Estimation of agricultural traffic intensity on the Dutch road network

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Preface

In front of you lays five and a half month of real hard work. A master thesis written at the Kadaster about agricultural traffic intensity. As almost half of a year sounds like a long time, it flew by like it was nothing. Months felt like weeks, and weeks like days. Preparing, conceptualizing, performing and documenting an entire project is intensive.

The fact that the subject fits my interests very well, helped a lot to end the project in time. As I have been born, and raised at a farm, is agriculture something that always interests me, and I was so lucky to be able to combine this with my other passion, geographical information.

Furthermore my project is not only scientifically relevant, it also is in the society. As farms become bigger the amount of agricultural traffic can increase, and how can this traffic be facilitated in a satisfying manor for all parties. Insight in the agricultural traffic movements can help with the tasks of the future and this has already proven to be true because the Kadaster has obtained a new order in which the model, created in this study, will play an important role!

From this project I have learned how difficult it is to plan software in time. Though these systems are made to make your life easier, sometimes these systems are real pain in the asses. Furthermore it is an art to create a model that works, and create visuals of these models, though explaining the model in text is possible even more difficult.

I have furthermore learned that if you ask people about their passion, like farming, they are eager to help you with your project. I have enjoyed all the conversations I had with farmers, policy makers, supervisors, colleagues, students, and so on, and I want to thank all interviewees for their time, and their willingness to share their knowledge so it was possible to improve my model.

Furthermore I want to thank my supervisors. Paul Peter Kuiper from the Kadaster, for the brainstorm sessions, the comments on my texts, and enthusiasm. Moreover I want to thank my supervisor from the university, Ron van Lammeren, for his comments on the texts, the ideas on how to look different to the model, and his positive attitude towards the possibility to end this project in time. Also Marije Louwsma from the Kadaster has helped a lot with comments, and I want to thank her for these comments, and ideas.

Not only I needed educational assistance I also needed emotional, and social support. Without my parents, friends, brothers, and many others I would not have ended this project in time, and with the same satisfaction as I have did today. I am grateful for all the support.

As a map can say thousands words I hope you will enjoy the maps I have created, and of course I hope you enjoy reading my report, and I am curious to your comments, and ideas about it!

Summary

The **inducement** of this study is the limited knowledge of agricultural traffic intensity on the Dutch road. The expectation is that several developments result in an increase of this intensity, for example the ongoing growth of farm sizes. An agricultural traffic increase may result in conflicts with other road users. It is difficult to automatically count agricultural vehicles with infrastructural based devices. Furthermore agricultural traffic intensity fluctuates, because of the seasons. Consequently it is not possible to interpolate measured locations to estimate unmeasured locations, a methodology used in several car traffic density studies. Hence the **objective** is to model the agricultural traffic intensity in space, and time. Therefore the Kadaster model is extended. This model calculates the routes between a home and field parcel, but does not show how frequent this route is used. Therefore has been researched in this study which variables of the start, and endpoint influence the number of times a route is used by a farmer which is expressed in rides. A ride is trip from the home to the field parcel, and back. The five **research questions** of this study examine: the factors influencing the number of rides, implementing these factors, analysing the implementation, examining the influence of time, and validating the results. A network-based Geographic Information System is used as a **method** to calculate the routes, and rides. The researched factors that influence the number of rides are; crop type, soil type, and dumper size. Expert interviews are done in the Noordoostpolder, to research the implementation, and the validation. The interviews showed that the factor quantifications gave a first good view, but that some quantifications are adapted as a result of agricultural developments. The study **result** is a model that estimates the agricultural traffic intensity on road segments, for different time frames, and can give an impression of the traffic intensity pattern in a region. Because several uses of agricultural vehicles are not taken into

account, it is expected that the actual intensity is underestimated. The model results are compared with a study by the province of Zeeland, to the number of agricultural vehicles on an average workday. This comparison showed a weak correlation. It was difficult to compare both studies, because the methodologies were different. It is therefore **recommended** to research further validation options, and to extend other uses of agricultural vehicles. In the future it may be possible to use GPS tracking systems of agricultural vehicles to follow their movements. For now these systems on the researched agricultural vehicles are not yet commonplace and not suited for on-road tracking.

Samenvatting

De **aanleiding** van deze studie is de beperkte kennis van agrarische verkeersintensiteit op de Nederlandse wegen. De verwachting is dat een aantal ontwikkelingen leiden tot een intensiteitstoename, zoals de voortgaande groei van de bedrijfsgrootte. Een toename kan leiden tot conflicten met andere weggebruikers. Het is moeilijk om landbouw voertuigen automatisch te tellen met op infrastructuur gebaseerde apparaten. Bovendien fluctueert de agrarische verkeersintensiteit, als gevolg van de seizoenen. Daarom is het niet mogelijk om resultaten van gemeten locaties the interpoleren om de intensiteit op niet gemeten locaties te schatten. Daarom is de **doelstelling**: het modelleren van de agrarische verkeersintensiteit in ruimte en tijd. Daarvoor is het Kadaster mode uitgebreid, dit model berekent de routes tussen een huis en veld perceel, maar dit laat niet zien hoe vaak deze route wordt gebruikt. Daarom is onderzocht welke variabelen van het begin en eindpunt bepalen hoe vaak een boer een route gebruikt, die wordt uitgedrukt in ritten. Een rit is een reis van de huis naar de veld kavel, en weer terug. Met vijf onderzoeksvragen is onderzocht: de factoren die het aantal ritten bepalen, de implementatie van deze factoren, het analyseren van de implementatie, het effect van tijd, en de resultaten validatie. Een netwerk gebaseerd geografisch informatiesysteem is gebruikt als een **methode** om de routes en ritten te berekenen. De onderzochte factoren zijn; gewas, bodem type en kipper grootte. Expert interviews in de Noordoostpolder zijn gedaan om de implementatie en de validatie te onderzoeken. Uit de interviews bleek dat de factor kwantificering een goed eerst beeld gaf, maar dat sommige kwantificaties zijn verandert vanwege agrarische ontwikkelingen. Het studie **resultaat** is een model dat de agrarische verkeersintensiteit op wegvakken schat, voor verschillende momenten, en het kan een indruk geven van het verkeerspatroon in een regio. Niet met alle verschillende gebruikstoepassingen van landbouw voertuigen

wordt rekening gehouden, daarom wordt verwacht dat de werkelijke intensiteit wordt onderschat. De model resultaten zijn vergeleken met een studie van de provincie Zeeland, naar het aantal agrarische voertuigen op een gemiddelde werkdag. Deze vergelijking toonde een zwakke correlatie. Het was moeilijk om beide studies vergelijken, omdat de methoden verschillen. Het wordt daarom **aanbevolen** om verdere validatie opties te onderzoeken, en om andere toepassingen van landbouw voertuigen toe te voegen aan het model. In the toekomst is het misschien mogelijk op GPS tracking systemen te gebruiken of de bewegingen van agrarische voertuigen te volgen. Nu zijn deze systemen nog niet gemeengoed en niet in alle gevallen geschikt voor het volgen van bewegingen op de weg.

