hierarchy Process.

One of the main reasons for choosing AHP was that it allows taking into consideration not only quantitative factors but also qualitative ones which are also rather important in the selection process. Additionally, the pairwise comparison allowed identifying inconsistencies in the judgments about attractiveness of one macro-region over another for various factors. Not the least, the availability of professional software Expert Choice which offers very visual display of the final results also played in favour of AHP selection.

7.5 Centre of Gravity

Since the new factory would be serving customers in Russia, Ukraine, and Kazakhstan, we wanted to find an “ideal” location, from a transportation standpoint for those three markets. We followed the method described earlier in this paper. In particular, at first we drew a grid on a map of Russia, Ukraine, and Kazakhstan and identified on the map all regions that represent potential markets. This map is represented in Appendix H. The area that we analyzed included entire Ukraine and Kazakhstan. As for Russia we did not analyse far-east region of Russia, because the amount of cultivated land in that area is not that significant and Väderstad Verken did not sell any machines there.

Then we assigned weight to each region in terms of area of cultivated land under grains and sun seeds. For this method we aggregated the information at the level of region (oblast) in order to get a more accurate centre of gravity. The X and Y coordinates for all regions were identified and input into table for calculation, which is presented in Appendix I, together with values for the area of cultivated land.
The final result revealed that the centre of gravity for markets in Ukraine, Russia, and Kazakhstan was lying at coordinate 7.57 (x) and 11.96 (y). This point (red circle on the map in Appendix H) is lying near city called Kuybyshev.

7.6 AHP

The centre of gravity approach helped us identify the optimal location for a factory from a transportation standpoint. However, there are many other factors which we wanted to take into consideration and which were ignored by the centre of gravity approach.

Since we have already completed the first AHP step and made hierarchal break down of all factors, we can proceed with the second step – comparing objectives and alternatives.

7.6.1 Pairwise comparison

Following the recommendation written by Forman et al (2001) at first I evaluated the performance of the alternatives with respect to the objectives before giving weights to the objectives. On subjective factors such as availability of welders and access to airports I conducted the pairwise comparisons, in order to have a more accurate evaluation. The following Figure 11 is a pairwise comparison that shows judgements relative to two possible alternatives on Availability of welders factor: macro-regions Russia central and Ukraine west. The comparison shows that Russia central has almost 3.5 times better availability of welders than Ukraine west. Additionally, in the Figure 11 it is possible to see the inconsistency ratio in the last row. In this comparison, the inconsistency ration is 0.01 which indicates the validity of the analysis and is considered acceptable since it is lower than the maximum allowable inconsistency of 0.1.

![Figure 11: Pairwise Comparison](image)

On the other hand, those factors for which we managed to find quantitative descriptions it is more appropriate to directly enter data values. It is possible to use direct data entry feature of the Expert Choice. Figure 12 shows the direct data entry for Cultivated land factor.
A special care should be given to the objective criterion of cost for such factors as Average monthly salary for welder, Average salary in a region and Yearly salary increase, since the alternative with the minimum cost should have the maximum rating. To achieve these goals the minimum cost was divided by all other costs. Since all costs are subjected to the same transformation, the relative weights between them do not change. However, because the cost is converted into relative ranking, the high-cost option is ranked lower than the low cost option.

<table>
<thead>
<tr>
<th>Macro-region</th>
<th>Monthly salary for a welder</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia north</td>
<td>494</td>
<td>0.8360</td>
</tr>
<tr>
<td>Russia central</td>
<td>496</td>
<td>0.8327</td>
</tr>
<tr>
<td>Russia south</td>
<td>620</td>
<td>0.6661</td>
</tr>
<tr>
<td>Russia volga</td>
<td>627</td>
<td>0.6587</td>
</tr>
<tr>
<td>Ukraine west</td>
<td>413</td>
<td>1.0000</td>
</tr>
<tr>
<td>Ukraine east</td>
<td>418</td>
<td>0.9880</td>
</tr>
<tr>
<td>Ukraine central</td>
<td>504</td>
<td>0.8194</td>
</tr>
</tbody>
</table>

