Adoption of Automation in the Horticulture Industry: A Case Study at a Robotics Company in the U.S. and Canada

SIMON JOSEFSSON
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by

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Acceptans av Automatisering inom Hortikultur: En Fallstudie på ett Robotföretag i USA och Kanada

av

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Abstract

The purpose of this thesis is to fill the previous research gap concerning automation in the horticulture industry by discovering the adoption of automation in the U.S. and Canada, exploring the possibilities of introducing autonomous solutions and provide recommendations as to how this could create opportunities for small robotics companies targeting the industry. A case company in the U.S. and Canada was used as an example of a small robotics company for the case study. Two research questions were formulated:

RQ1: Which major tasks in the horticulture industry should a small robotics company aim to automate?
RQ2: What are the barriers for companies in the horticulture industry to invest in automated solutions?

A mixed methods research with a pragmatic, inductive and exploratory approach was employed. The primary source of data was gathered from surveys, due to the geographical diversity of the region studied. The surveys reveal that the average level of automation across all respondents averaged at 47%.

Given the strategy of the case company, a small robotics company is argued to aim to automate the following tasks: placing plant liners, sticking cuttings and planting seed, spacing of plants and containers, plant pruning, harvesting and grading production, and pesticide application.

The horticulture industry is showing low barriers to invest in automation. The relatively high levels of automation are leading to increased trust in automation and further investments in automation. This is shown in the technology being perceived as useful amongst 75-85% of respondents and perceived as easy to use amongst 94% of respondents.

Key-words

Horticulture automation, average level of automation, barriers to investing, nursery, greenhouse, case study, U.S., Canada, technology acceptance model, automation acceptance model
Sammanfattning
Syftet med denna avhandling är att fylla det tidigare forskargapatet om automatisering inom hortikultur, genom att utforska acceptansen av automatisering i USA och Kanada, utforska möjligheterna att införa autonoma lösningar och ge rekommendationer om hur detta kan skapa möjligheter för små robotföretag som riktar sig mot branschen. En fallstudie på ett robotföretag i USA och Kanada användes som ett exempel på ett litet robotföretag. Två forskningsfrågor formulerades:

RQ1: Vilka stora uppgifter inom hortikultur bör ett litet robotföretag sträva efter att automatisera?
RQ2: Vilka hinder finns för företag inom hortikultur att investera i automatiserade lösningar?

En blandad metodforskning med ett pragmatiskt, induktivt och utforskande tillvägagångssätt användes. Den primära källan till data samlades från undersökningar, på grund av den geografiska mångfalden i regionen som studerades. Undersökningarna visar att den genomsnittliga automatiseringsgraden för alla svarande i genomsnitt uppgick till 47%.

Med tanke på bolagets strategi rekommenderas ett litet robotföretag att automatisera följande uppgifter: rada upp planter, stick och plantera frön, skapa avstånd mellan växter och behållare, beskära och kvalitetsgranska skördar, och applicera bekämpningsmedel.

Hortikulturindustrin visar låga hinder för investeringar i automatisering. De relativt höga automatiseringsnivåerna leder till ökat förtroende för automatisering och ytterligare investeringar i automation. Detta framgår av tekniken som uppfattas som användbar bland 75–85% av de svarande och uppfattas som lätt att använda bland 94% av de svarande.

Nyckelord
Automatisering i hortikultur, genomsnittlig automatisering, barriärer för att investera, handelsträdgård, växthus, fallstudie, USA, Kanada, modell för acceptans av teknik och automatisering.
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<th>Abbreviation</th>
<th>Explanation</th>
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</thead>
<tbody>
<tr>
<td>USC</td>
<td>The U.S. and Canada</td>
</tr>
<tr>
<td>ALMA</td>
<td>Average level of mechanisation or automation</td>
</tr>
<tr>
<td>MA</td>
<td>Mechanisation/automation</td>
</tr>
<tr>
<td>TAM</td>
<td>Technology acceptance model</td>
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<tr>
<td>AAM</td>
<td>Automation acceptance model</td>
</tr>
<tr>
<td>PU</td>
<td>Perceived usefulness</td>
</tr>
<tr>
<td>PEU</td>
<td>Perceives ease of use</td>
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1 Introduction

This chapter presents the current situation of the horticulture industry and the opportunities that arise for robotics companies that arise from an increased automation of this industry. The following sections describe the background and problematisation of the horticulture industry, the purpose of the study, research questions answering to the problem formulation, the scientific contribution of the study and its delimitations. The last section is a presentation of the case company at which the study was conducted. Chapter 2 presents the relevant literature and theoretical framework for the report, Chapter 3 the research design, Chapter 4 the results of the empirics, Chapter 5 discussions of results and recommendations towards the case company and Chapter 6 conclusions and suggestions for future research.

1.1 Background

The history and development of the horticulture industry are similar to the agriculture industry. However, while agriculture concerns the process of cultivating plants and livestock primarily for food purposes, the horticulture industry mostly cultivates plants for non-food purposes, such as landscaping, ornaments and to help restore damaged native ecosystems. The plant types commonly cultivated in horticulture are ornamental plants, flowers, trees, and shrubs. While the two industries share many similarities, the biggest difference is that the crops grown in the horticulture industry does not include large-scale production to the same extent. (Province of British Columbia, 2019; von Baeyer, 2010)

The horticulture crops are grown in either greenhouses or plant nurseries. The main difference is that greenhouses are enclosed and allow regulations of the environment, such as temperature and humidity levels, while nurseries grow their plants in outdoor fields. The plants grown here are also protected from the weather and pests. As such, the plant variety often differs depending on whether they are grown in a greenhouse or nursery. (Province of British Columbia, 2019; von Baeyer, 2010)

The typical supply chain in the horticulture market is illustrated in Figure 1, where nurseries and greenhouses produce crops that are sold to consumers through wholesalers and/or retailers. (IBISWorld, 2019a; IBISWorld, 2019b)

![Figure 1. Typical supply chain in the horticulture market. (own work)](image-url)
Over the last five years, horticulture producers in the U.S.-Canada (USC) region have faced problems with remaining relevant in the supply chain of their market, partly due to increased competition from low-cost countries. Nurseries and greenhouses in South America are exporting cheaper products to the horticulture market in the USC region, creating a price war amongst producers. The market is already in a mature stage and is characterised by declining profits. Smaller retailers selling the end products are being forced out of business while the large retailers gain an increased purchasing power. The price pressure extends all the way to wholesalers, which are now threatened by declining profit margins. (IBISWorld, 2019a; IBISWorld, 2019b)

The market not only has problems generating revenue. The labour costs are also strikingly high - almost three times the average labour costs of all industries in the USC region. With profits already being slim and under the average for industries in the USC region, nurseries and greenhouses must increase their profit margins to stay competitive in the global environment or risk going out of business. (IBISWorld, 2019a; IBISWorld, 2019b)

The main reason for the high labour costs is the fact that the horticulture industry traditionally has been characterised by significant manual labour with repetitive tasks that could be more difficult to automate. Some of the tasks still require the dexterity of human hands; however, there are several tasks performed by a human that could be automated. The nature of many of these tasks often includes stooping, heavy lifts and exposure to chemicals, such that injuries related to the workplace are frequently occurring. The stakeholders in the industry are not only expressing a problem with labour shortage but also a high employee turnover of the labour they manage to find. (IBISWorld, 2019a; IBISWorld, 2019b; von Baeyer, 2010)

One possible solution to address these labour related issues is to replace manual labour in certain tasks, through autonomous solutions in the crop production. With artificial intelligence, the autonomous solutions can perform many of the tasks in nurseries and greenhouses today performed by human labour.

1.2 Problem formulation

The horticulture industry in the USC region is facing declining profits due to high labour costs, employee turnover and increased competition from low-cost countries that push price reductions through the supply chain. Nurseries and greenhouses must change this negative trend and increase their profit margins to stay competitive in the global environment or risking going out of business. One possible option is to fill the labour gap with autonomous solutions, which in turn challenges robotics companies to accommodate the needs expressed by nurseries and greenhouses.

Previous research in the field is lacking, both in terms of the region studied, up-to-date information about automation in the horticulture industry, and its implications specifically for robotics companies.
1.3 Purpose
The purpose of this study is to fill the research gap concerning automation in the horticulture industry by discovering the adoption of automation in the USC region, exploring the possibilities of introducing autonomous solutions and provide recommendations as to how this could create opportunities for small robotics companies targeting the industry.

1.4 Research Questions
The following research questions are formulated to address the problem formulation:

**RQ1:** Which major tasks in the horticulture industry should a small robotics company aim to automate?

**RQ2:** What are the barriers for companies in the horticulture industry to invest in automated solutions?

1.5 Scientific Contribution
The field of autonomous solutions in nurseries and greenhouses is in a developing stage and there is a limited number of studies conducted within this field in recent years, especially on a commercial scale. Most previous studies concern product specifics of either autonomous greenhouses or robots. (Abas & Dahlui, 2015; Masuzawa et al., 2017, Wang et al., 2019) A current state-of-the-art report reviews the most recent advances in automation in greenhouses but also focus solely on the technical aspects. (Tangarife & Díaz, 2017) While the technical aspects are fundamental, the potential market for these autonomous solutions is ultimately determining their commercial success. Wang et al. mention that there may be barriers to deploying robots in greenhouses that may hinder the success of current technologies. (Wang et al., 2019)

This study contributes to the literature by filling the research gap concerning automation in the horticulture industry, through examining barriers and opportunities for implementing autonomous solutions in nurseries and greenhouses. The study discovers the adoption of automation and how robotics companies can use this information to better service the needs in the industry. A system perspective is applied, that Blomqvist and Hallin (2015) describes as the following three levels:

1. The individual and organisational level, from the perspective of management and employees,
2. The functional level, from the perspective of processes and production,
3. The industrial level, from the perspective of a wider industry.

To effectively conduct a study, all these levels must be considered in a different context. The report shows how automation affects all these three levels in the system perspective. Given the wide extent of decisions that affect investments such as autonomous solutions in a nursery, the
industrial level is appropriate for including dimensions associated with industrial development and regulations. The functional and organisational levels are used when analysing specific cases. For example, the functional level is appropriate when analysing the production chain of nurseries and greenhouses. Likewise, the individual and organisational level are appropriate when analysing the case company, described in Section 1.7.

1.6 Delimitations
To enable deeper analysis and provide a clear contribution to existing literature, this study is focused on the following aspects:

- The horticulture market of the USC region, being the area of interest for the case company,
- Nurseries and greenhouses with more than 100 acres (approximately 40 hectares) of farmable land that mainly focus on the production of potted plants. Companies with smaller areas of farmable land are considered less viable to gain the same benefits from investing in automation and are therefore excluded from the study,
- An exploratory and inductive research design that aims to generate insights about the research area. Other research designs may yield different results,
- The research explores research questions with both quantitative and qualitative elements, which is explored with the use of a mixed method research and survey methodology. Because of this, a pragmatic approach is employed, as discussed in Section 3.1. Another option is to study these research questions separately, with the use of different research designs respectively.
- The applications and usage aspects of the technologies examined, not the technology itself. That means the technical feasibility will not be assessed for the automation,
- An approach that does not assess costs associated with automating specific tasks, and instead is customer- and task-centred.

1.7 Case Company
This study combines knowledge from literature and survey results and applies it in a case study at a robotics company, based in the USC region, that is targeting the horticulture industry. To maintain anonymity, the company will be referred to as Company X throughout the report. The purpose of involving a case company is to provide real-life applications and insights regarding strategies towards an automated industry.

Company X was founded 2013 and is designing, developing and manufacturing autonomous solutions that provide solutions primarily for the plant nursery industry. The company currently employs between 50 and 100 people, with most employees focusing on the designing and developing process. This size is what is referred to as a small robotics company in RQ1. The solutions mainly focus on autonomous solutions used in the local chain of potted plant processing and transportation with abilities such as autonomous navigation and collision avoidance while working cooperatively with other robots and humans. The company strives to attain an automated chain of potted plant processing and transportation that is cheaper, safer
and more efficient than current manual labour. In the longer term, the company intends to automate even more tasks in the horticulture industry and cover bigger parts of the production chain.

While the company is in a young phase and is striving to broaden its product portfolio, internal resources are limited, as in many smaller companies. Prioritising R&D efforts is therefore key to allocate these resources in the most efficient way. Before resources are invested in new projects, the company is interested in scouting market opportunities and evaluating planned products. As Company X has discovered a strong competition amongst robotics companies for the industry and region, one strong priority is exploiting market opportunities that may have less competition.