1 Background and problem statement

This research studies the agricultural traffic intensity in the Netherlands. Little is known about agricultural traffic intensity. Therefore this chapter describes both the inducement of this study and the so far performed traffic intensity researches. The existing researches mainly focus on other vehicles instead of agricultural vehicles. Thereafter the objective and the research questions are presented. At the end follows a reader's guide for the remaining report.

1.1 Agricultural traffic moving

Agricultural vehicles can be defined in different ways. In general these are defined as: *"motor vehicles with a restricted speed (Onderzoeksraad voor Veiligheid, 2010)"*. These vehicles can be used for work in the agriculture, forest industry or in the construction industry, like ground and (water) way industry. In this research not all uses of all types of agricultural vehicles are taken into account, only those that are used for agricultural purposes by the farmer.

The rural area in the Netherlands changes and these developments may lead to more agricultural traffic on the public road (Jaarsma & Hoofwijk, 2013). This rise is expected as a result of three different development in the agricultural sector. Firstly there is a broadening of activities on farms (Jaarsma & Hoofwijk, 2013; Rienks, Galama, Hermans & Jaarsma, 2009). Examples are camps and farm shops.

Secondly, farms still grow in size, while other farmers quit (*Appendix 1.1, p.67; Appendix 1.2, p.67*). Farmers buy or use more parcels for their activities. These parcels are not always near their home parcel and this can therefore result in longer and more rides over the public road (Jaarsma & Hoofwijk, 2013).

Thirdly farmers specialise (Jaarsma & Hoofwijk, 2013), which among other things leads to exchange of parcels between farms, because of the crop rotation system. Next to these developments the agricultural vehicles have become larger, broader and faster. For a period the growth of agricultural vehicles and machinery have moderated an increase of agricultural traffic intensity as result of scale increases. Currently the growth of the machinery seems to have reached its limits. The width of the roads does simply not allow broader vehicles (Rienks et al., 2009) and a further grow will result in compaction of the soils (Bochtis, Sorensen & Busato, 2014). The growth in size can result in unsafe situations. As a consequence the municipality of the Noordoostpolder has decided to no longer give exceptions for machinery broader than 3.5 meters (personal communication, Municipality Noordoostpolder).

Next to an expected increase in agricultural traffic, also the amount of recreational traffic has increased because of the broadening of activities on farms (Rienks et al., 2009). As a results of these developments there are concerns about the traffic safety (Jaarsma, Hoofwijk & Vries, 2013). From 1987 till 2005 the total number of deadly accidents has decreased while the amount of accidents with an agricultural vehicle involved has been stable (on average 15 a year) (Jaarsma & Hoofwijk, 2013). The share of accidents in which an agricultural vehicle is involved has become bigger.

It is therefore interesting to gain insight in the traffic flow of agricultural traffic. Because traffic flow volumes are important for transportation planning, maintenance scheduling and road construction (Selby & Kockelman, 2013). Insight in the agricultural traffic movements can therefore improve understanding of traffic situations, help with planning network renovation and it can increase the awareness of land consolidation benefits. Land consolidation is used to solve land fragmentation in order to improve agricultural efficiency (Demetriou, Stillwel & See, 2011) and can be used to improve the total rural area (Cay & Iscan, 2011). This can reduce the amount of agricultural traffic and also the commuting costs of farmers, because less rides lead to less fuel costs.

Unfortunately not much is known about agricultural traffic intensity on the Dutch road. In Louwsma and Kuiper (2013) a model is made which calculates the shortest route between home parcels and field parcels. However, this model does not show the number of times these routes are used. It gives only a limited insight in the agricultural traffic intensity. To this model is further referred as the Kadaster model.

Recently the Province of Zeeland (Oosthoek & Pouwer, 2014) has published a study to agricultural traffic intensity on the road. Within this study has been made use of automatic agricultural vehicle counts in the province of Zeeland in 2012 and 2013. On eight locations is permanently counted and five mobile devices are used on different locations.

Within this study has been made use of infrastructure based counting devices while it is difficult to differentiate agricultural vehicles automatically from other vehicles. Therefore expensive and time consuming visual control counts are necessary to confirm the automatic counts (Oosthoek & Pouwer, 2013). Furthermore temporary counts are not always reliable because agricultural traffic intensity fluctuates over time, as a result of the weather and seasons.

In the next paragraph is explained how other researchers have examined traffic intensity of for example cars and what therefore the possibilities are to create a generic, nation-wide model.

1.2 Traffic intensity researched

Several studies have been made use of different methodologies to investigate the traffic intensity (e.g. Darwish & Abu Bakar, 2014, Rebolj & Sturm, 1999, Schrekenberg, Neubert & Wahle, 2001) and for various reasons. For example to generate traffic information (Darwish & Abu Bakar, 2014), test new roads or estimate road traffic air pollution (Rebolj & Sturm, 1999). Within this paragraph different studies in which other road uses than agricultural are described. This is done to investigate possible methodologies for this study to research traffic intensity of agricultural vehicles. There are two main methodologies; infrastructure based devices and in-vehicle based devices. The results of these studies can be used to estimate traffic intensity in unmeasured locations.

Infrastructure based

Conventionally most of the traffic intensity studies are based on counts that are obtained from infrastructure-based devices (Darwish & Abu Bakar, 2014). This implies that the devices only count at one specific point at the network. The devices can be permanent, for example loop detectors or mobile, like traffic surveillance cameras, but always count at one place in one time frame. These devices can have high maintenance costs (Darwish & Abu Bakar, 2014) and are mostly installed in urban regions at intersections (Schrekenberg, Neubert & Wahle, 2001).

This study researches agricultural traffic intensity in the rural area in which permanent counting devices are scarce and therefore not useful methods for this study. Furthermore it is difficult to filter agricultural vehicles from the counting results and visual control counts are necessary to confirm the automatic counting results (Oosthoek & Pouwer, 2013).

Also in other studies has been made use of visual counts. These counts can be used for specific vehicles and in areas in which no counting devices are installed. Like boats in Widmer and Underwood (2004). These count results can be used to make a simulation in which network-wide information is generated (Schrekenberg, Neubert & Wahle, 2011). Therefore the intensity at unmeasured locations is estimated with kriging. This spatial interpolating of the results from observed locations can be used to obtain the annual average traffic intensity (AADT) for unobserved locations (Wang & Kockelman, 2009; Selby & Kockelman, 2013).

In these studies is made use of several explanatory variables. For example number of lanes and speed limit (Selby & Kockelman, 2013). In both studies is made use of the Euclidean distance (Selby & Kockelman, 2013; Wang & Kockelman, 2009). Selby and Kockelman (2013) found that the network distance showed little improvement and uses a longer calculation time.

However Lowry (2014) used a different technique because for some areas the explanatory variables do not vary much (Lowry, 2014). Lowry (2014) also used interpolation to estimate the intensity, but with the use of network distances and stress centrality. With centrality is searched to the *"topological importance of each element in a network (Lowry, 2014, p. 99)"* and stress centrality is *"the number of times a link would be used if someone were to travel from every node to every other node via the shortest path (Lowry, 2014, p. 100)".*

There are therefore several methods to estimate the traffic intensity for unobserved locations, with the use of infrastructural based counts.