Table 19: Relative Ranking of Data for Monthly Salary for a Welder

After all alternatives have been compared, the weight was assigned to every objective and sub-objective. It was decided that Market potential should get the highest weight – 0.53, followed by Labour (0.316) and Infrastructure (0.158). In Figure 13 the Expert Choice decision hierarchy is depicted that shows alternatives, objectives and sub-objectives relative to the goal. It is also possible to see the weights assigned to all objectives and sub-objectives. Thus sub-objectives with the highest scoring total weight were Cultivated land (0.217), Yield (0.217), Availability of welders (0.126), and Sold machines (0.093).
In the upper right corner it is seen that Russia central has the best overall rating relative to the goal with a ratio scale measure of 0.166. The ratio scale measurements for all alternatives are as follows:

- Ukraine west: 0.140
- Ukraine central: 0.157
- Ukraine east: 0.161
- Russia north: 0.089
- Russia central: 0.166
- Russia south: 0.135
- Russia Volga: 0.153

7.6.2 Sensitivity analysis

Sensitivity analysis is used to investigate the sensitivity of the alternatives to changes in the priorities of the objectives. These analyses can be performed from the goal perspective or from the objective.

The performance sensitivity in Figure 14 shows the relative importance of each of the objectives as bars, and the relative preference for each alternative with respect to each objective as the intersection of the alternative’s curves with the vertical line for each objective. From the graph it is possible to see that the relative importance of Market is about 0.53, Labour -0.32, and Infrastructure – 0.16. The total sum of all preferences adds up to 1.
As it is seen from the graph, Russia Volga macro-region is the best on Market potential objective, while Ukraine east is the best on Labour, and Ukraine west on Infrastructure. However, it is Russia central macro-region which performs best overall and thus is a preferred solution.

Additionally, top four macro-regions – Russia central, Ukraine east, Ukraine central and Russia Volga – do not have very big difference between them in terms of overall performance score. This can indicate that that if we change priorities of some factors, then the overall performance of these macro-regions can change as well. Dragging any of the vertical bars causes immediate change in the priority of each alternative. In Figure 15 we can see how these actions in changing priorities could effect the overall performance.
As it is seen from the Figure 15 reducing the priority of Market potential to 0.30 changes the overall performance of the alternatives in a way that Ukraine east becomes the preferred option instead of Russia central.

If a management decides to change its judgement to one particular objective then a gradient sensitivity analysis may be helpful to see how this would effect the choice of alternatives. The Figure 16 shows a gradient sensitivity analysis of the results with the respect to the importance of Market potential. We can see our initial decision analysis indicated with the solid red line. The graph shows that the current priority for Market potential is about 0.53 (see vertical solid line). Then assuming that the management wishes to place a smaller emphasis on Market potential, the decision line can be moved to another indication (identified as the blue dashed line). By doing so we can see that the overall preference for Russia central would decrease while that of Ukraine east would increase. If the priority of Market potential were decreased below 0.47 (blue dotted line), then Ukraine east would be the preferred alternative. On the other hand, if the priority of Market potential was increased to more than 0.85 then Russia Volga would become the preferred option. From this sensitivity analysis we can see that it would take a significant change in the priority of Market potential in order to change the ranking of the alternatives, thus the results are not very sensitive to small changes in the priority of Market potential.
Figure 16: Gradient Sensitivity Analysis for Market Potential

Similar analyses could be conducted on Labour and Infrastructure in case management would like to change their preference of these factors. The Figure 17 visualises the gradient sensitivity analysis of the results on the importance of Labour. The graph shows that the current priority for Labour is about 0.32. If Labour were to become more important, then the overall preference for Russia central decreases while that of Ukraine east increases. If the priority of Labour were increased above 0.39, then Ukraine East would be the preferred alternative. The change in priority from 0.32 to 0.39 appears to be not very significant, and this indicates that the results could be sensitive to small changes in the priority of Labour.
Figure 17: Gradient Sensitivity Analysis for Labour