Since the endeavour of automating certain tasks in the horticulture industry is a complex task, a side memorandum for Company X is presented in Appendix B, covering certain important feasibility aspects. This information is not required to answer the research questions of this report but help support decision making for robotics companies.
2 Literature Review and Theoretical Frameworks

This chapter presents the literature and theory of importance for the study. It covers the review of previous research with a recollection of findings from relevant areas. These include the characteristics of the horticulture industry in the USC region, automation adoption in the horticulture industry, and frameworks describing the most important aspects affecting the technology acceptance.

2.1 Horticulture Industry in the USC region

Company X is located in the USC region and is targeting plant nurseries and greenhouses primarily in Canada and the United States. The horticulture industry, as defined in Section 1.1, is therefore analysed for the USC region in Section 2.1.1 and 2.1.2 below.

The industry studied in this section concerns the growing of nursery and floriculture products, such as shrubbery, cut flowers, ornamental plants, and short-rotation woody crops (crops bred for ultra-high rate of growth). These plants may be grown in covered greenhouses or in open fields to accommodate different varieties. As opposed to many agricultural practices, this industry is far less volatile because of its indoor production capacity and reduced risk of exposure to the elements. Information about this specific horticulture industry in the U.S. and Canada is presented below. (IBISWorld, 2019a; IBISWorld, 2019b; von Baeyer, 2010)

2.1.1 Horticulture Industry in Canada

The two key factors affecting the growth of this industry in Canada are increased competition from low-cost countries and a recent depreciation of the Canadian dollar. Lower-priced imports have taken over a bigger part of the Canadian horticulture market at an increase of 6% per year, now accounting for 30% of the market. (IBISWorld, 2019b)

As of 2018, 1659 Canadian producers are operating in the horticulture industry and most of these are small, independent farms with small market shares. Many nurseries and greenhouses of this size employ only a limited permanent staff and part-time seasonal workers as needed, leading to a big fluctuation of employment for one year. Increasing competition has for the last years caused more businesses to show signs of consolidation and higher default rates. Nearly 25% of all nurseries in Canada have been forced out of business in the last five years and the outlook is a continuing trend. Increasing wages and difficulties to find labour are two important reasons. The industry is in a mature and declining phase in terms of production, relative revenue and number of industry operators. This means the companies that remain in the business become fewer but bigger, and economies of scale is one of the key success factors for these businesses, ultimately resulting in increased profit margins and investment opportunities. (IBISWorld, 2019b)

Wage costs represent the largest industry cost, over 43% of revenues, and are expected to increase even further. This cost is already four times the average labour cost of industries in Canada. This can be put into perspective of the average labour costs for all industries,
amounting to about 11%. This is significantly higher than in other agricultural industries since growing potted plants and flowers is much more labour intensive. (IBISWorld, 2019b)

The current industry outlook of the mature, centralised market with economies of scale and declining efforts in product development suggests that a bigger fraction of wages will be shifted towards operational work in the future. (IBISWorld, 2019b)

The biggest exporting countries of horticulture products into Canada are the U.S., Colombia, the Netherlands, and Ecuador, constituting about 87% of all imports. (IBISWorld, 2019b)

2.1.2 Horticulture Industry in the U.S.

The U.S. horticulture industry is very similar to the Canadian horticulture industry but is significantly bigger. There are 32,915 producers of the horticulture industry in the U.S., which represent 95% of producers in the USC region. A big part of the Canadian horticulture market and its outlook are dictated by the demand in the U.S., as more than 99% of Canadian horticulture exports are sold to the U.S. The industry situation in the U.S. has also been tough due to increased competition from low-cost imports. The U.S. is home to several large-scale retailers that have increasingly purchased from imports and forced down prices, volumes and revenues for US farmers. Although the U.S. is one of the biggest producers of crops and nursery plants, most of the production is sold domestically and exports remain relatively low. (IBISWorld, 2019a)

Price war within the industry has led to a consolidation where larger farms have survived, while smaller players have been forced out of business. This is also leading to a centralisation of revenues and the average establishment being bigger. Profit margins peaked in 2014 and have declined since. Even though growers receive assistance from various governmental programs, they have failed to keep the industry growing. (IBISWorld, 2019a)

In the coming years the USD trade-weighted index, the effective exchange rate of the USD, is expected to decline. This would boost industry revenue due to increased exports and declining value of imports. The US horticulture market is in the same mature, declining stage as the Canadian horticulture market. The consolidation is strongly due to increased competition from low-cost imports and bigger companies expanding their domestic market due to more integrated and efficient transport. Likewise, as in Canada, the smaller businesses are those that lose market share in favour of bigger companies and international competition. (IBISWorld, 2019a)

The biggest exporting countries of horticulture products into the U.S. are Canada, Colombia, the Netherlands, and Ecuador, constituting about 80% of all imports. (IBISWorld, 2019a)

2.2 Level of Automation in the Horticulture Industry

There are not many studies found that are considering the adoption of automation in the horticulture industry. Most of these concern technical feasibility, which is outside the scope of
this study. Of the literature review considered, there is one study that is especially interesting due to the similarities with this study. This is a study brought out by Posadas et al. (2008) in the beginning of the 2000’s, where the level of automation is evaluated in three selected states in the U.S. This work is the most relevant found on the subject and will be used as a comparison. (Posadas et al., 2008) Before proceeding with details, there are first three disclaimers that need to be clarified:

1. The material for the result was gathered between 2003 and 2005, over a decade ago by the writing of this report. Due to the fast-phased nature of robots and artificial intelligence technology, some of the information is expected to be outdated.
2. The material is gathered only from three selected states in the U.S. This report concerns a broader market of the whole USC region, that may not share the same characteristics.
3. The study does not distinguish between automation and mechanisation. The ranking system used for determining the average level of mechanisation or automation (ALMA) is stated as: “The level of automation or mechanisation would range from 0% to 100%, where 0% = task was performed manually or 100% = task was fully automated or mechanised.” As this report is focused on automation specifically, this will make it difficult to compare results as it is not clear from the study by Posadas et al., (2008) which tasks are mostly mechanised or automated.

The study by Posadas et al. considers a survey conducted amongst 87 randomly selected nurseries and greenhouses. The purpose of the survey was to determine a socioeconomic profile of horticulture workers and evaluate the impact of automation on their employment, safety, earnings, retention rates, and skill levels. Posadas use the findings to develop an index of the level of automation or mechanisation among nurseries and greenhouses in Mississippi, Alabama and Louisiana, and to measure the socioeconomic impact of automation on the factors brought up in the study. (Posadas et al., 2008)

The operations in nurseries and greenhouses that can be enhanced with technology can be divided according to two steps: mechanisation and automation. Mechanisation is defined as the replacement of a human task with a machine. Automation, however, involves the entire process, integrating several operations and ensuring that different parts communicate with each other to ensure smooth operation. (Posadas et al., 2008)

Mechanisation is usually accomplished by assisting the employees with mechanical equipment, such as vehicles and conveyor belts, which can provide benefits like mechanical power, speed, repetition, safety and a greater potential for consistency and quality control. (McKinsey, 2016; Posadas et al., 2008) While automation, as this report focuses on, includes the benefits of mechanisation it also provides greater flexibility and decision-making. For instance, automated solutions can mimic the behaviour of human labour to a much greater extent compared to mechanised solutions. The flexibility can prove useful in instances where seasonal labour is used to cover spikes in production, assuming capital is not tied into expensive investments that are excessive for the rest of the year. (Posadas et al., 2008)
Posadas et al. (2008) conducted an extensive study through surveying nurseries and greenhouses in three in the U.S. The surveys ask about factors such as level of mechanisation/automation (MA), sales, employment, worker’s earnings, safety and retention rates. The study then maps the relationship between the socioeconomic impact of MA and the rest of the factors answered in the study. (Posadas et al., 2008)

The level of automatisation was determined by analysing how each major task was performed (manually or different degrees of mechanisation and/or automation) and averaging out these values over participants. A total of 19 tasks were identified in the production and internal supply-chain of these businesses. For nurseries, 15 major tasks were included in this analysis. For greenhouses, ten major tasks were included. Businesses comprising of mixed nurseries and greenhouses would perform all these 19 tasks. These are all presented in Table 1, where green represents tasks performed by the category and red represents tasks not performed by the category. (Posadas et al., 2008)
<table>
<thead>
<tr>
<th>Task no.</th>
<th>Task description</th>
<th>Nursery</th>
<th>Greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Media preparation (the growing medium which seeds are planted in, for example soil/compost that helps retaining water)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Filling containers with substrate (materials with the right physical properties added to grow seeds in, for example mixtures of peat, bark, and other organic substrates)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cutting and seed collection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cutting and seed preparation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Placing plant liners, sticking cuttings, and planting seed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Environmental control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Moving containers from potting to transport vehicle for movement within the nursery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Transporting containers to field in nurseries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Removing containers from transport vehicle and placing in the field</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Spacing of plants and containers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Harvesting and grading production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Picking plants up and loading onto transport vehicle at time of sale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Removal of plants from transport vehicle and placing in holding area awaiting shipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Picking up plants from holding area and loading onto delivery vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Jamming plants for winter protection (crowding plants together to help them stay warm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Plant pruning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Fertiliser application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Pesticide application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Irrigation application and management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The ALMA is computed as the average percentage through all 15 tasks in nurseries or 10 tasks in greenhouses. Table 2 shows the values for the three types of operations. (Posadas et al., 2008)

Table 2. ALMA in nurseries and greenhouses. (Posadas et al., 2008)

<table>
<thead>
<tr>
<th>Type</th>
<th>ALMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursery</td>
<td>13</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>28</td>
</tr>
<tr>
<td>Mixed nursery and greenhouse</td>
<td>19</td>
</tr>
<tr>
<td>All categories combined</td>
<td>20</td>
</tr>
</tbody>
</table>

The results from the survey show that about 20% of the major tasks in the horticulture industry are performed with some form of mechanisation and/or automation. At least 8 of the 15 major tasks were performed by workers. Very few, if none at all, of nurseries and greenhouses, were using mechanised or automated systems for task number 3, 4, 5, 9, 10, 11, 12, 13, 14, and 15. On the other hand, a significant number of nurseries used mechanised or automated systems for task number 1, 2, 7, 8, 16, 17, 18, 19. Many greenhouses used mechanised or automated systems for task number 1, 2, 6, 17, 18, 19. (Posadas et al., 2008)

2.3 Technology Acceptance

This report relates to the phenomenon associated with emerging technology making its way into already established industries. To help understand how the horticulture industry view automation and structure the answer to RQ2, relevant frameworks are brought up and discussed. These include, but are not limited to, the Technology Acceptance Model (TAM), the Technology Acceptance Model 2 (TAM2), the Technology Acceptance Model 3 (TAM3), and the Automation Acceptance Model (AAM). There are many theoretical frameworks created, several of which being extensions of already existing ones. The main reason why this selection has been done for this study, is because these frameworks not only are widely recognised but also developed specifically for technical applications. In Section 2.3.5 the TAM and AAM are argued to be the most suitable frameworks of this selection for understanding automation in the horticulture industry.

2.3.1 Technology Acceptance Model

The TAM is a framework introduced by Fred Davis in 1986, showing how people come to accept and use technology by studying computer acceptance. The model is an extension of a previous theory of reasoned action developed by Ajzen and Fishbein. As seen in Figure 2, the model includes and tests two beliefs:

1. Perceived Usefulness (PU), the degree to which a user believes the technology would enhance job performance,
2. Perceived Ease of Use (PEU), the degree to which a person believes that the use of technology would be free from effort.