Unfortunately from agricultural vehicles are very little counting studies available. The study in the province of Zeeland (Oosthoek & Pouwer, 2013) is the only known study in the Netherlands in which frequent counts over a large area performed. Therefore these methods are not useful for this study.

In-vehicle based

In-vehicle sensors may be an option to create generic traffic intensity estimations. Darwish and Abu Bakar (2014) review recent techniques and algorithms that are used for traffic intensity estimation, like the infrastructure free in-built wireless communication systems of vehicles. More and more newly built vehicles are equipped with these wireless communication devices (Darwish & Abu Bakar, 2014). With the use of different algorithms the traffic intensity can be calculated (Darwish & Abu Bakar, 2014).

Also in more and more agricultural vehicles wireless tracking devices are used. Some of these vehicles make use of GPS (Global Positioning System) technology to increase cultivation precision. For example to drive in a straight-line or to precise the tool position (Perez-Ruiz, Slaugther, Gliever & Upadhyaya, 2012). Lehman, Reiche and Schiefer (2012) point out that the application of these (smart) sensors varies from different parts in the food sector. For example in the transportation sector the sensors are used to monitor truck movements, or identify fuel usage. The system on agricultural vehicles used by farmers are in most cases particular created for localization purposes on the field (Perez-Ruiz et al., 2011) and not for on-road tracking. The sensor determines were it is, for example to drive straight and this position is not always saved, so it cannot be reused (personal communication, employer Louis Nagel BV).

Adjacent to this the systems are not commonplace yet. Several persons from the sector are asked and they do not expect that more than thirty percent of the agricultural vehicles on the Dutch road have some type of tracking system (personal communication, employer Louis Nagel BV; personal communication, employer, PPO-AGV). The previous explained methodologies are therefore not applicable to study the frequency of which agricultural vehicles make use of the public roads. Though it is possible that in the future the devices are more commonplace and easier to use for on-road purposes.

1.3 Objective and sub questions

The conclusion therefore is that both infrastructural based and in-vehicle methods are not yet applicable to research agricultural traffic intensity for the entire Netherlands. Therefore the idea of Dijkstra, Timmermans and Jessurun (2014) is used for this study. Dijkstra, Timmermans and Jessurun (2014) have asked pedestrians what their motivations are to visit stores. With these motivations they want to make an agent-based model to simulate the pedestrian's behaviour in which these visits are related to gender, age and motivation. This model is not yet created (as far the author knows), but the idea is useful for the current study. Also in Gónzalez, Marey and Álvarez (2007) a simulation is used as a tool for rural road network management, because the development of Geographical Information Systems (GIS) integrates geographical databases and map visualisation. These GIS therefore form an enormous potential to improve land consolidation processes (Gónzalez, Marey & Álvarez, 2007).

Therefore is decided to create a motive-based model to extend the Kadaster model which calculates the routes between home parcels and field parcels (Louwsma & Kuiper, 2013). Both the spatial location and the temporal fluctuation of agricultural traffic is interesting. This can improve network management and form an incentive for land consolidation. These inducements are combined in one objective:

“The creation of a model that estimates and shows the spatial and temporal distribution of agricultural traffic intensity on the Dutch road network”

To be able to achieve the objective five research questions are formulated. The first question focusses on the factors that influence the number of times the calculated routes by the Kadaster model (Louwsma & Kuiper, 2013) are used. Thereafter is examined how these factors can be included in a model which is applicable for the entire Netherlands. Therefore the factors are classified and quantified. Thereafter this implementation is tested with expert interviews. The fourth question researched the effect of the different input datasets on the results. To gain insight in the influence of these datasets on the model results and what data is most useful. At last the model output is validated with the use of the study in Zeeland (Oosthoek & Pouwer, 2014) and expert interviews. All in all five research questions are created:

1. *Which (parcel) factors determine the number of rides with an agricultural vehicle between home and field parcels?*
2. *How can the determined factors be included in an agricultural traffic intensity model for the Netherlands?*
3. *To what extend is the model implementation in coherence with the expert judgements?*
4. *What is the effect of the input data on the model results?*
5. *How can the model be validated with the perception of the farmers and the results of a study in the Province of Zeeland?*

1.4 Readers guide

The next five chapters focus each on a research question. Every chapter consist of: relevant literature, the methodology, the results and at last a small and short conclusion. This implies that chapter 2 examines research question 1, chapter 3 research question 2 and so on. In chapter 7 an overall conclusion follows and several recommendations are given. This order leads the reader chronological through the study.

The figures and tables are not included in this document, but added in a separate “figures book”. This book consists of two parts; at first the illustrations directly related to the text and secondly the appendices. To these figures and tables is referred with page number so that the reader is able to open both this textual document and the figures books with the illustrations and appendices.

2 Conceptual model

In this chapter is focused on the conceptual model as used in this study. To be able to create this conceptual model the factors that influence the number of rides to a field parcel are defined. At first some theory relevant to modelling in space is described. Thereafter attention is paid to studies that research factors influencing the number of rides to a field parcel. The research question that is answered in this chapter is: "*Which (parcel) factors determine the number of rides with an agricultural vehicle between home and field parcels?"*

2.1 Modelling

The study objective is to create a model that estimates the traffic intensity. Therefore are factors to go to a field parcel used to estimate the traffic intensity. This is an idea derived from the study of Dijkstra, Timmermans and Jessurun (2014). In this study is to goal set to use a model to describe the behaviour in a system. A system is defined as: *"interacting components performing a function (Cassandras and Lafortune, 2008)"*. The system of farmers, parcels and network is in this study described with a spatial interaction model, in a geographical information system (GIS). This helps to understand and predict the location of movements of for example people. In this case is assumed that as long as the parameters are the same the behaviour is the same, when for example a crop changes, the behaviour will change. Two factors are important when the interaction between two locations is researched; the distance to the destination and the characteristics of

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the destination (Heywood, Cornelius & Carver, 2011). In this study is focused on the destination characteristics. The route is calculated by the Kadaster model (Louwsma & Kuiper, 2013), which calculates this route with Dijkstra's shortest path algorithm between a home and field parcel.

A model is *"a representation of an actual system (Banks, 1999)."* It has its limits with regard to the representation of the real world because *"models need to be simpler than the original (Breckling, Jopp & Reuter, 2011a, p. 3)"*. When a model is as complex as the reality, it would not enlighten the system patterns. Therefore the objective is to capture the essence (Breckling, Jopp & Reuter, 2011a, pp. 6-7).

With a cause-effect diagram the relevant structural components are identified. Such a diagram gives insight on the relations, in the specific context. Important is that the components must be quantifiable (Breckling, Jopp & Reuter, 2011b, pp. 44-46). In this cause-effect diagram the factors influencing the number of rides are visualised. The studies done to these factors are described in the next paragraph.