Figure 18 shows a gradient sensitivity analysis of the results with the respect to the importance of Infrastructure. The graph shows that the current priority for Infrastructure is about 0.155. If Infrastructure were to become more important, then the overall preference for Russia central decreases while that of Ukraine east increases. If the priority of Infrastructure were increased above 0.35, then Ukraine east would be the preferred alternative. This indicates that the overall performance is not very significant to the changes in the priority of Infrastructure since it has to be increased almost two times to effect the order of alternatives.
Another useful type of sensitivity analyses is Head-to-Head. It allows comparing the performance of two alternatives on each factor. For example, the head-to-head analyses of Russia central to Ukraine east (Figure 19.a) and Ukraine west (Figure 19.b) indicates that Russia central outperforms rather significantly these two macro-regions in terms of Market potential, whereas Ukraine east and Ukraine central have a better performance on Labour and Infrastructure. This could indicate in general that location of a new facility in Russia is more preferred if management considers Market potential to be the major factor. However, if they decide that such factors as Labour or Infrastructure are of higher importance then the better option for the factory location would be Ukraine.
7.7 Cost calculation

The management was interested to know how the start-up of assembly operations would effect total assembly cost of machines under the assumption that all components would be manufactured in Sweden and then sent directly from the factory in Väderstad to the factory in Eastern Europe.

Some costs would be reduced at the factory in Sweden while other costs would appear at the new factory. After thorough analysis we decided to take the following costs into calculation:

- packing cost
- transportation of assembled machines
- transportation of components
- assembly costs
- administration costs
- transportation costs from the new factory to customers

Now let us consider these costs in more detail.

7.7.1 Packing cost

Since we are considering the scenario when components will be shipped from the factory in Sweden to the factory in the Eastern Europe, it will be necessary to pack them. Hence, a new cost will be added to the total assembly cost.

Based on the records at Väderstad Verken it is necessary to perform 11 picking orders at a warehouse for one machine. Hence, we would assume that it will be the same amount of operations to package components sufficient for one machine. Additionally it will be required about 40 picking orders of the welded components. So the total amount of picking operations would be 73 per one truck.

On average it takes about 5 minutes to pick one order, hence, the total time required to pick all components to fill up one truck would be 6 hours, which is approximately one working
day. With the volume of 133 trucks per year, it will be necessary to have one forklift truck driver to pick all the orders. Additionally, it will be necessary to have people who would pack the picked components into the truck. We assume that it will be enough with 4 people. The calculation of total cost of packaging components for one machine is presented in Table 20.

<table>
<thead>
<tr>
<th>Picking orders</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unassembled machines per truck</td>
<td>3</td>
</tr>
<tr>
<td>Picking orders per machine</td>
<td>11</td>
</tr>
<tr>
<td>Picking orders per truck</td>
<td>33</td>
</tr>
<tr>
<td>Picking orders (welded components) per truck</td>
<td>40</td>
</tr>
<tr>
<td>Total amount of picking orders</td>
<td>73</td>
</tr>
<tr>
<td>Time required to pick one order (hours)</td>
<td>0,08</td>
</tr>
<tr>
<td>Picking time for a container (hours)</td>
<td>6</td>
</tr>
<tr>
<td>Trucks required per year</td>
<td>133</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packaging components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff</td>
<td>4 man</td>
</tr>
<tr>
<td>Total amount of work hours per year</td>
<td>6 800</td>
</tr>
<tr>
<td>Cost per hour</td>
<td>488 kr</td>
</tr>
<tr>
<td>Yearly cost (packaging)</td>
<td>3 318 400</td>
</tr>
<tr>
<td>Forklift truck driver (half time)</td>
<td>414 800</td>
</tr>
<tr>
<td>Total picking and packaging cost</td>
<td>3 733 200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Picking and packaging cost per machine</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly amount of machines</td>
<td>400</td>
</tr>
<tr>
<td>Cost per machine</td>
<td>10 000 kr</td>
</tr>
</tbody>
</table>

Table 20: Calculation of Packaging Cost of the Components

7.7.2 Transportation of assembled machines

The cost of transporting assembled machines to the customers in Russia and Ukraine would disappear since they would be assembled at the new factory rather than at Väderstad. On average it costs about 28,500 SEK to transport one machine to a customer.