The usefulness and ease of use is measured in terms of how it is perceived for the user. There are clearly other factors influencing the acceptance and these are referred to as external variables, including system characteristics, training, user involvement in design, and the nature of the implementation process. (Davis, 1986) Davis argued that these external factors directly impact the PU and PEU of the technology, according to the relationship plotted in Figure 2. The original TAM had a construct called attitude toward using, placed between the PU, PEU and the behavioural intention to use. Davis and Venkatesh later showed however that both PU and PEU were shown to have a direct influence on behavioural intention, thus eliminating the need for the attitude construct. The behavioural intention to use the technology is argued to be the final factor affecting the actual use of said technology for that user. The final model is shown in Figure 2. (Venkatesh & Davis, 1996; Venkatesh & Davis, 2000)

![Figure 2. Technology acceptance model. Venkatesh & Davis (1996, p. 453).](image)

The TAM has come to be the most used framework in predicting information technology adoption (Lee et al., 2003; Lee & Jun, 2007) and is cited in most of the research discovering users’ technology acceptance. It has been implemented in a variety of context beyond the mere acceptance of computers as initially designed for, such as mobile banking, online retailing, e-books etc., and shown to be useful for understanding technology acceptance in these cases. It has become well-established as a simple yet robust model for predicting user acceptance for technology (Park et al., 2012; Rondan-Cataluña et al., 2015; Sanchez-Franco, 2010)

Interestingly, the model does not talk about the technology itself but rather how the user perceives the technology. This makes the model simple to use and applicable to a wide range of situations which may help to explain its popularity. Obviously, this also incurs limitations that are technology-specific or based on the user and not explained by the model. For instance, the TAM does not describe how to make technology useful or easy to use. Therefore, it might not be useful to be used as a template when developing new technology. Another limitation is that the TAM also assumes that people plan their actions and that they are rational in their behaviour by evaluating the usefulness and simplicity of the technology, which is not necessarily true. (Davis, 1986; Davis, 1996)
2.3.2 Technology Acceptance Model 2

After the original TAM was introduced, Venkatesh and Davis did an extension of this called TAM2. It aims to provide more detailed explanations for the reasons user found a given system useful. Across empirical testing of TAM, PU was shown to be of increasing importance for the behavioural intention. TAM2 therefore incorporates additional theoretical constructs that spans social influence processes (such as subjective norm and image) and cognitive instrumental processes (such as the job relevance and output quality), according to Figure 3. In TAM2, the subjective norm (perceived social pressure to engage in behaviour or not) is argued to affect both the behavioural intention directly and through PU. (Venkatesh & Davis, 2000)

![Figure 3. Technology acceptance model 2. Venkatesh & Davis (2000, p. 188)](image)

2.3.3 Technology Acceptance Model 3

A few years later, with the same intention as in TAM2, Venkatesh and Bala developed TAM3 through testing in real-world settings of IT implementations. While TAM2 added the antecedents of PU, TAM3 extends TAM2 and enlarges it by the constructs that precede PEU, shown in Figure 4. The authors argue for TAM3 using the four different types of determinants of PU and PEU: individual differences, system characteristics, social influence, and facilitating conditions. Specifically, they build on anchoring (computer self-efficacy, computer anxiety, computer playfulness, and perceptions of external control) and adjustment framing (perceived enjoyment and objective usability) of human decision making. (Venkatesh & Bala, 2008)
2.3.4 Automation Acceptance Model

The AAM was introduced by Ghazizadeh et al. in 2012 and is an extension of the original TAM. The authors argue that two research communities, cognitive engineers and information systems have studied how attitudes toward technology affect reliance and use but have done so independently. The information systems community developed the TAM that considers the effect of macro-level factors (external variables) as they affect PU and PEU. In contrast, the cognitive engineers’ community has examined the factors influencing users’ belief and perceptions on a micro-level in terms of how automation is adopted and used. (Ghazizadeh et al., 2012)
Ghazizadeh et al. argue that the AAM integrates these two perspectives to provide a more comprehensive view of specifically automation acceptance. The model has previously mostly been applied and proven useful in the cases of driving assistance systems, such as lane departure detections, automatic braking and intelligent speed control. Researchers argue this is one of the most critical new applications of automation, as there obviously are high risks at stake. The AAM has been argued to be helpful in understanding the adoption of automation in these cases. (Beggiato & Krems, 2013; Ghazizadeh et al., 2012; Hengstler et al., 2016; Kwee-Meier et al., 2016; Körber et al., 2018; Nees, 2016; Reagan et al., 2018) It will in this report be investigated further to which extent the AAM can describe automation in the horticulture industry.

The AAM considers the dynamic and multi-level nature of specifically automation use and the influence of use on attitudes. Both the cognitive engineers and information system research have investigated the relationship between humans and automation and concluded two themes that merge from the findings: task-technology compatibility and trust in automation. As seen in Figure 5, TAM constitutes the core of AAM. The difference is that the two constructs of compatibility and trust have been added, both affecting PU and PEU directly. These two constructs will be discussed below. (Ghazizadeh et al., 2012)

**Figure 5. Automation acceptance model. Ghazizadeh et al. (2012, p. 45)**

**Task-technology Compatibility**
Automation is not a singular concept but varies across different levels of automation, ranging from fully manual to fully automated. Systems that heavily restrict an operators’ behaviour or force behavioural change generally have a high level of automation and are less likely to be adopted. High levels of automation can lead operators to rely on the automation when it fails,
and low levels of automation can lead to poor performance when the system exceeds the capacity of the operators. (Ghazizadeh et al., 2012)

The task-technology compatibility is described as being the “right level of automation” in a system for performing a certain task. Inappropriate level of automation reflects a poor task-technology compatibility, either when it exceeds the operator’s desired level of system autonomy or when it falls short of the operator’s desired level of automation. A high level of automation is necessary if a task exceeds the capacity of the human. For example, the avoidance of a car collision may require a reaction time much shorter than any driver, only achievable by automation that has full authority to brake. The task-technology compatibility is argued to go beyond technically competent automation and also match the automation design objectives to the task complexity, predictability, and criticality are equally important. (Ghazizadeh et al., 2012)

**Trust in Automation**

The other construct, trust in automation, depends on the degree of experience with automation. AAM suggests that a user’s past experience can affect the likelihood of adopting new technology. Several theoretical studies argue that predictability, dependability and faith are the three factors that affect trust the most. It is also supported that the importance of these factors shifts depending on the degree of experience of the user, although studies show conflicting answers on how this shift happens. (Ghazizadeh et al., 2012)

One theoretical study on the effect of experience in trust suggests that people initially base their trust on the predictability of automation. As more experience is accumulated, dependability dominates the degree of trust. With long-term usage of automation, trust is argued to be driven by faith. (Muir, 1987) Another study suggests that in the initial stage of automation, faith rather than predictability is the strongest influence on trust. (Muir & Moray, 1996)

Regardless of the order, the notion that trust in automation is dynamic and improves with the time exposed is significant. This can help explain why automation is more accepted in already technologically advanced environments, and why experience with technology is associated with greater use of that technology. (Ghazizadeh et al., 2012) A study by Frohm et al. (2008) states that there is a direct link between level of automation and relative wage costs, where a higher wage cost correlates to a higher level of automation and vice versa. This would suggest that the USC region, with its relative high labour costs seen in Appendix B3, is more likely to both adopt and trust automation. (Frohm et al., 2008)

### 2.3.5 Comparison and Criticism

The main difference between the frameworks introduced in this chapter is that TAM2 and TAM3 contain more factors that are argued to influence the acceptance of technology. The TAM and AAM are more centred around the tasks performed. The author argues that the importance of subjective norm, the perceived social pressure to engage or not engage in a behaviour, is situational. This is because a single individual is more likely to make prompt
decisions that may be resource efficient, but the greater participation rate of groups generally generate decisions of higher quality. The groups are less likely to be influenced by external social pressure in the decision-making process. (Davis, 1986; Davis, 1996; Venkatesh & Davis, 2000; Venkatesh & Bala, 2008) As this report is targeting companies of a certain size with likely group decision-making, the TAM and AAM are believed to better represent the decision-making process in this case.

There are some disclaimers that need to be brought up and discussed regarding the chosen frameworks. While the TAM has a strength of being a simple and flexible drawback, it is also its drawback. Bagozzi argues that the most notable drawbacks of TAM are the lack of methods for identifying the determinants for PU and PEU, and the neglect of group, social, and cultural aspects of decision making. He criticises the TAM for lacking depth and that most of the extensions (for example TAM2, TAM3 and AAM) have constituted a broadening of TAM. Little research has deepened TAM by explaining PU and PEU more deeply, reconceptualising existing variables in the model, or introducing new variables that could explain how the existing variables produce the effects they do. (Bagozzi, 2007)
3 Research Design

This chapter describes the method of the research process used for this report. Considering the research questions of neither strictly quantitative nor qualitative nature, a mixed methods research was conducted. Due to the geographical diversity of participants, the primary source of data had to be gathered from surveys, as explained in Section 3.3.2. An explorative case study was conducted at a robotics company in the USC region.

3.1 Choice of Research Paradigm

Mixed methods research has been established as a third methodological movement, that complements the traditional quantitative and qualitative movements. (Tashakkori & Teddlie, 2003) While the movement has received criticism regarding the incompatibility between quantitative and qualitative data, alternative approaches have been developed to address the criticism. These approaches can be classified into three categories: the a-paradigmatic stance, a multiple-, or single paradigm approach. The first ignores paradigmatic issues completely, the second asserts that alternative paradigms are not incompatible and can be used together, while the third claims that both quantitative and qualitative research can be accommodated under one paradigm. It is argued that the application of a single paradigm for all methods will enable integration of research findings and is the most appropriate approach for mixed methods research. (Tashakkori & Teddlie, 2003; Creswell & Plano Clark, 2007)

The research paradigm is defined as “the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed”. (Kuhn, 1962) The four commonly agreed worldviews are post positivism, constructivism, transformative and pragmatism. Of these, only the transformative and pragmatism worldviews are considered compatible with mixed methods research. Although, the transformative paradigm is limited to a small subset of social research and can for this reason not be considered a paradigm for mixed methods. Post positivism and constructivism are closely identified with only a quantitative and qualitative research respectively, making neither suitable for mixed methods research. (Hall, 2013)

Pragmatism has gained considerable support as a stance for mixed methods researchers. (Feilzer, 2010; Johnson & Onwuegbuzie, 2004; Maxcy, 2003; Morgan, 2007) It is oriented “toward solving practical problems in the real world”, rather than assumptions about the nature of knowledge. (Feilzer, 2010) The choice of a mixed methods research design is based on the research questions of the research. The pragmatic approach is applied for this report, which considers combinations of methodologies from post positivism and constructivism. This mixed method is a requirement to answer the research questions, given the geographical diversity explained in Section 3.3.2. (Hall, 2013)

3.2 Choice of Research Design

The fast-phased nature of industrial automation means literature provides limited insight into the associated opportunities and problems of the horticulture industry. The frameworks
presented Section 2.3 are merely used to help understand the results from the empirics, not help form any sort of hypothesis. A similar study by Posadas et al. (2008) was published 11 years ago and might not be fully representative today. Given the scarcity of previous research in the field and lack of known theory or phenomenon in the field to use as a basis for the research, any formulation of a hypothesis was difficult.

For this reason, an inductive and exploratory research approach was employed when sourcing knowledge from outside the realm of academia. (Blomkvist & Hallin, 2015) Sandhusen distinguishes between exploratory research resulting in a range of causes and options for a solution to a problem, while conclusive research identifies the final information that is the only solution to an existing problem. (Sandhusen, 2000) In an inductive approach, the goal of the method is to search for patterns from observations throughout the research process and develop theories for those patterns. This process is visualised in Figure 6. (Blomkvist & Hallin, 2015)

![Figure 6. The bottom-up reasoning of the inductive approach. (own work)](image)

The explorative approach also argues for the use of an explorative case study, where the combined knowledge from literature and surveys was applied in a case study at Company X. (Blomkvist & Hallin, 2015) The support provided valuable insights regarding current technology and strategies towards an automated industry. Given the type of research questions evaluated in this report, “what/which”, justifies an exploratory study. The exploratory approach is also appropriate when the area is characterised by a lack of preliminary research. For this study, there is only preliminary research conducted within three selected U.S. states, where there is no previous research found for other states or Canada. Considering the research covering technology acceptance in the horticulture industry, the case study is meant to include quantitative and qualitative elements and give insights beyond statistical results but also behavioural conditions. (Yin, 2003)

### 3.3 Choice of Data Collection

This section describes the data collection process used to conduct this study. To give information both from within and outside the realm of academia, the process was divided into two parts: a literature study and surveys that are discussed individually below. The goal is to generate data that can help answer the research questions of this report.
3.3.1 Literature Review

The first part of the data collection process consisted of a literature review. Literature has been sourced from Elsevier’s Scopus database, the largest abstract and citation database of peer-reviewed literature. Keywords used for finding the information in the literature review are shown in Table 3.

Table 3 - Keywords used for literature study.

<table>
<thead>
<tr>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>plant, grow*, nursery, greenhouse, automati*, automated, horticulture, agriculture, robot*, labour, feasib*, technology, acceptance, sustainab*, production chain</td>
</tr>
</tbody>
</table>

A combination of these keywords was used to saturate the inbound data sourcing and provide different perspectives but without a strictly technical focus. Additional constraints were added onto the literature of strict technical nature, as the rapid development causes articles to become dated fast. For that reason, only technical literature published since 2005 was considered. All relevant information found was considered for the final recommendations.