2.2 Studies to field parcel factors

An example in which is written about the factors influencing the number of rides is the CROW-publication 'Landbouwverkeer naar geëigende banen' (Martens, 1991 as quoted in Jaarsma, 2010). This method takes into account: farm type, parcel location, soil use, length and quality of the infrastructure.

In Gónzalez, Marey and Álvarez (2007) is a model created in which different factors are taken into account to calculate the economic benefits of land consolidation. In this model the situation before and after land consolidation are compared. Two costs are taken into account: working costs on the parcel (depending on parcel size and shape) and the transport costs to the parcel from the home parcel. In order to calculate these costs is assumed that the plots of land have homogeneous soil quality, one crop type and an equal sized dump truck (Gónzalez, Marey & Álvarez, 2007), but these factors can be interesting in this study.

Furthermore Rienks et al. (2009) researches the possible effect of an increase in size of dairy farms. In this research three fictive situations are made in which the traffic intensity is estimated. In these calculation is assumed that all farms produce grass and that there are annually eight rides necessary (per hectare). The result of this study is that an increase in scale results in less traffic, because the transportation of fertiliser and milk can be done more efficient. Furthermore an ideal land consolidation results in less rides (Rienks et al., 2009).

In conclusion the following factors are (partly) taken into account or identified in previous studies:

- Farm type, parcel location, soil use, distance and infrastructure quality (Jaarsma, 2010)
- Parcel size, parcel shape, crop type, soil quality, machinery size (Gónzalez, Marey & Álvarez, 2007)
- Land consolidation, crop type, scale size (Rienks et al., 2009)

The relation of these factors are visualised in a cause-effect diagram (*Figure 2.1, p.10*). The factors influencing the network are not taken into account, because the routes are based on the Kadaster model and or not further researched. Several factors are added to the diagram based on the knowledge of the author. Firstly the percentage of a parcel that is not used. This is for example not used because of the shape (Gónzalez, Marey & Álvarez, 2007). Secondly, most farmers source out a part of their work to contracting firms. For example many dairy farmers with fodder beets ask wage workers to do tasks related to that product (Nijssen & Scheppingen, 1995). Contracting firms have in general bigger machineries so this can have an effect on the number of bulk rides (personal communication, interview farmers). Thirdly the skills of the farmer and weather can influence the production size.

2.3 Factors not taken into account

As stated before a model must not be as complex as the reality and therefore capture the essence. As a consequence several factors are not taken into account, furthermore some factors are difficult to quantify or data is missing. The factors that are not taken into account are: contracting firms, farm type, percentage of the parcel that is not used, soil quality and skills of the farmer.

Farm type can have an effect on the production per hectare, for example biological farms produce less (PPO [Wageningen, Praktijkonderzoek Plant & Omgeving], 2012). Though is decided not to include this in the model because of the small share of biological farms[1] and the comprehensibility of the model.

The Kadaster model calculates the route between a home and field parcel. The contractor does not always take this route and therefore all activities in this model are performed by the farmer. Furthermore it differs from farmer to farmer which activities are sourced out to contracting firms.

The other factors that are not taken into account, are difficult to quantify. The weather changes of course each year, therefore is looked at the average production of a crop over five years (PPO, 2012). Soil quality is partly handled with the factor soil type.

2.4 Factors taken into account

The factors taken into account are: crop type, soil type, parcel size and dump truck size. In *Figure 2.3, p.11* is shown that crop and soil type result in 'fixed' activities. These activities are equal for each crop and independent form the parcel size. The number of bulk rides is also influenced by the crop and soil type. Furthermore by the production per hectare, dump truck size and parcel size.

In this study crop type refers to a certain product like potatoes or onions. Different crops need different attention rates. For example a crop like winter wheat needs about twenty visits in a year, while a plant potato needs about thirty rides (PAGV, 1995). The crop choice depends on the soil type, soil quality, farm type and the crop that grew on the parcel before. Some crops can be produced on different soil types, but the production can be higher on specific soil types (PPO, 2009; PAGV, 1995).

Furthermore the activities can be different. For example on sandy soils the ploughing is mainly done in the spring instead of the autumn, like on clay soils (Jong, 1985; Jorritsma, n.d.). Also some products are directly sold from the field parcel or stored on the field before transportation by trucks. For example starch potatoes are stored on the field parcel, from where these are transported to the factory by trucks (personal communication, farmer interviews). This results in less rides to the home parcel.

2.5 Other factors

Next to field parcel factors there are other factors part of the system, these factors are shown in *Figure 2.2, p.10*. In this paragraph is attention given to distance, parcels, time and the region.

[1] In 2012 was the share of biological farms 2.6 percent of the total Dutch agricultural land (CBS, PBL, Wageningen UR, 2014).

Distance

The route is calculated by the Kadaster model (Louwsma & Kuiper, 2013) with Dijkstra's shortest path algorithm, in which length is the only 'cost' influencing this shortest path.

Parcel owner or user

There are two datasets of parcel registration. The first dataset is the cadastral database (held by Kadaster) in which is registered who owns a parcel. Although, the user can be someone else than the owner. This can result in different routes, because the actual farmer (user) lives somewhere else. Furthermore, some owners are not farmers, but an organisation like Domeinen (state organisation that rents land to farmers). Without information of who the farmers are, these parcels cannot be divided in home and field parcels.

With the second database is registered who uses the parcel. This database is created by the farmers and held by the RVO[2]. It is possible that an owner is also the user. Fortunately the user data of the two case studies is made available by RVO.

Region

At last are the parcels and roads located in a region. Because of time constraints it is not possible to test the model in the whole of the Netherlands. Therefore two case study areas are chosen; the municipality of the Noordoostpolder and the province Zeeland (*Figure 2.4, p.12*; *Figure 2.5, p.12*). Within the Noordoostpolder interviews with experts are used to refine the quantifications and the model. In the Noordoostpolder many crop types are cultivated and both clay and sand are found there (*Figure 2.6, p.13*, *Figure 2.6, p.13*). Furthermore it has a natural boundary as it is surrounded by water on two sides, which results in less edge effects (see next chapter). A third reason is the reasonable to bad land consolidation (DLG, Kadaster & LTO Nederland, 2014), therefore it can be expected that there is agricultural traffic on the road.

The Province of Zeeland has done a research to agricultural traffic intensity. The results of this study are compared with the model results. Zeeland has similarities with the Noordoostpolder; both have a similar variance in crop types (*Figure 2.8, p.13*) and consist mainly of clay (*Figure 2.9, p.13*).

Time

Some of the factors change over time. This is the result of the crop rotation system, also the owner or user can vary over time. Next to this agricultural traffic intensity fluctuates over time, as a result of the weather and seasons. Time is therefore also a factor that is researched in this study and the classification is explained in the next chapter

2.6 Résumé

As a result of the literature study and the author's knowledge different factors are distinguished that are used in the model. These factors are: crop, soil type, dump truck size, production and parcel size. Furthermore the owner or user can differ from parcel to parcel. These parcels and the network are located within a region and can change over time. As it was not possible to research the entire Netherlands is looked at two regions; the Noordoostpolder and Zeeland. The route calculation is based on the Kadaster model.