7.7.3 Transportation of components

It is possible to transport maximum 2 assembled machines with one truck due to their dimensions, however, the maximum payload of a truck allows it to transport the weight corresponding to 3 machines. Hence, we are assuming that it will be possible to transport in one truck components enough for 3 machines and the transportation cost for one machine is reduced to about 19,000 SEK.

7.7.4 Assembly costs

Assembly costs would disappear at the factory in Sweden, however, it is necessary to calculate them at the new factory. According to the organization chart in Figure 8 it is
necessary to have 30 assembly staff. With the monthly salary of 6,765 SEK, which gives an hourly rate of 64 SEK.

Additionally we should take into consideration indirect costs, such as electricity, utilities, etc. associated with the assembly. We are assuming that the indirect costs at the factory in Eastern Europe could be calculated at the same rate as the one in Sweden because even though some costs are lower there, some additionally costs may come up which do not happen in Sweden, for example, various permits. Hence, the indirect assembly cost should be calculated at the rate of 166 SEK. Thus the total hourly assembly cost is 230 SEK or 9,655 SEK per machine.

7.7.5 Administration costs

An additional cost that should be taken into consideration is the administration cost, such as salaries for administrative staff that was identified in Figure 8 (the detailed breakdown of the monthly salaries is presented in Appendix J). Based on our research regarding the salaries in Russia we calculated the hourly administration cost 117 SEK or 4,924 SEK per machine.

7.7.6 Transportation cost from the new factory to customers

We will still have to deliver assembled machines to customers so we need to estimate the cost of it. We calculated the transportation cost from the center of gravity point which we identified earlier in paragraph 7.5 to the location of the potential customers. Since we assume that the amount of customers and hence future sales of the machines should be proportionate to the area of the cultivated land, we estimate the percentage of the cultivated land and its distance from the center of gravity as it is shown in Table 21.

<table>
<thead>
<tr>
<th>Region</th>
<th>Area of cultivated land (ha)</th>
<th>Distance from center-of-gravity to the region (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total area of cultivated land</td>
<td>&gt;500</td>
</tr>
<tr>
<td>Total area of cultivated land</td>
<td>76 942 956</td>
<td>11 250 667</td>
</tr>
<tr>
<td>Percentage from total area</td>
<td>14,62%</td>
<td>38,02%</td>
</tr>
<tr>
<td>Transportation costs per km, truck 83 m³ (EUR)</td>
<td>1,28</td>
<td>0,90</td>
</tr>
<tr>
<td>Total transportation cost, truck</td>
<td>319</td>
<td>448</td>
</tr>
<tr>
<td>Average transportation cost by truck (EUR)</td>
<td>606</td>
<td></td>
</tr>
</tbody>
</table>

Table 21: Calculation of the Transportation Cost from Factory to Customers

Based on the calculations in Table 21 the average transportation cost for one machine should be about 606 € or 5,703 SEK.
7.7.7 Cost analysis

Now that we have all major costs which will be effected by the factory start-up, we need to analyse them.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging costs</td>
<td>10 000 SEK</td>
</tr>
<tr>
<td>Transportation of assembled machines</td>
<td>-28 532 SEK</td>
</tr>
<tr>
<td>Transportation of components</td>
<td>19 021 SEK</td>
</tr>
<tr>
<td>Assembly costs in Sweden</td>
<td>-20 496 SEK</td>
</tr>
<tr>
<td>Assembly costs in E. Europe</td>
<td>9 655 SEK</td>
</tr>
<tr>
<td>Administrative costs in E. Europe</td>
<td>4 924 SEK</td>
</tr>
<tr>
<td>Transportation costs from the new factory to customers</td>
<td>5 703 SEK</td>
</tr>
<tr>
<td><strong>Difference between assembly in Sweden and E. Europe</strong></td>
<td><strong>276 SEK</strong></td>
</tr>
</tbody>
</table>