3.3.2 Surveys

Nurseries and greenhouses that fulfil the criteria in Section 1.6. were identified. A list of officially registered nurseries and greenhouses was obtained from authorities in respective countries. For the U.S., the information was sourced from the Census of Horticulture at the United States Department of Agriculture. (USDA, 2019) For Canada, the information was sourced from Infohort at the Canadian Agri-food Sector Intelligence. (Agriculture and agri-food Canada, 2019) While bigger companies are expected to be more likely to invest in automation, the companies were selected randomly, and the sample is therefore expected to be representative for the industry without skewness in terms of company size.

Although unstructured interviews with open-ended questions provide uncontested flexibility and is a natural choice for exploratory research, these were not possible to conduct because of three reasons:

1. Conflicting time zones and geographical diversity made it difficult to both find time slots and a mutual platform for conducting interviews with companies,
2. Many companies were not able to participate in interviews and preferred to answer a survey instead. A survey was expected to generate a higher response rate and thereby results that better represent the population.
3. Sourcing a sufficient amount of data from interviews would not have been possible given the time constraints of this report. The material for the study by Posadas et al. (2008) took several years to gather due to the interview methodology.
For these reasons, written, self-administered email surveys were instead chosen as the data collection method from nurseries and greenhouses. Since the surveys were designed to address the research questions, they contain both qualitative and quantitative elements. These are estimating levels of automation on a five-grade scale (quantitative) and questions about country of operations, the tasks they prioritise the highest for automation, and their barriers to investing in automation (qualitative). The survey forms are found in Appendix A.

To give mutually exclusive and collectively exhaustive insights into the industry, three different types of businesses were targeted. Companies with operations in 1) only nurseries 2) only greenhouses 3) mixed nurseries and greenhouses. (Lee & Chen, 2018) The reason these are split up is to show characteristics not only of the horticulture industry but also specific types of growers.

The total number of producers in the USC region is about 35,000 which represents the population size for the study. If the sample is less than 5% of the total population, Bartlett et al. (2001) argues that an appropriate survey sample for categorical data is calculated using the formula and standard values presented in Figure 7. The figure shows that the appropriate sample size is deemed 384 participants for all populations over 7680 companies. Since the companies had to be contacted manually by email and also screened to fulfil the criteria in Section 1.6, the time constraints of this report forced inadequate sample sizes to be used. A total number of 149 randomly selected companies were contacted, and 48 surveys were collected instead of the recommended 384. According to Figure 7, a sample size of 48 equals a margin of error of roughly 14% instead of the standard 5%, everything else equal. (Bartlett et al., 2001)

\[
\begin{align*}
N_0 &= \frac{\left(\frac{q}{2}\right)^2 \times (p)(q)}{d^2} \\
N_0 &= \frac{(1.96)^2 \times .5 \times .5}{.05^2} = 384
\end{align*}
\]

Where \( t \) = value for selected alpha level of .025 in each tail = 1.96, (the alpha level of .05 indicates the level of risk the researcher is willing to take that true margin of error may exceed the acceptable margin of error).

Where \( p(q) \) = estimate of variance = .25.

(maximum possible proportion (.5) * 1-
maximum possible proportion (.5) produces
maximum possible sample size).

Where \( d \) = acceptable margin of error for proportion being estimated = .05 (error researcher is willing to except).

*Figure 7. Sample size determination. Bartlett et al. (2001, p. 46)*
As found in Section 2.1.2, 95% of horticulture producers in the USC region are found in the U.S., which is reflected in the country representation in Table 4. Emails were sent to companies that fulfilled the criteria in Section 1.6 while meeting the country representation as shown in Table 4. Bigger companies are assumed to be more inclined to answer a survey about automation, as it is more relevant to them. The results do not however reveal any skewness in the responses in terms of an overrepresentation of bigger companies, as the survey design does not evaluate the company size of survey participants.

Table 4. Number of contacted companies and the country representation. (Agriculture and agri-food Canada, 2019; USDA, 2019)

<table>
<thead>
<tr>
<th>Country</th>
<th>The U.S.</th>
<th>Canada (CA)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>95%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td>Contacted companies</td>
<td>142</td>
<td>7</td>
<td>149</td>
</tr>
</tbody>
</table>

The survey participants were expected to exhibit a similar country representation as in Table 4. The results show that Canada was slightly overrepresented, by 11.1-13.8%, instead of the expected 5%. Since the surveys cover operational practices and strategic objectives of companies, specific expertise was requested in the email. Participants with a position of CEO/owner, president, director of operations/production or operations/production manager were asked to fill in the survey. Sourcing the relevant information from these stakeholders is crucial for a robotics company to understand the most current issues of the industry and ensure that their products matches expectations.

3.4 Data Analysis

The gathered data can be divided into two types of sources: primary and secondary. The primary sources consist of material gathered from the surveys. The secondary sources are interpretations and analyses based upon primary sources. Secondary sources used in this study are articles and reports found in the reference list.

3.4.1 Primary Sources

The surveys were conducted through the Google Forms online application and its results exported to and analysed in Microsoft Excel. A total of 48 survey results were gathered from the 149 surveys that were distributed, corresponding to a recorded response rate of 32%. No reminders were sent out due to the limited time allocated for gathering the surveys. According to a study by Baruch & Holtom (2008) that analyses the response rate used in organisational research, this is reasonable and within the range of acceptable response rates. The study analysed 490 different studies that utilised surveys, where the lower spectrum of response rates was just around 32%. (Baruch & Holtom, 2008) Due to the anonymity of the surveys, the characteristics of the survey respondents can only be measured in terms of country of...
operations. This metric is similar for the respondents to the 149 companies contacted and the whole market. Canadian producers were however slightly overrepresented in the results.

An open coding approach was used to manually organise the raw data and categorise codes that represent themes identified throughout the data. The framework used is described in Figure 8. As for analysing qualitative data, there are no universally applicable methods that can generate findings, which is why analytical skills play a role. This may lead to slightly different results for this step if the study is to be repeated. For this report, the following two methods described by Blomkvist & Hallin (2015) have been used:

1. Word and phrase repetition - identifying themes, patterns, and relationships through an inductive approach by scanning primary data for the frequency of themes and phrases brought up. The data analysis of the surveys followed the inductive framework seen in Figure 8.

2. Comparison between primary and secondary research. Using secondary research as inspiration for the primary research, findings can be compared, and differences discussed. As for this case, the secondary data is dated which may show differences in answers. The previous study by Posadas et al. (2008) provided several opportunities for data comparison.

![Figure 8. The inductive framework used for coding qualitative data. Creswell (2009, p. 247)](image-url)

The last step of the primary sources data analysis of the primary sources included summarising the data and link findings back to the objectives. No contradicting data was found and the main
themes describing the surveys were: tasks, cost/ROI/investment, options, knowledge, accuracy, product range, layout and customisation.

Participants provided many key insights required to help answer the research questions. The survey approach was generally time-efficient and ensured that no data was lost or misinterpreted. This is an advantage compared to conducting (non-recorded) interviews, especially by a single person. The key was to make sure participants understand the questions in a similar way and are able to provide accurate information. For this reason, the surveys were rather short and structured in a simple way and contained as short and clear questions as possible. (Blomkvist & Hallin, 2015)

3.4.2 Secondary Sources

Before findings from secondary sources were used, its quality was analysed. Aspects such as the purpose, context and delimitations were analysed from the perspective of trying to identify potential gaps, bias or other issues (Johnston, 2017). Statements were strengthened, if available, by other resources that claim the same or similar ideas. If contradictions were found, an attempt was made to understand why literature provided different answers. By comparing the methodology and results, it becomes clear whether the studies have provided conflicting data or similar data that has been interpreted differently. Authors might be biased and seek certain results from their design of experiments. (Blomkvist & Hallin, 2015) When the quality of the source is considered satisfactory and its context valid, it was added to the pool of secondary sources considered.

3.5 Research Data Quality

How data is collected and analysed affects the general quality of the research. The quality is discussed regarding ethical aspects, validity, and reliability.

3.5.1 Ethical Aspects

The content of the study has been restricted through a signed non-disclosure agreement between the author and the case company, protecting sensitive information from being published. Internal documents shared by Company X were destroyed after the completion of the thesis. Before the report was submitted, the company was also given the opportunity to review the content and agree that no sensitive data is included.

The study partly covers a social science phenomenon, regarding behaviour in the transition to new technology. Sourcing this information through surveys means it is necessary to evaluate ethical aspects and that data gathering respects confidentiality. For this report, the four principal requirements by the Swedish Research Council, Vetenskapsrådet (2018), have been considered:

1. The participants are informed about the purpose of the study,
2. The participants have agreed on participating in the study,
3. The data gathered from the surveys are treated confidentially, where the participants cannot be identifiable,
4. The collected data are used for the specific purpose that was stated before conducting the survey.

In accordance with the four principles, the survey process was initiated by informing the respondents about the purpose of the study, themes to be discussed and information about the anonymity. The data gathered from the surveys was treated with confidentiality, where no names, states/provinces or states are mentioned. As a result, participants and companies remain completely anonymous. (Vetenskapsrådet, 2018).

Through a high level of confidentiality, the participants are likely to feel more comfortable to answer the questions in a truthful way and ultimately contribute to higher quality empirics. (Baez, 2002)

3.5.2 Sustainability

The growing demand for sustainability has also the potential to serve as a trigger for the deployment of automated solutions, as they have been shown to positively influence all three aspects of sustainability (environmental, economic and social). There is a limited amount of studies conducted on sustainability aspects of automation and robotics specifically in the horticulture industries. Therefore, the data in this section is sourced from robotics applications in the field building production technology, that share many features like extensive manual labour and hazardous working conditions. The sustainability discussion will be broken down into each category; environmental, economic and social. (Pan et al., 2018)

Automation has been shown to help save on raw material consumption and waste through more efficient usage of resources (Cousineau & Miura, 1998; Lee et al., 2015), reduce air pollution and greenhouse gas emissions compared to many diesel-fuelled tractors used in the industry (Bock & Linner, 2016; Hong et al., 2015), while complying with environmental legislation, policies and standards. (Dunmade, 2002; Pan & Garmston, 2012; Qi et al., 2010)

Automation has been shown to give direct economic benefits by saving in resources and labour through more efficient use of materials, labour, time and increased quality. (Abbott, 2013; Bock and Linner, 2015; Pan et al., 2018)

Automation can increase social sustainability by replacing labour for the most hazardous and unhealthy tasks, which may lead to a reduction of injuries and fatalities, improved job security and attractiveness. (Castro-Lacouture, 2009; Bock & Linner, 2012) It also provides high-tech job opportunities in the industry for maintaining and developing robots. (Bock, 2015; Mahbub 2008) While critics raise concern that automation might lead to job losses, McKinsey & Company, a U.S. based management consulting firm, argues that automation in terms of replacing occupations is misleading. They claim that there are not entire professions but certain tasks that are more likely to become automated, for different reasons. In the case of this report,
it is because the producers have difficulties finding and retaining labour that is willing to perform certain tasks. That does not imply that horticulture producers do not need manual labour anymore, as it is necessary for other tasks. Automation allows producers to shift the focus of manual labour from hazardous tasks to other tasks. (McKinsey, 2015)

3.5.3 Validity and Reliability

To assess the quality of the methodology, the four-dimensional quality criteria by Yin (2003) was used:

- Construct validity - identifying correct operational measures for concepts being studied,
- Internal validity - seeking to establish a causal relationship (not applicable for this research, as it does not aim to establish causal relationships),
- External validity - defining domain to which findings can be generalised,
- Reliability - demonstrating that operations can be repeated.