[2] *Rijksdienst voor Ondernemend Nederland, Civil service of Enterprising Netherlands.*

3 Implementation in a spatial model

After the creation of the conceptual model, in this chapter this is implemented in a model with the second research question: *"How can the determined factors be included in a agricultural traffic intensity model for the Netherlands?"* **The model is a spatial model and therefore some theory related to spatial data and problems related to this are described. Thereafter is explained how the factors are classified and quantified. Subsequently is explained how the parcel data is prepared and how the route and ride calculation is performed.**

3.1 Network

Networks are all around us and used for transportation of all kinds of goods. A network is used to connect things and therefore consists of elements which are interacting. These interconnected features transport materials, people, but also communication can be transported (Heywood, Cornelius & Carver, 2011). In this study a transportation network is researched and visualised with geographical information systems (GIS). I

In these systems the vector model is used to represent an abstract of the reality, the network. Within these networks the impedance is an important characteristic. This is "*the cost associated with traversing a network link, stopping, turning or visiting a centre (Heywood, Cornelius & Carver, 2011, p. 96)*". In this research length is the only the impedance.

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3.2 Bordered case studies

In the previous chapter is explained that the parcels and roads exist in a region. The model is tested in two case studies and the boundaries of these areas are based on administrative regions, while the researched system does not 'stop' at those borders. This is called the 'modifiable areal unit problem (MAUP)', the form of the researched zones is usually arbitrary to the system and they can be termed 'modifiable' (Lloyd, 2014).

For example in this research some parcels are not taken into account, because some farmers have parcels outside the research area, but have their home parcel within the research area. The same accounts for farmers who have their home parcel outside the research area, but have field parcels within the research area. Because this has more influence at the borders of the area, parcels outside the area are more nearby, is referred to this problem as the 'edge effect'.

Furthermore there is the risk of ecological fallacy, this is the fault of making assumptions about individuals from aggregated data (Lloyd, 2014). Also in this research generalised assumptions are made about the behaviour of the farmers, but this does not imply that every single farmer acts like the assumed average does. In this research the objective is to research the amount of traffic in average, not on an individual scale, but this must be taken into account when the output is used.

3.3 Time classification

As stated in the previous chapter, time has influence on the agricultural traffic intensity. Many crops in the Netherlands have a grow cycle of less than a year (Mulder et al, 1996). Examples are potatoes, wheat and sugar beets. Furthermore most crops are planted in the spring (or in the autumn after the harvesting of the previous crops) and harvested in the autumn or summer (PAGV, 1995). It is not possible to assign a specific month to an activity, but the seasonal activities are on average the same each year. The seasons are divided in four categories:

- Spring: March, April, May
- Summer: June, July, August
- Autumn: September, October, November
- Winter: December, January, February

3.4 Parcel factor classification

In this paragraph is explained in which categories crop and soil type are divided and how. In this study several databases are used. A list can be found in: *Appendix 3.1, p.69*.

Crop type

The crops cultivated on a parcel are registered in the public available anonymous BRP (Basis Registratie Percelen, Basic Registration Parcels) (PDOK, 2014a). This dataset is based on the report that farmers make each year and around eighty different soil uses are distinguished.

At first the fifteen crops that cover the largest area in the Netherlands are selected (*Appendix 3.2, p.70*). Of this list permanent grassland was the most important, thereafter corn, temporary grassland, wheat and sugar beets. This list is used as a start point for the classification. Some of these crop types are combined because the number of activities are similar. For example temporary and permanent grassland and wheat and barly. Thereafter other crop categories were added because the classification was not nationwide with only the most important types.

Also a group of small crop types is created, the category 'agricultural crops'. Furthermore some crop types are not taken into account, as a result of lack of time and some of these types result in more truck traffic instead of agricultural traffic, like greenhouse cultivation. These are placed in the group 'Not researched'. This results in twelve classes (*Table 3.1, p.16*, *Appendix 3.3, p.71*).

Soil type

After the classification of the crop types the factor soil is categorised. The database that is used is called 'Fysisch geografische regios'. It consists of nine different soil types: closed estuary, dunes, tides area, hilly country, higher sandy soils, low peaty soil, river clay, sea clay and non-identifiable category (PDOK, 2014b). Examined is at which soil types which crops are dominant for crops in 2013 (*Table 3.2, p.16*). This examination shows that higher sandy soils, sea clay, river clay and low peaty soil are the main soil types. Peaty soil is especially important for two categories: grassland and fallow ground.

In PPO (2012) in which the production for the crops are estimated. These are divided over different soil types; clay, sand, 'dalgrond' and river clay ground. Clay and sand are also divided over different regions for example clay in the 'IJsselmeerpolders' and 'Zuidwest Nederland'. In many cases the production is the highest on clay in the IJsselmeerpolders (for the relevant crop types the production per category can be found in *Appendix 3.4, p.73*).

Because the clay in the IJsselmeerpolders gives the most production, is decided to create a category with clay, which includes river clay and a category with IJsselmeer clay. Sand is also added as a category, because in all cases the production is lower in comparison with clay. At last the fourth class 'peat' is made, because this is important for the crop category grassland. The grass production on peat is relative low in comparison with sand ground, furthermore most farmers on peat ground are more extensive in comparison with farmers on sand ground (Aarts, Daatselaar & Holshof, 2005). In conclusion the soil categories are: clay IJsselmeerpolders, clay other, sand, peat and rest (*Table 3.3, p.17* + *Figure 3.1, p.17*).

3.5 Parcel factor quantification

This paragraph explains the quantification of the factors soil, crop and dump truck size. As already described soil and crop type influence the number of activities and the production. For the different crop and soil types the production is estimated and the number of activities per season. These quantifications are made with KWIN publications (Kwantitatieve informative, Quantitative Information) (PAGV, 1995; PPO, 2009; PPO, 2012; WUR [Wageningen UR Livestock Research], 2013),

Production

The production per hectare influences the number of bulk rides from and to a field parcel. For ten of the created crop categories a production per hectare is estimated (*Table 3.4, p.18*, 'Fallow ground' and 'Not researched' do not have a production. The production of the crop categories is divided over the four soil categories and is for all categories obtained from PPO (2012; *Appendix 3.4, p.73*) except for the categories green fodder plants and grassland, these are obtained from WUR (2013) and Aarts, Daatselaar and Holshof (2005).

The production per hectare of a specific crop category is calculated by mediating the known production of the crops within this category. This is done proportionally, so the production of a crop type that is cultivated more in the Netherlands weights heavier. Furthermore PPO (2012) divides clay from North Netherlands, the Southwest of the Netherlands, river clay, clay in general and IJsselmeer clay. The first four are used for the category 'Clay rest'. IJsselmeer clay production of course for the category 'IJsselmeer clay'.

The grassland production is based on five mow moments in a year and the production for sand is the mean of wet and dry sand production. In cases that the production was not divided over different soil types the one that is given is used. For example in the case of 'Starch potatoes'. From this category only the production in general is given.