Table 22: Cost Comparison

According to the calculations in Table 22 it will be 276 SEK more if the company decides to assemble the machines in E. Europe. This difference is not very significant and indicates that the cost would be virtually the same. Just as it was mentioned at the interview with Company A, it is not possible to reduce costs by having just assembly operations. However, it could be a good first step in the establishment of full scale operations at the new factory.
8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary

The purpose of this thesis was to recommend a list of factors which should be taken into consideration during the factory start-up in the Eastern Europe. Additionally, suitable areas for the factory start-up should have been analysed based on the identified factors. Also it was necessary to create a specification for the future factory and operations as well as conduct a cost comparison of the machine assembly in the Eastern Europe versus Sweden.

During this pre-study it was discussed that Väderstad Verken should start the production in the Eastern Europe in several stages in order to minimize possible problems with quality. The first implementation stage should include the start-up of assembly operations from the components shipped from Sweden. At the beginning only one or two products should be assembled at the factory. As soon as Väderstad Verken achieves desirable assembly quality and establishes all processes at the factory they can proceed with the expansion of factory by starting other production operations such as welding, painting and finding local suppliers of the components.

The draft layouts proposed in Appendix D and Appendix E could be used for planning the factory since they take into consideration the expansion possibility at the factory in terms of products and operations, as well as they are designed in a way that optimises the production flow.

For the analysis of suitable location we used two methods, centre of gravity and AHP. The centre of gravity method is often used when there is uncertainty of the cost for the transportation and volumes. The parameters that we used in the model were the location and size of potential customers. Using the centre of gravity method we identified that the centre of gravity for Russia, Ukraine and Kazakhstan is lying near a city called Kuybyshev. However, since this method does not provide the optimal solution it should be used only as a rough guide.

Since centre of gravity takes only transportation issues into consideration, we used AHP to analyse other important factors for the factory location. AHP allowed us to analyse both qualitative and quantitative factors. The analysis of the suitable macro-region for the factory location showed that there is no definite answer in terms of the best option. Russia Central appears to be the best option if the company gives a high priority to the market potential. However, if the management decides to increase the priority of labour or infrastructure, then Ukraine East or Ukraine Central could become preferred options.

The cost comparison showed that if Väderstad Verken decides to have only assembly operations then it can find itself in the situation that the total cost of one machine would remain the same or may even become higher, since the savings on assembly in the Eastern Europe rather than Sweden would be negated by additional administrative costs at the new factory as well as increased cost of packaging components.
8.2 Recommendations for the future work

In my opinion, before deciding on that in which macro-region Väderstad Verken should continue the site search, it is necessary to conduct a profound risk analysis of two different scenarios – building the factory in Russia and Ukraine. To have production operations in these two countries can involve high degree of risk, for example, intervention of state authorities into private business, imposition of import duties on agricultural machinery by Russia on Ukraine or vice versa. Additionally, as it was mentioned by Company A and Company B, the image of the quality of locally assembled machines could be worse than of those assembled in Sweden. This in turn can either cause the demand to decline, force the company to reduce sales price or require additional resources to improve the product image.

After the company chooses the suitable macro-region for the factory location they can proceed with choosing the appropriate community and site following the steps described in paragraphs 5.4 and 5.5. The company can continue using AHP for analysis of various factors applicable during the selection of the community and site. Additionally, at the stage of the site selection they can use one of the economic models described in paragraph 5.7.2 to compare various costs and benefits associated with each site candidate.