Considering the research questions formulated, a mixed methods research was necessary to address both quantitative and qualitative elements. Applying an exploratory and inductive approach is suitable for the type of research conducted, as it aligns well with the type of research questions formulated (“what/which”). Automation in the horticulture industry is merely an option for a solution to a range of causes, characterising explorative research. (Blomkvist & Hallin, 2015; Brown, 2006)

Due to the geographical diversity and requests of horticulture producers in the USC region, all empirics had to be gathered from surveys. The results would be expected to have a higher construct validity if interviews were conducted instead of surveys, as the qualitative elements would have been easier to discuss and understand. Ideally, semi-constructed interviews with open-ended questions would provide better insights into the barriers to investing in automation. (Blomkvist & Hallin)

However, an interview methodology may not necessarily provide the same holistic view for the case study. This is because three different types of operations had to be considered, while addressing the vastness of the USC region and different types of plants grown in different climate/regions. The survey methodology is therefore argued to sacrifice some depth in the qualitative elements, while being superior in sample size. If Company X was targeting a more confined horticulture industry, the case study would yield more accurate results and could easily be generalised to the population. In such a case, the interview methodology may be more feasible and generate deeper insights without compromising the diversity within the population studied. (Blomkvist & Hallin)

Given the big population of producers in the USC region, an interview methodology would not have been possible given the time constraints of this study. The survey sampling procedure was based on the information found in Section 2.1 and is aimed towards representing the horticulture industry. Therefore 95% of survey participants were sourced from the U.S., as they
represent 95% of all producers in the USC region. The appropriate sample size was not attained, causing the margin of error in the answers to be 14% instead of the standard value of 5%. An increase of participants is expected to generate results representing the population more accurately. The survey participation rate was satisfactory, even if an increase would yield a lower margin of error. To assure a satisfactory construct validity, only participants with a certain knowledge were asked to participate in the surveys. Participants were selected according to the expected positions described in Section 3.3.2. They all have managerial roles but different positions, which may provide different perspectives to the issues addressed. The different perspectives expect to generate less biased and more diverse answers. (Blomkvist & Hallin, 2015; Tsang, 2013)

The gathering of the literature was done through various sources, all of which the credibility was evaluated. A triangular approach was used to confirm the internal validity of the information by comparing the different sources of the same information and evaluate how well it corresponds. Likewise, the data gathered from the surveys were triangulated with previous research to estimate the rationality of answers. No conflicting data from the empirics were identified. (Malterud, 1998; Yin, 2003) One aim of the research process is to keep a generic view throughout to make results applicable to a broader audience. The results are believed to be applicable to at least similar cases in the USC region. Regions that exhibit similar industry specific characteristics as those for the USC region explained in Section 2.1, meet the criteria stated in Section 1.6, have a similar climate and horticulture fauna, and attitudes towards automation may yield similar results as in this case study. (Blomkvist & Hallin, 2015)

The overall quality of the report was studied through several feedback sessions. These consisted of contact with the supervisor at both the author’s home university and partner university, as well as peer-review sessions at seminars at the author’s home university. The sessions provided feedback from an outsider’s perspective, in which questions and unclarities could be identified and adjusted. This helped to maintain an impartial study by adding new perspectives during the research. In addition, biases could be avoided by including different perspectives, which is believed to be of extra importance when no research partner was present. (Blomkvist & Hallin, 2015; Yin, 2003)
4 Results

This chapter presents the findings from the three conducted surveys. The survey is based on the three categories of operations presented in Section 4.1 and the templates presented in Appendix A. The level of automation in each task for all three categories of operations are presented in Appendix C. The level of automation for all individual tasks are presented in Appendix D.

4.1 Distribution

A total of 48 survey results were gathered, corresponding to a recorded respondent rate of 32%. Of the 48 surveys, the distribution amongst the categories of respondents is illustrated in Figure 9.

![Categories of Respondents](image)

*Figure 9. Categories of respondents*

The country representation amongst the three categories is presented in Figures 10-12.
Figure 10. Country representation amongst nurseries

Figure 11. Country representation amongst greenhouses

Figure 12. Country representation amongst mixed nurseries and greenhouses
4.2 Tasks
For the questions determining the level of MA in tasks, the answers range from 1 to 5, where $1 = \text{task is performed fully manually (0\%)}$ and $5 = \text{task is performed fully automatic (100\%)}$. The ALMA in the three categories was calculated and is presented in Figure 13, ranging from most automated task to least automated task. The ALMA for each category of horticulture producer, see Appendix C2-C4.

![ALMA for all tasks across all three categories of operations in the industry](image)

*Figure 13. ALMA for all tasks across all three categories of operations in the industry*

4.3 Prioritisation to MA
Figure 14-16 explain how participants from the three categories would prioritise which tasks to mechanise or automate.
Figure 14. The tasks nurseries prioritise to mechanise or automate

- Transporting pots within nursery (38%)
- Placing plant liners, sticking cuttings, and planting seed (13%)
- Pruning (13%)
- Spacing of plants and containers

Figure 15. The tasks greenhouses prioritise to mechanise or automate

- Harvesting and grading production (58%)
- Pesticide application (12%)
- Fertilizer application (12%)
- Placing plant liners, sticking cuttings, and planting seed (12%)
- Environmental control
- Filling containers with substrate
Figure 16. The tasks mixed nurseries and greenhouses prioritise to mechanise or automate

4.4 Barriers to Invest

Figure 17-19 explain what the biggest barriers are that prevent participants from the three categories to invest in automation. The categories presented are derived from the open coding approach described in Section 3.4.1.

Figure 17. Barriers to invest for nurseries
Figure 18. Barriers to invest for greenhouses

- Cost: 46%
- Too inaccurate technology: 13%
- Lack of knowledge of appropriate equipment: 8%
- Older facilities that require additional upgrades: 8%
- Greenhouse layout not ideal for the purpose: 4%

Figure 19. Barriers to invest for mixed nurseries and greenhouses

- Cost: 45%
- Hard to customise to our facilities: 20%
- Broad range of products: 10%
- Too few options available: 25%
5 Discussions and Recommendations

The literature review and surveys have been used to evaluate the current horticulture industry and how it could be approached by a robotics company.

5.1 Tasks to be Automated

RQ1: Which major tasks in the horticulture industry should a small robotics company aim to automate?

Posadas et al. (2008) studied 10 major tasks in greenhouses and 15 major tasks in nurseries and found that the ALMA is 20%. While this study does not conduct the same survey, the ALMA is estimated at 47% for the same major tasks amongst nurseries and greenhouses in part of the same region. The level of automation is expected to have increased during this period, but it cannot be proven by comparing these studies. This is because the study by Posadas et al. (2008) evaluates the ALMA but does not distinguish between automation and automation. The study is also not replicable for this report, given the criteria to be fulfilled in Section 1.6. For that reason, it is not possible to prove an automation trend by comparing the data samples, as the methods differ.

By studying Appendix C1-C4, a few key takeaways can be made:

1. Greenhouses have the highest ALMA at 52%, followed by nurseries at 49% and lastly mixed greenhouses and nurseries at 45%.

2. Most tasks have similar degrees of MA across the three categories of respondents.

3. The highest degree of MA in nurseries, all being over the ALMA, is found in the following tasks:

4. The lowest degree of MA in nurseries, all being under the ALMA, is found in the following tasks:
   (14) Pick up plants and put them in delivery vehicles, (10) Space containers, (16) Prune plants, (5) Place liners, stick cuttings and plant seed, (15) Jam plants for winter protection, (13) Unload plants into holding area, (7) Move containers to transport vehicle, and (9) Remove containers from transport vehicle.

5. The highest degree of MA in greenhouses, all being over the ALMA, is found in the following tasks:
   (6) Environmental control, (2) Fill containers with substrate, (19) Apply irrigation, (1) Prepare growing media, and (17) Apply fertiliser.
6. The lowest degree of MA in greenhouses, all being under the ALMA, is found in the following tasks:
   (11) Harvest plants and grade production, (4) Cut and prepare seeds, (18) Apply pesticide, (3) Cut and collect seeds, and (5) Place liners, stick cuttings and plant seed.

7. The highest degree of MA in mixed nurseries/greenhouses, all being over the ALMA, is found in the following tasks:
   (2) Fill containers with substrate, (6) Environmental control, (1) Prepare growing media, (18) Apply pesticide, (19) Apply irrigation, (9) Remove containers from transport vehicle, (8) Transport containers to nursery field.

8. The lowest degree of MA in mixed nurseries/greenhouses, all being under the ALMA, is found in the following tasks:

These empirical findings correlate well with results from existing literature. Since this study differs in nature from existing literature, it is not possible to draw conclusions of how levels of MA have changed over time. Existing literature can, however, be used as a comparison for the results. Posadas et al. (2008) estimated the ALMA at 20% and considered all tasks above ALMA to have a high degree of MA and tasks under ALMA to have a low degree of MA. The ALMA was estimated to 47% in this study and all tasks above 47% are considered a high degree of MA and tasks under 47% are considered a low degree of MA. The difference is that most values appear to be inflated compared to the study by Posadas et al. (2008).

Since the same method of categorising tasks according to degree of MA has been done between the study by Posadas et al. (2008) and this study, the values can be compared. This means the degree of MA of different tasks are categorised according to a high or low degree of MA, where the limit between the two is ALMA. Between the study by Posadas et al. (2008) and this study, some tasks appear to no longer be considered a high or low degree of automation. Either because they are now considered more or less automated, relative to the degree of MA for all other tasks.

Tables 5-8 show which tasks have remained neutral or changed its position from more or less automated between the study by Posadas et al. (2008) and this study. Table 5 and 6 present the tasks that all have a degree of MA under ALMA. Table 7 and 8 present the tasks that all have a degree of MA over ALMA. Tasks that have remained neutral are considered to be the same relative degree of MA in both studies.
Table 5. List of how the **low** degree of MA in nurseries relates to literature.

<table>
<thead>
<tr>
<th>Tasks that have remained neutral between measures</th>
<th>(5) Place liners, stick cuttings and plant seed, (9) Remove containers from transport vehicle, (10) Space containers, (13) Unload plants into holding area, (14) Pick up plants and put them in delivery vehicles, (15) Jam plants for winter protection.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks that are now considered a low degree of MA but was considered a high degree of MA by Posadas et al. (2008)</td>
<td>(16) Prune plants, (7) Move containers to transport vehicle.</td>
</tr>
<tr>
<td>Tasks that are now considered a high degree of MA but was considered a low degree of MA by Posadas et al. (2008)</td>
<td>(3) Cut and collect seeds, (4) Cut and prepare seeds, (11) Harvest plants and grade production, (12) Move plants to transport vehicle.</td>
</tr>
</tbody>
</table>

Table 6. List of how the **low** degree of MA in greenhouses relates to literature.

<table>
<thead>
<tr>
<th>Tasks that have remained neutral between measures</th>
<th>(11) Harvest plants and grade production, (3) Cut and collect seeds, (4) Cut and prepare seeds, (5) Place liners.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks that are now considered a low degree of MA but was considered a high degree of MA by Posadas et al. (2008)</td>
<td>(18) Apply pesticide</td>
</tr>
<tr>
<td>Tasks that are now considered a high degree of MA but was considered a low degree of MA by Posadas et al. (2008)</td>
<td>(9) Remove containers from transport vehicle, (10) Space containers, (12) Move plants to transport vehicle, (13) Unload plants into holding area, (14) Pick up plants and put them in delivery vehicles, (15) Jam plants for winter protection.</td>
</tr>
</tbody>
</table>

Table 7. List of how the high degree of MA in nurseries relates to literature.

<table>
<thead>
<tr>
<th>Tasks that have remained neutral between measures</th>
<th>(1) Prepare growing media, (2) Fill containers with substrate, (8) Transport containers to nursery field, (17) Apply fertiliser, (18) Apply pesticide, (19) Apply irrigation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks that are now considered a high degree of MA but was considered a low degree of MA by Posadas et al. (2008)</td>
<td>(14) Pick up plants and put them in delivery vehicles.</td>
</tr>
<tr>
<td>Tasks that are now considered a low degree of MA but was considered a high degree of MA by Posadas et al. (2008)</td>
<td>(7) Move containers to transport vehicle, (16) Prune plants.</td>
</tr>
</tbody>
</table>

Table 8. List of how the high degree of MA in greenhouses relates to literature.

<table>
<thead>
<tr>
<th>Tasks that have remained neutral between measures</th>
<th>(1) Prepare growing media, (2) Fill containers with substrate, (6) Environmental control, (17) Apply fertiliser, (19) Apply irrigation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks that are now considered a high degree of MA but was considered a low degree of MA by Posadas et al. (2008)</td>
<td>-</td>
</tr>
<tr>
<td>Tasks that are now considered a low degree of MA but was considered a high degree of MA by Posadas et al. (2008)</td>
<td>(18) Apply pesticide</td>
</tr>
</tbody>
</table>

As seen in Tables 5-8, the majority of the tasks identified in existing literature as high or low level of MA remain neutral and in the same category for this study, despite this study estimating a higher ALMA. The tasks (7) Move containers to transport vehicle, (16) Prune plants, and (18) Apply pesticide, have switched their position from previously being considered a high level of MA to now being considered a low level of MA. Their values are all below the ALMA for this study. The task (14) Pick up plants and put them in delivery vehicles, was previously considered a neutral level of MA (close to the ALMA) and is now considered a high level of MA. Its value is above the ALMA for this study.