Activities

Next to the bulk activities there are fixed activities. These are identical for each crop lot and do not depend on parcel size. For example plant potatoes are visited twenty-five times each year. These activities are based on the PAGV (1995) and WUR (2013). The activities are divided over the seasons. For several crop categories there was no information about the differences in activities per soil type. In those cases one quantification per crop category is made that is used for each soil type (*Table 3.5, p.18*). In *Appendix 3.5, p.74* is shown which activities are taken into account.

Dump truck size

About the factor dump truck size was not much specific information. Therefore only two categories are made that depend on crop category. The category 'green fodder plants' and 'grassland' are in the model transported with a dump truck of eleven ton and to the other crop categories with a dump truck of eighteen ton (PPO, 2012; WUR, 2013) (*Table 3.6, p.19*).

3.6 Parcel preparation

This paragraph explains the preparation of the parcels. First is explained which two methods there are to select the home parcel.

The selection of the home parcel is done in two different ways for these two databases. For the owner dataset the home parcel is selected with the use of the GBKN (Grootschalige Basiskaart Nederland, Large scaled key map Netherlands). In this database the addresses and buildings are given. The category 'main building' is used to select a home parcel. Though it is unknown if this main building is indeed the home of the farmer. Therefore the address point is better. For the owner data this cannot be used, because the PHT code (Postal code House number Additive, Postcode Huisnummer Toevoeging) is not in the correct format. For the user database this PHT can be used and is obtained from, the ACN (Adressen en Coördinaten Nederland, Addresses and Coordinates of the Netherlands).

Both methods can result in a wrong home parcel selection. It is possible that the retired father owns the land, but lives in the city while the son uses the land. Or the address point is not the location of the machinery storage.

Preparation database with owners

The owner dataset is prepared in the software package Geomedia and the steps as followed in Geomedia can be found in *Figure 3.2, p.19* and are explained below. The numbers and letters between the brackets correspond with those in the figure.

At first the owner lot file (A) is clustered geographically. This means that all lots that have the same owner and share a border are combined in one parcel (1) (*Figure 3.3, p.20*, step 1). The cadastral borders are in the middle of the ditch, it is therefore possible that there is a ditch between two lots, but this is not taken into account.

In step two the home parcels are selected (2) (*Figure 3.3, p.20*, step 2). This is done with the GBKN. Those parcels that contain a main building are selected (2). In a new field (HUIS_VELD) the selected parcels are labelled with 'Huis' (3).

After the creation of the HUIS_VELD column (3), an EIGENAARID is made (4). This must be a unique value, but equal for the parcels that are from the same owner. This value can be the 'subjectnummer' and 'subjectnaam. Thereafter the surface is calculated (5) and saved in the attribute OPPERVLAK.

In conclusion the dataset is tested on its validity. Double home parcels must be removed (6), because the route calculation can only use one home parcel. Not all owners are farmers and therefore these must be removed from the owner dataset (7). These owners are for example; the energy companies, industries, investment companies and municipalities. These owners are removed on the basis of their name. Furthermore owners who have more than 100 parcels are not farmers and can be removed.

The parcels are now clustered on their adjacency and three attributes are added (HUIS_VELD, EIGENAARID, OPPERVLAK). The creation of EIGENAARID and OPPERVLAK are the same for the user dataset. The clustering procedure and home parcel selection is different and explained in the next paragraph.

Preparation database with users

The user dataset is made available by RVO and prepared in ArcGIS with the model builder (*Appendix 3.6, p.86*). In the following text the numbers and letters in brackets correspond to those in *Figure 3.4, p.20*.

The user dataset is more difficult to prepare than the owner dataset, because it is created differently than the owner dataset. The user dataset is made by the farmers and they draw topographical borders instead of cadastral borders (*Figure 3.5, p.21*). The user lots are therefore smaller and as a consequence the address point or a main building may fall outside the lot border, since the building or address point is located on the farmyard. Furthermore the lots are not drawn from middle point of the ditch to the other middle point in the ditch and therefore these lots are not located directly next to each other (*Appendix 3.7, p.88*). As a consequence it is not possible to cluster the adjacent parcels. Therefore a buffer is made around the lots (1) (*Appendix 3.8, p.89*). The size of this buffer depends on the size of the ditches. Since the width of the ditches is the smallest natural border between two lots, the width of the ditch is taken. The parcel dataset is prepared as the owner dataset and in the cadastral data the ditches are not taken into account, therefore the lots with a ditch in between, must be clustered. The buffer size must not be bigger than the ditch because there are also roads and wider waterways, in between parcels.

For both the Noordoostpolder and Zeeland is chosen for a buffer

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size of four meters. This results in ditches of eight meters, because lots on both sides of the ditch get a buffer of four meters. After a visual check this buffer size appeared to be large enough (in most cases) to cover the ditches, while small enough not to cover the width of larger waterways or roads. After the creation of the buffer, the lots are clustered geographical (2) (*Appendix 3.9, p.90*). For some lots the four meter buffer is too small (*Figure 3.6, p.21*, brown parcels 1, 2 and 3). These parcels can all be reached over land, but only 1 and 2 are geographical connected. The buffer size is not increased since lots are already connected while these are not connected. For example the dark purple parcels (*Figure 3.6, p.21*, A and B) are connected while in reality they are not connected.

It is possible that some lots are clustered while there is a road between them. To solve this problem, the parcels are cut by the roads from the Top10NL (4). To be able to do this, the polygon circles must be transformed to lines (3) (like the network dataset). Thereafter the lines are transformed to polygons (5). Thereafter the parcels are selected and the PHT code is again added (6), because the software has removed it. Thereafter the attribute EIGENAARID is added. The method has some flaws, but is considered as the best method for now.

The ACN dataset (B) consists of points and as stated before these points do not fall within the borders of the user lots, in contrast to the owner data. At first a selection is made of ACN points that match the PHT code of the user dataset made in step 6. Thereafter a buffer is made around the ACN points (9) (*Appendix 3.10, p.91*). In this case is chosen for a buffer of 50 meters, because most farmyards in the Noordoostpolder are 100 by 100 meters. This buffer size is also used for Zeeland. This buffer can reach to the other side of the road (*Figure 3.7, p.22*). If this happens it is possible that lots on each site of the road are clustered. Therefore the ACN circles are combined and cut with the network dataset in step 10 to 12 (*Appendix 3.11, p.92* and *Appendix 3.12, p.93*). This results in half circles of which only the polygons intersecting with an ACN point are selected (13, *Appendix 3.13, p.94*) and to these polygons the correct PHT and EIGENAARID is added (13 and 14).

The ACN polygons can be seen as 'farmyards' and these are combined and clustered with the adapted parcels on the bases of the PHT code and EIGENAARID (15 and 16) (*Appendix 3.14, p.95*). Thereafter the attributes HUIS_VELD and OPPERVLAK are added (17 and 18).

3.7 Network

In this paragraph is explained how routes are calculated in FME (Feature Manipulation Engine) within the Kadaster model. The numbers and letters in brackets correspond to those in *Figure 3.8, p.22*.