We have created the specification for the future factory which could be used during the stage of site selection. The company may want to consider adding more characteristics which are specified in Appendix A.
9 REFERENCES

Books:


Articles:


**Electronic Sources:**


**Interviews:**

10 APPENDICIES

Appendix A: Site Requirements for a Proposed New Facility (Hack, 1999)

1. Number of hectares required?
   Minimum _____ hectares
   Maximum _____ hectares
2. Preferred dimensions (in m²)
   Minimum _____ m²
   Maximum _____ m²
3. Preferred topography (level, sloping, etc.)
4. Load-bearing requirements
5. Preferred water depth below surface
6. Preferred depth of rock below surface

Plant Construction
1. Sketch of general plant layout, if possible
2. Total floor area
3. Building dimensions
4. Ceiling heights
5. Maximum outside building height
6. Will the plant require a subsurface basement or subbasement?
7. Will subsurface pits be required to house operating machinery? If so, to what depth below floor level?

Utility Service
1. Electric power
   Preferred delivery voltage to plant substation
   Are two separate feeds to plant substation required?
2. Gas
   Size line and gas pressure required at plant
   Can standby propane or oil be used for part heating or processing requirements if interruptible gas proves more economic than firm gas? If so, how much of total gas load can be interruptible?
3. Water
   Size municipal water line required
   Must all water requirements be met with municipal water, or is the company willing to develop its own wells or surface water supply? If so, what part of total water usage could be company wells or streams?
4. Sewer
   Size municipal line required
   Capacity of line?

Transportation
1. Is rail siding essential?
   Number of cars loaded and unloaded each day
   Capacity of siding
2. Truck
Number of trucks loaded and unloaded each day
Number of truck doors to be installed

**Special Site Considerations**
1. Do operations create objectionable odour, noise, vibration, smoke, etc.?
2. Sensitivity of the process to similar conditions
3. Does the company prefer an industrial park location or to be separated from other firms?  
   If separated, by what distance?
4. Prefer location within or beyond city limits?
5. Importance of advertising value of site
6. Maximum cost per hectare
Appendix B: Results from the Interview with Company A

LOCATION SELECTION

Why did Company A decide to start the production in Russia?

They moved to Russia:
- To be the first western company to manufacture in Russia
- There is a tremendous market in Russia

They had about 1,000 used machines in Russia 10-12 years ago.

Company A gave an example of how quickly the Russian government can increase import duty. In two weeks the government imposed a duty which increased the price of the imported machines by 25,000 €.

What factors did you take into consideration when analysing the appropriate production location? Which ones did you consider to be the most important?

1. Customer potential
2. Industrial infrastructure
3. How much money the region has. Company A was looking for rich regions.

Which regions did you consider for establishment of the production? Why did you choose Southern Russia?

Company A wanted to be in the middle of agricultural area. At that time they had 15 regions in which their products were used: from south of Moscow to East Ural and up to Altai.

Southern Russia was selected as the result of site selection. Even though it is not most industrially developed, Southern Russia occupies just 3% of Russia’s area and produces 10% of country’s grain. Additionally yield is very high in the region and there is chernozym.

The biggest agricultural university in Russia with 18 different faculties is located in Southern Russia.

Company A had a possibility to buy land. They own the plant and the land on which it is located.

If you should start a factory again with the knowledge you have today will it still be in Southern Russia?

Yes absolutely.

What where the major difficulties that you experienced during the start up? When the factory is running?

The major difficulty is sales of the machines. Russians have a belief that if something is produced in Russia then it cannot have a good quality. Company A had to show its customers that Russian-produced machines are as good as the ones produced in western Europe, or maybe even better. Now after 1-1.5 year customers started to get convinced that the quality is high.
Authorities

Company A recommends to have good relations with authorities and do everything yourself. Never trust the administration!

Company A does not recommend giving any bribes to the authorities since it can only complicate things.

PRODUCTION

What production steps do you perform at the factory (i.e. deliver parts to the factory and mount them, or produce some parts at the factory, etc.)? Why did you choose such a production process?