By considering Figure 14 in Section 4.3, the two tasks that nurseries prioritise to MA the most are transporting pots within the nursery and placing plant liners, sticking cuttings and planting seeds (38% of respondents each), followed by pruning (13% of respondents each) and spacing of plants and containers (13% of respondents each). All of these tasks are considered the low level of MA for nurseries.
By considering Figure 15 in Section 4.3, the task that greenhouses prioritise to MA the most is harvesting and grading production (58%), followed by pesticide/fertiliser application and placing plant liners, sticking cuttings and planting seeds (12% of respondents each), followed by environmental control and filling containers with substrate (4% of respondents each). Of these tasks, harvesting and grading production, pesticide application, and placing plant liners, sticking cuttings and planting seeds are all considered the low level of MA. Fertiliser application, environmental control and filling containers with the substrate are all considered the high level of MA for greenhouses.

By considering Figure 16 in Section 4.3, the task that mixed nurseries and greenhouses prioritise to MA the most is transporting pots within nursery (38%), followed by spacing of plants (31%), placing plant liners, sticking cuttings and planting seeds (19%), and irrigation application and management (13%). All of these tasks, except irrigation application and management, are considered the low level of MA for mixed nurseries and greenhouses.

Which tasks a robotics company chooses to address is dependent upon their strategy. Given that the prerequisite of feasibility in Appendix B is fulfilled, these insights can be assessed to determine market possibilities of a robotics company. Company X has a priority to focus on market opportunities that may have less competition. The tasks that may have a high potential of automation are those tasks that AAM describes as having a poor task-technology compatibility, meaning it falls short of the operator’s desired level of automation. The tasks with a poor task-technology compatibility are found in the low level of MA while also being requested to be automated by the horticulture industry. If Company X is to automate tasks that are considered high levels of MA, a system/technology that is updated or different from existing solutions is essential. (Coker et al., 2010)

For nurseries, the tasks Company X should aim to automate are (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers, (16) Plant pruning.
For greenhouses, the tasks Company X should aim to automate are (5) Placing plant liners, sticking cuttings, and planting seed, (11) Harvesting and grading production, (18) Pesticide application.
For mixed nurseries and greenhouses, the tasks Company X should aim to automate are (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers.

Considering Appendix B and Figure 21, the only other major factor affecting the adoption of a successful automation is the cost of developing and implementing it. That means Company X should prioritise to automate the tasks listed above and decide between the specific investments based on net income potential.

5.2 Barriers to Invest

*RQ2: What are the barriers for companies in the horticulture industry to invest in automated solutions?*
Figure 17-19 are combined and displayed for comparative purposes in Figure 20.

**Figure 20. Barriers to invest, comparison**
As seen in Figure 20, the biggest barrier for nurseries to invest in automation is cost (50%), followed by an opinion that there are too few options available on the market (30%), and nursery layouts that is unfavourable (for example specified as spread out farm locations) for automation (20%).

For greenhouses, the biggest barriers are cost (45%), followed by an opinion that the technologies are too inaccurate for their requirements (29%), a lack of knowledge about the required equipment (13%), older facilities requiring additional upgrades before any automation could be installed (8%), and a greenhouse layout that is unfavourable for automation (4%).

For mixed nurseries and greenhouses, cost (45%), followed by a difficulty in customising an automated solution to the facilities, for example due to different types of ground material/surfaces throughout (25%), a broad range of products that is more difficult to customise (20%), and an opinion that there are too few options available on the market (10%).

A key takeaway from the barriers to investing in automation for the horticulture industry is that cost not only is the single biggest factor but also the only factor being brought up in every category of operations. Even if Company X is to focus only on providing a generic automated solution with the comparable cost of manual labour, up to half of the potential customers would be inclined to invest. Many respondents gave additional insights that the cost of investing in the only factor stopping them from automating parts of their operations. Respondents express a concern with labour that is not willing or able to perform the manual tasks that are required in the industry and that a cost-competitive automated solution would solve HR related issues they face. Several respondents express their cost consciousness in terms of ROI if they were to buy the equipment required for automation, where a two-year ROI would incline them to invest.

As of today, not all tasks can be automated, which is why a 100% ALMA is not feasible in the foreseeable future. Appendix B1 only mentions two out of 133 tasks that are feasible to automate to a degree of more than 90%. In combination with the feasibility of automation, the TAM and AAM by Venkatesh and Davis (1989) and Ghazizadeh et al. (2012) can help interpret the results. The TAM and AAM describe four factors that could impact the acceptance of technology and automation, which in turn become barriers to invest:

1. The PU, the degree to which a person believes the technology would enhance job performance,

Respondents expressed general positivity towards automation and no respondent raised scepticism towards the technology. Some acknowledge that automation would be key for them to grow their business. There is one category of respondents in the survey questioning the technology. They claim that automation is not currently accurate enough for some tasks in the greenhouses, primarily harvesting and grading production. The respondents represent approximately 15% of respondents for this survey. Another 10% of survey respondents suggest that there are too few options available on the market. The survey does not however discover
what is insufficient with existing options, if it is the performance of technology or other factors. This adds a degree of uncertainty to the answers, giving a span where 75-85% of survey respondents seem to have a high degree of PU towards automation in their operations.

2. The PEU, the degree to which a person believes that the use of technology would be free from effort,

Respondents did not express much concern about the complexity of the automated solutions available and that it is preventing them from investing. Only 6% of respondents, all operating greenhouses, assert a lack of knowledge regarding the appropriate equipment required for automating certain tasks. Not surprisingly these respondents also display lower levels of MA than the ALMA across the category.

One of the most important factors in the successful adaption of technologies is some degree of technological knowledge. If a certain level of technical knowledge or education is observed amongst the users, the complexity of the technology should be adjusted accordingly. (Kim, 1988) In this case, the automated solutions offered in the horticulture industry are not too complex. An 94% of survey respondents perceive the automated solutions to have a high PEU.

3. The task-technology compatibility, the right level of automation in a system for performing a certain task,

The task-technology compatibility is assessed by studying cases where the level of automation exceeds the operator’s desired level or when it falls short of the operator’s desired level of automation. The study does not investigate whether there are any tasks that are above the operator’s desired level of automation. To adequately test this construct, the surveys would therefore need to include another question about which tasks that they prioritise to automate the least. The surveys do however investigate the cases where the level of automation falls short of the operator’s desired level of automation. By considering Section 4.3 and Appendix C, there are some tasks in the industry that are considered low levels of MA and have a high demand for being automated. These tasks all have poor task-technology compatibility, because they fall short of the operator’s desired level of automation:

**Nurseries:** (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers, (16) Plant pruning

**Greenhouses:** (5) Placing plant liners, sticking cuttings, and planting seed, (11) Harvesting and grading production, (18) Pesticide application

**Mixed nurseries and greenhouses:** (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers
A task should not necessarily be pursued to be automated if customers do not value it. A sign that an ideal level of task-technology compatibility is met is when users are satisfied with the level of MA in their operations, listed above.

It can be argued that achieving an overall right level of automation is difficult. When efforts are put into increasing the level of automation for one task, other tasks are likely to fall behind, because the ALMA is now higher. There will for that reason always be some tasks that are more and less automated than others. Of course, there are also other factors affecting the adoption of automation, most importantly cost as seen in Section 4.4. It can therefore be assumed that some tasks being too costly (or technically difficult) to automate will not reach a sufficient task-technology compatibility in the short term.

4. Trust, the degree of experience with automation.

Considering the answers stated in 1), that 75-85% of respondents have a high degree of PU of automation and 2), only 6% of respondents express a lack of knowledge and low PEU of automation, the AAM suggests two categories of automation acceptance. The first that uses automated solutions and experiences positive benefits, which makes the person more likely to adopt new technology and automate other tasks. This creates a positive feedback loop that promotes increased automation. The second category remains slightly positive towards automation but has a low degree of experience or negative experiences with automation and therefore is less likely to adopt technology to automate their tasks. This creates a negative feedback loop that counteracts automation.

For this survey, all survey respondents displayed moderate levels of MA and a general positivity and trust towards automation. They therefore fit best under the category one of automation acceptance. This, combined with the AAM stating that trust in automation improves with time exposed, can explain the level of automation of the horticulture industry in the USC region. Considering a higher wage cost correlates to a high level of automation argues that the USC region with its relatively high wage costs are more likely to adopt and develop trust for automation. It is therefore possible that companies in the USC region less likely to adopt technology have been struggling to sustain their profit margins, as discussed in Section 2.1, and are therefore underrepresented at the time this study is conducted.

The other big horticulture exporters with high wage costs examined in this report, the Netherlands, is assumed to show similar characteristics of trust in automation as the USC region. Nothing can be said about the characteristics of the automation but the high wage costs of Netherlands, shown in Appendix B3, argue that the dynamic trust should be in a similar stage as the USC region. The other big horticulture exporters, Colombia and Ecuador, have low wage costs and are therefore argued to have been exposed less to and develop less trust in automation.
6 Conclusion, Limitations and Further Research

6.1 Conclusion
The purpose of this thesis was to fill the research gap concerning automation in the horticulture industry by discovering the adoption of automation in the USC region, exploring the possibilities of introducing autonomous solutions and provide recommendations as to how this could create opportunities for small robotics companies targeting the industry.

Previous research in the field is lacking, both in terms of the region studied, up-to-date information about automation in the horticulture industry, and its implications specifically for robotics companies. This report provides much-needed updated information about the adoption of automation in the horticulture industry to a bigger region and discusses why this information is relevant for robotics companies.

A case company in the USC region was used as an example of a small robotics company. Five different categories of horticulture operations were studied: nurseries, greenhouses and mixed nurseries and greenhouses. Two research questions were formulated and are discussed separately below:

RQ1: Which major tasks in the horticulture industry should a small robotics company aim to automate?

The ALMA for each category of horticulture industry was determined and averaged at 47% across all categories. The tasks being automated corresponds well with previous research, suggesting that the characteristics of automation in the USC region is comparable to those of Mississippi, Alabama and Louisiana. Given the strategy of Company X, to invest in areas that may have less competition, recommendations were given to automate tasks with a poor task-technology compatibility, meaning they fall short of the operator’s desired level of automation. The tasks with a poor task-technology compatibility are found in the low level of MA while also being requested to be automated by the horticulture industry.

For nurseries, the tasks Company X should aim to automate are (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers, (16) Plant pruning.

For greenhouses, the tasks Company X should aim to automate are (5) Placing plant liners, sticking cuttings, and planting seed, (11) Harvesting and grading production, (18) Pesticide application.

For mixed nurseries and greenhouses, the tasks Company X should aim to automate are (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers.
The only other factor affecting the adoption of a successful automation is the cost of developing and implementing it. That means Company X should prioritise to automate the tasks listed above and decide between the specific investments based on net income potential.

**RQ2: What are the barriers for companies in the horticulture industry to invest in automated solutions?**

The study explores barriers to invest in automation and uses TAM and AAM to interpret the results. The models distinguish 1) PU, 2) PEU, 3) task-technology compatibility, and 4) trust to be the four core constructs that affect the adoption of automation.

1) The horticulture industry in the USC region is showing low barriers to invest in automation. The technology is perceived as useful amongst 75-85% of respondents, all exhibiting a high degree of PU towards automation in their operations.

2) The technology is also perceived as easy to use amongst 94% of respondents, all exhibiting a high degree of PEU.

3) The task-technology compatibility was used to help find RQ1. The results only show one side of the task-technology compatibility however: where the level of automation falls short of the operator’s desired level of automation. It does not investigate whether there are any tasks that are above the operator’s desired level of automation. To adequately test this construct, the surveys would therefore need to include another question about which tasks that they prioritise to automate the least. There are some tasks in the industry that are considered low levels of MA and have a high demand for being automated. These tasks all have poor task-technology compatibility, because they fall short of the operator’s desired level of automation:

**Nurseries:** (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers, (16) Plant pruning

**Greenhouses:** (5) Placing plant liners, sticking cuttings, and planting seed, (11) Harvesting and grading production, (18) Pesticide application

**Mixed nurseries and greenhouses:** (5) Placing plant liners, sticking cuttings, and planting seed, (10) Spacing of plants and containers

4) All respondents displayed moderate levels of MA and a general trust towards automation. According to the AAM, they are best described as users that use automated solutions and experience positive benefits, which makes the user more likely to adopt new technology and automate other tasks. The AAM also states that trust in automation improves with time exposed. Considering a higher wage cost correlates to a high level of automation, it is argued that the USC region with its relatively high wage costs is more likely to adopt and develop even more trust for automation.
A key takeaway from the barriers to investing in automation for the horticulture industry is that cost not only is the single biggest factor but also the only factor being brought up in every category of operations. Producers claim that the cost is much more important than other factors, meaning this is the crucial focus point of Company X. Even with a generic automated solution with the comparable cost of manual labour, up to half of the horticulture producers would be inclined to invest. Producers prefer cost-effective approaches than more complicated and costly solutions.