For the routes calculation three input files are needed; the road network, the parcel file and the ACN points. From the road network (A) the roads are selected on which in general agricultural vehicles are allowed to drive (1). This are the roads with the main use: 'mixed' and 'other'. Based on local knowledge some roads within the Noordoostpolder are removed, because agricultural vehicles cannot drive on these roads. In the case of the province Zeeland this local knowledge was not available. Though the network of Zeeland is adapted, because Zeeuws-Vlaanderen and the remaining of Zeeland were not connected. Therefore is a road made between Zeeuws-Vlaanderen and the remaining of Zeeland.

Thereafter a unique ID is attached (2) to either the user file (B) or owner file (C). This ID is also attached to the routes that are calculated between the home and field parcel, which makes it possible to combine the correct route with the correct parcels. The home and field parcel are handled differently in the model and are separated on the bases of the field 'HUIS_VELD'. For the home parcels the address point is used as start point, the field parcels do not have an address point within their borders and therefore the centroid is calculated (3). From this centroid a straight line is made to the nearest road (4). At the place where the line cuts the road, point A is placed (5), which is the starting point of the route.

Thereafter the end point is generated. At first the double home parcels are filtered (6). The biggest home parcels are chosen, the other double home parcel(s) are not taken into account in the remaining of the calculation. These double home parcels are grouped in one file (G). The parcel file is at its best if there are no double home parcels. The end point of the route is the address point within the home parcel, point B (7). From these address coordinates a line is made to the nearest road, but the endpoint B is the same as the ACN coordinate (7). Between the created points, point A and B, the shortest routes is calculated (8). This is done with the use of the Dijkstra's algorithm.

After this calculation several output files are generated. The routes per owner (E), with all separate routes between home and field parcels. One owner can have more than one route, because (s)he has more field parcels. Furthermore the road is cut in segments. These segments are created were routes stop using the road or enter it. This means that as long only one route goes over the road it is not cut, if another route enters this route at some place, there the roads are cut. These road segments are given in (F). This file is used to calculate the traffic intensity per road segment. Furthermore the double home parcels are given in dataset G, if these are found. At last some statistics are given in an Excel file (H).

3.8 Traffic intensity calculation

The traffic intensity is calculated with the routes that are made in the previous step. Furthermore the crop and soil data is needed (PDOK, 2014a; 2014b). In the next description the numbers and letters in brackets correspond to those in *Figure 3.9, p.23*.

The crop data and the soil data are first clipped by the research region (1), so that the amount of data is diminished. Thereafter both the crop and the soil dataset are classified in less categories (2). This is done with the classification as made in the previous chapter, which is stated in two tables (*Appendix 3.15, p.96*, *Appendix 3.16, p.97*). So that the classification is clearly visible and is easy to change.

After these steps the EIGENAARID is attached to the crop lots (3). Thereafter the crop lots are cut with the soil data (4). This results in more lots (*Figure 3.10, p.23*), because some crop lots consist of different soil types. The crop category and soil category are combined in one column (5), for example 'Clay potatoes'. Thereafter the surface of the lots is renewed (6), because the size of the lots is changed and the surface is not instantly calculated again.

The production and activities table (F) is combined with the attribute in which both the soil and crop type are stated (7). Behind every type is now stated what the production per hectare is, the usual dump truck size and the other activities for the different seasons.

In step 8 the bulk and fixed activities are calculated. Therefore the production per hectare is multiplied with the parcel size and divided by the machinery size. The activities as stated in table F are one-ways, although the farmer needs to go back and forth, so the number of activities is doubled.

After this the lots are clustered with the use of the IDPercelen (G) and the attribute EIGENAARID that both data files have (IDPercelen and the lots with activities) (9). The lots are now combined in parcels, which means that the crop lots that lay within a parcel are combined into one parcel. These parcels have the ID from IDPercelen. This ID is also used in the dataset in which the routes are saved, ‘Routes per owner’ (H). Therefore is it possible to connect the routes to the correct parcels (10). This is attached to the ID of the field parcel, because this parcel implies the number of activities. Now the length of the routes per owner are calculated (11). Thereafter a dataset is made that has information about the number of activities and the length of the routes for each owner (J).

In step 12 and 13 the traffic intensity on a region level is calculated. Therefore all individual routes are cut by the road segments (I) (12). This results in small line parts to which the activities of all routes are attached. In step 13 these small line segments are summed on their geographical location. In other words, routes on the same location are the activities combined in one line segment. This results in the dataset ‘Rides per road segment’ (K).

3.9 Résumé

The factors crop and soil category influence the number of fixed activities and bulk activities. The bulk activities are quantified with the production size per hectare, dump truck size and parcel size. The fixed activities depend on the crop and soil type. Also the dumper size depends on the crop type. The crop type therefore has an important influence on the activities.

The two different parcel datasets are prepared. The user parcel is made with different standards and the preparation is therefore more time consuming. The shortest route is calculated with the kadaster model and thereafter the frequencies are added.

Expert judgment 4

In this chapter the third research question is examined. *"To what extend is the model implementation in coherence with the expert judgements?"* First is the interview methodology explained. Thereafter are the interview results described and the subsequent factor adaptations. At last a short conclusions is given

4.1 Interview methodology

In this study are interviews held to improve the quantification and the classification that has been made in the previous chapter. Furthermore the model results, like the route chosen and the agricultural traffic intensity are discussed. The results of these subjects are described in the next chapter. This chapter solely focusses on the changes that are made to the factor quantification as a result of the interviews.

These interviews are done by phone and face-to-face. There is made use of interviews, because of the depth that can be reached. This is why this qualitative method is used, furthermore the interviewees and interviewer can give and ask for extra explanations (Dunn, 2010).

The interviewees found it easier to discuss a number and how this number is calculated, instead of estimating a number without some footing. Since the questions can differ per interviewee is made use of a semi-structured topic list, which implies that the questions are not strict (Dunn, 2010). These topic lists can be found in *Appendix 4.1, p.101*. In the face-to-face interviews the persons are asked to draw the route they take to a specific parcel, how many times they are going

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to that parcel and their perception on the pressure of agricultural traffic in that region.

The interviewed persons are called 'key figures'. Key figures are persons who are able to give information and give deeper insight into the situation because of their position in the society or because of their personal abilities (Marshall, 1996, p. 92). Therefore the assumption is that behaviour of farmers is predictable and can be deducted from a group of key figures. This assumption may not be true, but in general the experts or key figures are well informed about their specific farm type. Another issue can be that the key figures have thought their answers through and therefore give an adjusted answer (Marshall, 1996). Therefore it is probably that the answers slightly differ if the research is repeated. To enable a repetition the topic lists are given in the appendix and an explanation is given on the choice of key figures.

Who is interviewed and a description can be found in *Appendix 4.2, p.108*. The interviewees have fake names to be able to refer to them. In the Noordoostpolder nine face-to-face interviews are done. One is farmer advisor, two farmers who also perform farmer advisor activities and five other farmers. These farmers are selected on having knowledge of field parcels and various crops. Furthermore different sizes of farms are selected, small (<24 hectare), middle sized (24 – 75 hectare) and large (>75 hectare).