Company A started with pure assembly. Advice from them is to do everything in phases.

What kind of material do you buy locally now and plan to buy in the future? What is the price level compared to the one in western Europe?

Currently all materials and components are shipped from western Europe or directly from company’s suppliers.

The localization of supplied materials is a big problem. There is a horrible situation with plants in Russia. In the past, big factories used to produce everything themselves for their needs.

Company A finds suppliers who are willing to cooperate and teaches them how to produce quality materials.

What markets are you going to supply with the machines produced in Southern Russia?

Right now they produce machines only for the Russian market; however, they have plans to export to Ukraine, Belarus, and Kazakhstan. So far they’ve produced 1,000 machines and all of them were sold in Russia.

There is a problem with VAT (value added tax) refund. They sold a machine to Belarus about 2 years ago and still did not get the tax refund.

Does the factory have own ERP system?

They are introducing/introduced lean version of SAP in Southern Russia for 3 major reasons:

1. If you get SAP then places become transparent
2. If you run the system then you have to run it in all your divisions
3. Easier to handle big BOM. For example, they will start assembly of a new product in Southern Russia and it consists of 5,000 part numbers. It is almost impossible to handle so much information in Excel.
EMPLOYEES

How difficult was it to find management staff in the area of production in Russia?

At Company A in Southern Russia there are working four expatriates who fluently speak Russian. In Company A opinion it is a good solution because they can trust these employees and at the same time these employees talk the same language as local authorities which makes it is easier to deal with them. Also the employees know the peculiarities of local culture.

What is the salary level compared to the one in western Europe?

The monthly salary is 300-400 EUR including all taxes. The salary is growing 10+% every year.

How strong and active are unions in Russia (or Southern Russia)?

They have no union at the factory.

People

Currently there are 50 people working at the factory. During high season they have 100 employees. In their opinion it is easier to control a small factory and easier to introduce “Company A culture” when there are not so many people. If they grow slowly they can inject the “Company A culture”.

Other

Standard cost. Do not disclose standard cost to authorities, otherwise it will become a public knowledge.
Appendix C: Results from the Interview with Company B

ABOUT COMPANY B IN RUSSIA
Company B has a Joint venture in Nothern Russia. They own 51% in the factory, the rest is owned by a Russian owner. The factory is about 50 years old and Company B started its operations there in 2000. Currently there are 180 people working at the Company B factory in Nothern Russia. They recently started with 12-hour shift: 3 days working – 3 days off. Since this kind of shift-scheme is not very common in Russia, they have some problems implementing it. The production at the factory is 50-55 tons per shift.

START-UP
Factors for site selection
In Russia there are not so many production buildings to buy. Probably it would be easier to find them in Ukraine. It can take from 1 to 2 years to build the greenfield site depending on the local authorities. Availability of the energy supply is an important factor during site selection. The electricity does not cost so much but it could be very expensive to add additional power supply/capacity to the factory.

Which regions did you consider for establishment of the production? Why did you choose Nothern Russia?
They selected Nothern Russia for factory location, because the factory’s owner was open for cooperation and foreign investment. Otherwise, the optimal factory location would have been probably near Chelyabinsk (eastern part of Ural Mountains).

What where the major difficulties that you experienced during the start up? When the factory is running?
One of the biggest problems that they experienced was to understand and accept the system; in particular finance, accounting and reporting that should be done in accordance with local standards. In general, it is difficult to start up with the things but later on as all procedures are worked through things go easier.

PRODUCTION
Quality
It took Company B about 2-3 years to show their customers that they produce good quality product which is not worse than the one in Sweden.

How big is the support (administrative) function to take care of the production?
There should be at least 5 people in Finance and accounting department. The role of Chief Accountant is rather important in the company. They are personally responsible for the errors which are found by tax authorities. In general, the administration function should be bigger than in Sweden due to more bureaucracy, whereas production function would require similar amount of people.
What kind of material do you buy locally now and plan to buy in the future? They buy certain components locally (i.e. powder, steel), however, the quality of the products delivered by suppliers is not consistent and can vary. This in turn affects the quality of the final product produced by Company B.