For nurseries, the biggest barriers to invest in automation are cost (50%), followed by an opinion that there are too few options available on the market (30%), and nursery layouts that is unfavourable (for example specified as spread out farm locations) for automation (20%).

For greenhouses, the biggest barriers are cost (46%), followed by an opinion that the technologies are too inaccurate for their requirements (29%), a lack of knowledge about the required equipment (12.5%), older facilities requiring additional upgrades before any automation could be installed (8%), and a greenhouse layout that is unfavourable for automation (4%).

For mixed nurseries and greenhouses, cost (45%), followed by a difficulty in customizing an automated solution to the facilities, for example due to different types of ground material/surfaces throughout (25%), a broad range of products that is more difficult to customise (20%), and an opinion that there are too few options available on the market (10%).

6.2 Limitations

This study is limited to approximately five months, which impacts the extent and the depth of the research. Given the vast area of the USC region, this also posed practical problems with the research design. The survey methodology was necessary to gather information from a representative selection of the USC region, as this would not have been possible with an interview methodology. The time limitation led to the number of participants in the surveys not being satisfactory – 48 instead of the recommended 384. Increasing the time spend contacting horticulture producers would likely generate more survey respondents and more accurate results. The results now have a margin of error of roughly 14% instead of the standard 5%, everything else equal.

One option would be to study a smaller region more intensely and thereby unlock an interview methodology as a viable option for gathering data. This would also avoid the disagreements regarding the incompatibility between quantitative and qualitative data in a mixed methods methodology. An open-ended interview approach is arguably more feasible for an exploratory case study, which is why studying a smaller region studied would make it easier to generate more depth in the results.

The companies that the surveys were sent to and answered by adequately represent the horticulture industry in terms of country representation. There are however other factors that
do not show in the results, most importantly the size of the companies participating in the study. It can be argued that bigger companies are more inclined to answer a survey about automation, as its relevance scales with the size of the company. The results do not reveal any skewness in the responses in terms of an overrepresentation of bigger companies, as the survey design does not evaluate the company size of survey participants. If bigger companies indeed are overrepresented, the results might be skewed towards the more positive side than what the industry actually suggests.

The adoption of automation is clearly a complex topic with many underlying determinants. For this reason, the selection of frameworks and theory is a limitation in the research, especially with a lack of previous research that is up to date. The results are therefore not conclusive and may be analysed differently if a different approach or theory is implemented.

6.3 Further Research

As the horticulture industry in the USC region is facing challenges with labour costs due to a high employee turnover and work-related injuries, opportunities arise for automated solutions. There are many interesting areas of which further research could cover, excluding the obvious of improving on the limitations stated in Section 6.2.

This is an exploratory study and to the authors understanding the first of its kind that assesses the USC region. There is clearly much more to be investigated and different ways to do so. The TAM and AAM can be investigated further, primarily how the external variables in the horticulture industry impact the PU, PEU, compatibility and trust. Different findings can help support the findings of this report and give other implications for robotics companies targeting the industry. Employing a different research design can also give deeper insights into the industry. For that purpose, a smaller region should be selected and analysed more in depth. The results can also be extended and compared to other similar industries in the same or similar regions, such as agriculture or manufacturing in the USC region.

There is also an abundance of theoretical frameworks to be used and a different selection may yield results that are different in character. This report argues for the usage of the TAM and AAM but depending on the research aim, other extensions or predecessors of TAM can be argued to also help explain the adoption of automation in the horticulture industry. This study approaches automation around the needs of the horticulture producers and the tasks that are currently lacking in levels of MA. However, it does not assess which tasks are the most technically feasible or economically beneficial to automate. There are several other factors that influence the decision of automating certain tasks, some of which touched upon in Appendix B, and the most important being cost. A natural and interesting continuation on this theme could be to map which tasks are the most economically beneficial to automate. The combined findings could then, together with this report, give more conclusive answers as to which tasks should be prioritised to automate.
References

This section presents the literature used to conduct this study.

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Statistics Canada, (2019a), URL: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1110023901&pickMembers%5B0%5D=1.1&pickMembers%5B1%5D=2.1&pickMembers%5B2%5D=3.1&pickMembers%5B3%5D=4.3 (2019-02-11)


Addendum

The addendum consists of Appendix A-D with supplementary information left out from the report.

Appendix A. Templates for the Surveys

This appendix contains the templates for the surveys.

Appendix A1. Surveys Nurseries

The following table shows a typical production chain of potted plants within nurseries. For each of the following tasks, please state how it is currently performed at your nursery, ranging from fully manual to fully automatic.

Mechanisation refers to the replacement of human labour with a machine (such as a tractor or conveyor belt). Automation refers to a system that controls and monitors itself.

<table>
<thead>
<tr>
<th>Task no.</th>
<th>Task description</th>
<th>Fully manual</th>
<th>Mostly manual/partly mechanised</th>
<th>Mostly mechanised/partly manual</th>
<th>Mostly mechanised/Partly automatic</th>
<th>Fully automatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Media preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Filling containers with substrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Placing plant liners, sticking cuttings, and planting seed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Moving containers from potting to transport vehicle for movement within the nursery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Transporting containers to field in nurseries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Removing containers from transport vehicle and placing in the field</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Spacing of plants and containers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Picking plants up and loading onto transport vehicle at time of sale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Removal of plants from transport vehicle and placing in holding area awaiting shipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10 Picking up plants from holding area and loading onto delivery vehicles
11 Jamming plants for winter protection
12 Plant pruning
13 Fertiliser application
14 Pesticide application
15 Irrigation application and management

Which of the above tasks (if any) would you prioritise for mechanisation/automation?

What prevents you from investing in automation?

Where are your operations based?

Appendix A2. Surveys Greenhouses

The following table shows a typical production chain of potted plants within greenhouses. For each of the following tasks, please state how it is currently performed at your greenhouse, ranging from fully manual to fully automatic.

Mechanisation refers to the replacement of human labour with a machine (such as a tractor or conveyor belt). Automation refers to a system that controls and monitors itself.

<table>
<thead>
<tr>
<th>Task no.</th>
<th>Task description</th>
<th>Fully manual</th>
<th>Mostly manual/party mechanised</th>
<th>Mostly mechanised/party manual</th>
<th>Mostly mechanised/Party automatic</th>
<th>Fully automatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Media preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Filling containers with substrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cutting and seed collection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cutting and seed preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Placing plant liners, sticking cuttings, and planting seed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Environmental control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Which of the above tasks (if any) would you prioritise for mechanisation/automation?

What prevents you from investing in automation?

Where are your operations based?

**Appendix A3. Surveys Mixed Nurseries and Greenhouses**

The following table shows a typical production chain of potted plants within nurseries. For each of the following tasks, please state how it is currently performed at your nursery, ranging from fully manual to fully automatic.

Mechanisation refers to the replacement of human labour with a machine (such as a tractor or conveyor belt). Automation refers to a system that controls and monitors itself.

<table>
<thead>
<tr>
<th>Task no.</th>
<th>Task description</th>
<th>Fully manual</th>
<th>Mostly manual/partly mechanised</th>
<th>Mostly mechanised/partly manual</th>
<th>Mostly mechanised/Partly automatic</th>
<th>Fully automatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Media preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Filling containers with substrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cutting and seed collection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cutting and seed preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Placing plant liners, sticking cuttings, and planting seed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Environmental control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Moving containers from potting to transport vehicle for movement within the nursery</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Task Description</td>
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<td>-----</td>
<td>----------------------------------------------------------------------------------</td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>Transporting containers to field in nurseries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Removing containers from transport vehicle and placing in the field</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Spacing of plants and containers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Harvesting and grading production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Picking plants up and loading onto transport vehicle at time of sale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Removal of plants from transport vehicle and placing in holding area awaiting shipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Picking up plants from holding area and loading onto delivery vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Jamming plants for winter protection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Plant pruning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Fertiliser application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Pesticide application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Irrigation application and management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Which of the above tasks (if any) would you prioritise for mechanisation/automation?

What prevents you from investing in automation?

Where are your operations based?
Appendix B. Feasibility of Automation

A report by McKinsey & Company, a U.S. management consulting firm, argues that automation in terms of replacing occupations is misleading. Instead, there are instead certain activities that are more likely to become automated in the near or medium term. For that reason, analysing work activities instead of occupation is the most accurate way of examining the feasibility of automation. (McKinsey, 2015)

According to McKinsey (2016), there are five major factors affecting the success of automation of any task:

1. Technical feasibility,
2. Cost of developing and deploying hardware and software,
3. Cost of labour and related supply-and-demand dynamics,
4. Benefits beyond substituting labour,
5. Regulatory and social-acceptance issues.

While these are not required to elaborate on to answer the research questions on the report, they are touched upon here to help robotics companies make informed decisions. The rest of Appendix is devoted to breaking down these success factors one by one and examining them from the perspective of the horticulture industry.

Appendix B1. Technical Feasibility

The highest technical feasibility of tasks to be automated are physical activities or machine operations in a predictable environment. While automation is technically feasible for many activities, some are more affected than others. It is more technically feasible to automate predictable physical activities than unpredictable ones, according to the figure below. (McKinsey, 2016)
In the case of the horticulture industry, not listed in the figure above, it is arguably a hybrid between the agriculture and manufacturing industry as it shares common elements with both. The predictable tasks such as moving items from one place to another and applying pesticide/fertiliser to unpredictable tasks such as plant grooming, research, etc. As seen in the heat map in the figure above, the tasks in this industry range in feasibility from applying expertise (10-40%) to predictable physical work (70-90%). This can be put into perspective through the figure below, showing that 51% of all time spent in US occupations have technical feasibility of automation of 64-78%. (McKinsey, 2016)
This shows that it is not possible to fully automate all tasks in the horticulture industry with today’s technology but even the most unpredictable occupations contain tasks that can be automated with today’s technology. Yet, it is arguably more beneficial from a technical standpoint to automate occupations with a high degree of predictable physical activities. (McKinsey, 2016)

**Appendix B2. Cost of Developing and Deploying Hardware and Software**

This report does not assess specific costs associated with the development and deployment of different platforms for automating tasks, as they generally are situational and not generalisable. The cost, however, stands in relation to the factor the product aims to replace - manual labour. This labour therefore somewhat restricts the cost of developing and deploying hardware and software. The current trend for the USC region is however considered to favour automation over time, as labour is becoming increasingly more expensive and robots cheaper, according to the figure below. (McKinsey, 2017)
The producers of the horticulture industry in the U.S. consist of 32,915 businesses that share revenues of $13.6 billion. With an average labour cost of 44.5% of revenues, each establishment, therefore, spends approximately $413,000 on labour every year. (IBISWorld, 2019a) Canada has 1,659 of these establishments that share revenues of $2.0 billion. With an average labour cost of 43.3% of revenues, each establishment, therefore, spends approximately $522,000 on labour every year. (IBISWorld, 2019b)

These values can be considered benchmarks when developing and deploying automated solutions for the USC region, as the relative cost generally has a high impact on the success of automation (Kerremans et al., 2012)

**Appendix B3. Cost of Labour and Related Supply-and-demand Dynamics**

The labour characteristics of the horticulture industry strongly affects the development of automated solutions. A relatively expensive labour force favours automation but disfavours exports and vice versa. (Autor, 2015) As pointed out in Section 2.1.1 and 2.1.2, the biggest exporting countries of horticulture products into or within the USC region are the U.S., Canada, Colombia, the Netherlands, and Ecuador. Mapping the labour characteristics of these countries and making comparisons for the horticulture industry specifically is complicated due to insufficient data. For the purpose of benchmarking the cost of labour and related supply-and-demand dynamics of the biggest producing countries, the median wage will be considered. These median wages are presented in the table below. By comparing the reported median wage of each producing country, the economic feasibility of automation can be assessed for each country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Median Wage</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Median Salary (USD/year)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>the Netherlands</td>
<td>34,000</td>
<td>CBS, 2019</td>
</tr>
<tr>
<td>The U.S.</td>
<td>31,500</td>
<td>Social Security Administration, 2019</td>
</tr>
<tr>
<td>Canada</td>
<td>30,600</td>
<td>Statistics Canada, 2019a; Statistics Canada, 2019b</td>
</tr>
<tr>
<td>Ecuador</td>
<td>6,000</td>
<td>Cedlas, 2019</td>
</tr>
<tr>
<td>Colombia</td>
<td>4,000</td>
<td>Cedlas, 2019</td>
</tr>
</tbody>
</table>

By applying these medians across the horticulture industry, the five exporting countries can clearly be divided into two groups: the high-cost labour countries (the Netherlands, the U.S., and Canada) and the low-cost labour countries (Ecuador and Colombia). It can be concluded that the economic benefit of replacing labour with automated solutions is 5-8.5 times more efficient in high-cost countries as opposed to low-cost countries. Adding on the high unemployment rate of the low-cost countries suggests a surplus of manual labour that further makes it less attractive for a robotics company to target. (Cedlas, 2019)

**Appendix B4. Benefits Beyond Substituting Labour**

The study by Posadas et al. (2008) shows through regression analysis that nurseries and greenhouses with higher sales also have higher levels of automation, suggesting that automation is more prevalent in bigger establishments. (Posadas et al., 2008) An explanation may be that the higher marginal efficiency of capital justifies investing in capital expenditures only if revenues are already large enough to utilise the increased efficiency. (Wright, 1959) This, in turn, unlocks faster throughput and quality control, which in turn potentially yields even higher sales. (Posadas et al., 2008)

Further, automation has a neutral impact on employment, indicating it does not necessarily reduce the number of total man-hours employed. One possible explanation is that labour tends to be utilised more efficiently with any improvements in automation. On the other hand, the workers’ skills are expected to be negative as a result of automation, allowing businesses to hire significantly less-skilled workers. (Posadas et al., 2008)

The study shows that automation has a neutral effect on workers’ safety as measured by the number of man-hours lost due to injuries. At the same time, the most common injuries reported were back strains and cut fingers. Very few, if none at all, reported any form of MA in the cutting and seed collection and preparation, placing plant liners, sticking cuttings and planting seed, harvesting and grading production, spacing of plants and containers, removal, picking up,
loading, and placing of plants, and jamming of plants for winter protection. (Posadas et al., 2008)

The mechanised or automated investments are generally put into environmental control and application of fertiliser, pesticide, and irrigation. Automation would arguably have a positive effect on workers’ safety given more investments into those tasks that actually cause the most common injuries. For this study, each full-time employee added to the labour force would most likely lead to an additional 9.6 man-hour lost every year as a direct result of these work-related injuries. (Posadas et al., 2008)

Automation has a neutral impact on workers’ retention rates as they tend to be more influenced by the type of operations, benefits, and conditions rather than levels of automation. If automation can be used to change the type of operations however, it can have a positive impact on the retention rate. (Posadas et al., 2008)

Producers in the horticulture industry that have higher sales also have higher levels of automation, suggesting that automation is more prevalent the bigger the farm gets. An explanation may be that a certain amount of revenues is required to utilise the increased efficiency that are enabled through automation. The increased efficiency of the farms can potentially lead to even higher sales which creates a bigger distance between the business that utilise automation from those that do not. This is a threat to smaller businesses, as the automated solutions are not as profitable for small scale operations but also a necessity to achieve bigger scale operations.

The automated solutions in the horticulture industry can provide consistent quality over time, as opposed to human labour that experience fatigue. The effect of automation is extra prevalent when replacing labour intensive tasks in hazardous conditions, reducing injuries, while improving job attractiveness and labour retention rate. Automation does not necessarily reduce the number of total man-hours employed, because it causes labour to be utilised more efficiently. It does however make it easier to manage labour. The horticulture industry is characterised by a significant amount of seasonal labour. The automated solutions provide higher flexibility, meaning the seasonal hiring and firing of labour is not necessary if the pricing structure of the robot is set in a way that avoids running costs during low seasons.

Appendix B5. Regulatory and Social-acceptance Issues

As autonomous robots make their way into industries and people’s lives, there are some regulatory dilemmas that arise and require the attention of regulators: law, market, social norms, and code. Below, these dilemmas are addressed, and solutions proposed. (Palmerini et al., 2017)

Law: It is common that law lags behind technological development and even more so for new technologies. Regulations should aim to be technology-neutral by abstracting away from concrete technologies and instead focus on the adverse effects of technologies. Today there is
no specific regulation even for the class of robot that is surgical robots and bionics, nor robots performing less critical tasks. (Palmerini et al., 2017)

**Market:** Another major regulatory challenge in technology regulation is to create a balance between not stifling technology and ensuring the health and safety factors of new innovation. A key legal instrument is a liability law that addresses the adverse effects of technological innovations. Liability risks can, however, cause developers and producers to fear to take on costs for risks they cannot calculate. (Palmerini et al., 2017)

The European and American systems for protecting consumers against product- and enterprise liability (Directive 85/374/EEC on Defective Products and Product Liability law) have been criticised for stifling innovation without a substantial increase in safety standards. While these effects can prevent new innovations to be pursued through the imposition of strict standards of liability on producers, there are many ways to reduce this risk. By carefully controlling the quality of products and reviewing procedures in the company, product liability becomes less of a risk. Once a truly autonomous machine has been achieved, producers could feel safe in ensuring their product does not require human intervention or supervision and therefore assuming liability if the system fails or causes an accident. (Duffy et al., 2014; Palmerini et al., 2017)

**Social norms:** Social norms vary in time and place and in terms of robotics, clear differences can be seen between for example western and many Asian cultures. While western cultures often fear automation as robots get depicted as evil, many Asian culture predispose the population to see robots as helpers. One main issue with robotics is the value of human autonomy. As many may feel threatened by the idea of robots replacing humans, regulators do not want to neglect this while stimulating automation for reasons of efficiency or safety. (Palmerini et al., 2017)

As robots do not only automate tasks but also create new tasks, higher skilled tasks that require a development that may intensify inequality on the labour market. As a general rule, the social norms are stronger in the cases where the robotics are visible to the customer. Whether a nursery or greenhouse replaces human labour is not considered to affect the customers negatively. (Palmerini et al., 2017)

**Code:** Code refers to the architecture that makes up the software of technology. The issue of the code is that whether and how a robot collects, and processes personal data will be determined by its software. Whether and how much this software complies with regulations is up to the developers of the robot. As of robotics in the horticulture industry today, the robots are not subject to sensitive customer data and thereby poses no threat to breaking the regulations of data protection and privacy regulation. (Palmerini et al., 2017)
Appendix C. Results for ALMA in the Three Types of Operations

Appendix C1. Results for ALMA Comparison

*Cells marked with “-” indicate a task not performed by the specific category.*

<table>
<thead>
<tr>
<th>Major task</th>
<th>Automation level [%] - nursery</th>
<th>Automation level [%] - greenhouse</th>
<th>Automation level [%] - mixed</th>
<th>Combined average [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prepare growing media</td>
<td>78</td>
<td>65</td>
<td>76</td>
<td>73</td>
</tr>
<tr>
<td>2. Fill containers with substrate</td>
<td>98</td>
<td>80</td>
<td>82</td>
<td>87</td>
</tr>
<tr>
<td>3. Cut and collect seeds</td>
<td>-</td>
<td>28</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>4. Cut and prepare seeds</td>
<td>-</td>
<td>26</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>5. Place liners, stick cuttings and plant seed</td>
<td>33</td>
<td>35</td>
<td>25</td>
<td>31</td>
</tr>
<tr>
<td>6. Environmental control</td>
<td>-</td>
<td>89</td>
<td>81</td>
<td>85</td>
</tr>
<tr>
<td>7. Move containers to transport vehicle</td>
<td>38</td>
<td>-</td>
<td>36</td>
<td>37</td>
</tr>
<tr>
<td>8. Transport containers to nursery field</td>
<td>56</td>
<td>-</td>
<td>59</td>
<td>58</td>
</tr>
<tr>
<td>9. Remove containers from transport vehicle</td>
<td>44</td>
<td>-</td>
<td>61</td>
<td>53</td>
</tr>
<tr>
<td>10. Space containers</td>
<td>29</td>
<td>-</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>Activity</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>----------------------------------------------</td>
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</tr>
<tr>
<td>11. Harvest plants and grade production</td>
<td>-</td>
<td>25</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>12. Move plants to transport vehicle</td>
<td>22</td>
<td>-</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>13. Unload plants into holding area</td>
<td>38</td>
<td>-</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>14. Pick up plants and put them in delivery vehicles</td>
<td>51</td>
<td>-</td>
<td>42</td>
<td>47</td>
</tr>
<tr>
<td>15. Jam plants for winter protection</td>
<td>36</td>
<td>-</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>16. Prune plants</td>
<td>33</td>
<td>-</td>
<td>42</td>
<td>38</td>
</tr>
<tr>
<td>17. Apply fertiliser</td>
<td>53</td>
<td>63</td>
<td>39</td>
<td>52</td>
</tr>
<tr>
<td>18. Apply pesticide</td>
<td>49</td>
<td>28</td>
<td>66</td>
<td>48</td>
</tr>
<tr>
<td>19. Apply irrigation</td>
<td>71</td>
<td>76</td>
<td>65</td>
<td>71</td>
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<tr>
<td>Combined average [%]</td>
<td>49</td>
<td>52</td>
<td>45</td>
<td>47</td>
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</table>
Appendix C2. Results for ALMA Nurseries

Appendix C3. Results for ALMA Greenhouses
Appendix C4. Results for ALMA Mixed Nurseries and Greenhouses

Automation level for all tasks in mixed nurseries/greenhouses

- Filling containers with substrate: 83%
- Environmental control: 81%
- Water supply: 76%
- Pruning and trimming: 66%
- Fertilizer application: 65%
- Dusting: 61%
- Pesticide application: 59%
- Planting: 42%
- Harvesting: 42%
- Picking plants: 39%
- Marketable: 36%
- Cutting and leaf collection: 36%
- Harvesting and grading production: 50%
- Cutting and leaf collection: 25%
- Handling and grading production: 25%
- Sorting: 23%
- Cutting and leaf collection: 22%
Appendix D. Results for Level of Automation in Individual Tasks

Appendix D1. Results Level of Automation Nurseries

1. Media preparation
   9 responses

   0 (0%)
   1 (22.2%)
   2 (66.7%)
   1 (11.1%)

2. Filling containers with substrate
   9 responses

   0 (0%)
   1 (11.1%)
   8 (88.9%)
3. Placing plant liners, sticking cuttings, and planting seed
9 responses

4. Moving containers from potting to transport vehicle for movement within the nursery
9 responses
5. Transporting containers to field in nurseries
9 responses

6. Removing containers from transport vehicle and placing in the field
9 responses
7. Spacing of plants and containers
9 responses

8. Picking plants up and loading onto transport vehicle at time of sale
9 responses
9. Removal of plants from transport vehicle and placing in holding area awaiting shipment

9 responses

10. Picking up plants from holding area and loading onto delivery vehicles

9 responses
11. Jamming plants for winter protection
9 responses

12. Plant pruning
9 responses
13. Fertilizer application
9 responses

14. Pesticide application
9 responses
Appendix D2. Results Level of Automation Greenhouses

1. Media preparation

9 responses
2. Filling containers with substrate
22 responses

3. Cutting and seed collection
22 responses
4. Cutting and seed preparation
22 responses

5. Placing plant liners, sticking cuttings, and planting seed
22 responses
6. Environmental control
22 responses

7. Harvesting and grading production
22 responses
8. Fertilizer application
22 responses

9. Pesticide application
22 responses
Appendix D3. Results Level of Automation Mixed Nurseries and Greenhouses

1. Media preparation

17 responses
2. Filling containers with substrate
17 responses

3. Cutting and seed collection
17 responses
4. Cutting and seed preparation
16 responses

5. Placing plant liners, sticking cuttings, and planting seed
17 responses
6. Environmental control
17 responses

7. Moving containers from potting to transport vehicle for movement within the nursery
17 responses
8. Transporting containers to field in nurseries
17 responses

9. Removing containers from transport vehicle and placing in the field
17 responses
10. Spacing of plants and containers
17 responses

11. Harvesting and grading production
17 responses
12. Picking plants up and loading onto transport vehicle at time of sale
17 responses

13. Removal of plants from transport vehicle and placing in holding area awaiting shipment
17 responses
14. Picking up plants from holding area and loading onto delivery vehicles
17 responses

15. Jamming plants for winter protection
16 responses
16. Plant pruning
17 responses

17. Fertilizer application
16 responses
18. Pesticide application
17 responses

19. Irrigation application and management
17 responses