In Russia you should always make an advance payment for materials to suppliers.

What markets are you supplying with the products produced in Northern Russia? 40% of their market is in Siberia (oil companies) and Ural area. They also export to Ukraine, Kazakhstan, and Belarus. There are no duties for exporting to Belarus. Maybe some fees for export to Ukraine and Kazakhstan.

A big problem is VAT (value added tax) refund. The VAT in Russia is 18%. For example, if Company B factory exports something directly then it can take them up to 1 year to get VAT refund. Additionally, a lot of papers and documents are required. However, if the factory sells its products to sales company and then the sales company exports the product then it is faster to get VAT refund. It takes about 3 months for their sales company to get VAT refund. However, the time it takes to get VAT refund depends on the tax authorities the company works with. At the beginning of company’s operations authorities control extra carefully those companies. In general, the attitude of the authorities to a new company is that it wants to full the authorities.

EMPLOYEES
How difficult was it to find management staff in the area of production in Russia? Right now the management is Russian. In the board of directors they have one Swedish person and one Russian person who is the owner. At the beginning Swedish was working as a production manager for one year.

If a company works the Swedish way in terms of attitude to people, than it would be easier to attract employees to the company. For example, Company B regularly pays the salaries, all salary is official, employees get medical insurance, etc.

It was difficult to change employee’s attitude since they were used to work the old way. In their opinion it is easier to buy old building and hire new people than to take over an existing factory with all employees.

If to start up production in Russia then it is necessary to have some Swedish person working permanently in at that factory for several years. At the start up stage a lot of people came from Sweden to help with it. For example, COMPANY B has Production and Sales Managers who are Russians. They do not always cooperate very easily with each other, and the Swedish person has to intervene sometimes in their relations. Russian management is stronger and more dictatorship style than in Sweden. In their opinion it is better to raise and train own management staff from within the company rather than hiring somebody directly on the top-management position externally.

What is the salary level?
Salary increase is the same as inflation. It is harder to find people with the knowledge of English and special education. The average salary at the factory in Northern Russia is about 700 EUR. This is for the positions that require some previous education with process industry and do not require special skills. In Moscow the salary would be 15-20% more than in Northern Russia, whereas in areas which are located further from Moscow they would be 50% lower (i.e. Southern Russia). In their opinion the salary of the welder would be higher than the one they pay to production staff.

**BUREAUCRACY AND CORRUPTION**

**Customs.** At the beginning Company B was importing products to Russia from different places in Sweden and it was difficult. However, later they started sending all products through one customs station from Sweden to Russia and it became easier to deal with customs.

In their opinion there is more corruption in Ukraine than in Russia.

**SOME OTHER DISCUSSIONS**

Caterpillar is welding frames near Northern Russia, Russia, and send them abroad (i.e. to factory in Belgium) for assembly. If they were to assemble the machines in Russia then they would have to charge a lower price for the final machines. Russians do not believe in the quality of things that are produced in Russia.

Metal sheets are coming from the area in Ural or Eastern Ukraine.
Appendix D: Factory Layout, 3,250 m²

Layout for factory with 3,250 m² area

Area for possible expansion

Inkomende gods, till platsbygg och maskiner

Administrativa kontor, ca 340 m²

Yta under skäredask för godsvättning, container m.m.

Yta för lätta produkter

Bufferyta för lastning avgående gods
Appendix E: Factory Layout, 7 150 m²
Appendix G: Map of Regions in Russia

Volga
15,277,892 ha

Southern
11,110,836 ha

Central
7,379,215 ha

North-west
384,814 ha

Volga
15,277,892 ha
Appendix H: Center of Gravity
### Appendix I: Values for X and Y coordinates

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Center-of-Gravity Coordinates

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## Appendix J: Salary Breakdown

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