Interviews are also held with farmers who do not have field parcels. These farmers still know how many times they need to go to a specific crop and it was possible that the farmers with no field parcels act different. This difference is however not apparent among the interviewees. There is some difference in the habits of the larger farmers in comparison with the other two groups. Because they are able to buy machineries which can combine activities, or can make a water sources for spraying activities at each field parcel. This results in less back and forth rides.

Next to these interviews three phone interviews are done with farmers from Groningen and Drenthe. Because of their knowledge of grass and starch potatoes. At last interviews are done with three traffic policy employees of the municipality of the Noordoostpolder and two policy employees of the Province Zeeland.

A disadvantage is that the key figures may not stand representative for their organisation or farm type (Marshall, 1996, p. 92). Therefore both qualitative and quantitative research methods are used (mixed method). The combination of different data sources about the same phenomenon is also called 'triangulation' (Denzin, 1978, as quoted in Homburg, Klarmann, Reimann & Schilke 2012, p. 5904). In this case the KWIN publications and other literature are used as another source.

4.2 Interview results

The following text explains the general comments of the interviewees on the model method and the adaptations made to the factors, production and activities.

Comments on the model implementation

During the interviews there are three comments made on the general model implementation. Furthermore is interesting that in the past the farmer had to bring the wheat to a specified point. Currently it is possible that the wheat is collected at the home parcels by trucks (Aart). Farmer Evert states that the transport with trailer trucks may not be safer and adds that in total his number of rides to Emmeloord (main city in the Noordoostpolder) has decreased.

Crop independent

The interviews revealed that some activities are not crop related and are therefore not counted in the model. For example mowing of the ditch sides is not counted as an activity. Furthermore a farmer also has to go to the mechanization, has a coffee break or goes to the tank station.

Double counting

In the model the fixed activities are attached to the crops, although some farmers plough their parcel in one go instead of several times for each crop. This method can result in double counting, because the activities are calculated per crop while some farmer wait until they can do that activity for the entire parcel. When the increase in scale further develops the effect of this double counting in the model may increase, because farmers need to be (even) more efficient. The parcels are for example farther away, which makes it inefficient to plough crop lot by crop lot.

Furthermore are the activities calculated per crop lot and one clustered parcel can consist of several crop lots (*Figure 4.1, p.29*). When this parcel is divided in three lots with two crops (situation 1), the total number of activities is higher in comparison with a parcel of the same size at which the two crops are divided over two lots (situation 2). This 'double counting' is not always correct, because it is possible that the farmer combines the activities for the two flower bulb parcels. Therefore in some cases there are too many activities counted if solely is looked at the crop related activities, but this does not result in too many activities in general because other crop independent activities are not counted.

Parcel size dependent

In this study only the production is parcel size dependent. The fixed activities are identical for each crop category, independent from the parcel size on which they grow (*Figure 4.1, p.29*). This is not justifiable for all activities, for example organic fertilizing is parcel size dependent. For now these activities are not made parcel dependent, because of time restrictions. Some activities are therefore counted more than ones, for example harvesting or planting, to simulate the parcel size dependent effect.

Factor adaptations

From the interviews appeared that soil does no (longer) have much influence on the number of activities, but rather on when these activities happen and the crop type. An example is ploughing. At sandy soils this is done in the spring (Aart, Bas, Cor, Fons) while at clay it happens after in the autumn. On sand soil the spraying amount is possible somewhat lower, but not much (Evert). Therefore the number of fixed activities is no longer dependent on soil type.

The farmers think that chosen factors cover most of their motives to go to a field parcel, but farm type and crop independent activities could be added. The production for biological farms is for example lower, which results in a lower number of bulk activities. Furthermore activities like mowing of the ditch sides is not included in the model.

Production adaptations

In general is changed that the production is divided over the different seasons. Grass is cultivated during the year (Dirk) and therefore the intensity is better approached if this is also divided over the different seasons. The old and new production can be found in *Table 4.1, p.26* and *Table 4.2, p.26*.

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Tare weight

The dump truck size is equal for most of the agricultural products like, potatoes and onions, but these dump trucks cannot be filled to the maximum with each product (Aart, Bas, Gert, Isaac). This differs to the tare weight that is involved. In one cubic meter 525 kilos onions can be transported, 650 kilos of potatoes and 730 kilos of wheat. In this study the size of the dump truck remains the same, but a tare weight is added to the production of the categories. This is the share of dump truck volume that is brought to the home parcel, that consists of soil and other redundant products.

Agricultural crops

As a result of the interviews the classification of the category 'Agricultural crops' is adapted to the production and activities of endive, plant onions and carrots (*Appendix 3.5, p.74*).

Endive and carrots (part of the group 'Agricultural crops') are within the Noordoostpolder important agricultural products and the production is underestimated for these products. Therefore the production is risen to forty ton. This is correct for endive and plant onions. It is an underestimation for carrots, but also other crops (with a lower production) are part of this category. In other regions the production can be different as a result of other dominant crops.

Plant onions are placed in the 'Agricultural crop' category, because the new production fits better for plant onions in comparison with the production that was estimated for the previous 'Onions' category. Also the number of fixed activities of 'Agricultural crops' fits better.

Flower bulbs

The crop types in the category 'Flower bulbs' vary a lot in types and the production differs from type to type. For example tulips have a production of 50 ton per hectare and gladiolus and lilies about 80 ton per hectare. While the gross amount also differs from type to type. When lilies are harvested almost half of the dump truck size consists of tare. On the other hand gladiolus are harvested 'clean' and for tulips on fourth is tare (Cor). Only to flower bulbs harvested from sand soil have got a tare weight. Within clay the flower bulbs are cultivated in a 'net', which results in little tare weight. Within the crop information (BRP) is no distinction made between these types. A further distinction of these types can improve the production estimation.

Sugar beets

Sugar beets are sometimes preserved on the field parcel and picked up by trucks. Though this seems not to be commonplace yet and is therefore not implemented in the model. For starch potatoes this is commonplace and therefore there are no dump trucks going back and forth to the home parcel in the model.

Furthermore the sugar beets production has risen a lot in the past years. The production based on KWIN (PPO, 2009) is therefore no longer up-to-date. The production for the different soil types are changed (*Table 4.2, p.26*).

Activity adaptations

Also the fixed activity quantification is changed. The main changes are explained in this paragraph. The changes are presented in *Table 4.5, p.28* to *Table 4.12, p.28*. The old and new activities per crop category can be found in *Table 4.3, p.27* and *Table 4.4, p.27*. In *Appendix 3.5, p.74* can be found what estimations the different farmers have done and the new and old activities are shown. This is done per activity.

Cereals

The number of activities for cereals was estimated to high, mainly because the number of spraying activities was too high. This is lowered from eight to four on an annual base (*Table 4.5, p.28*).

Furthermore the sowing and cultivation activities are performed in on go by some (larger) farmers. The combination of cultivation and sowing happens two times a year, wheat at the beginning and green manure at the end of the year. Not all farmers combine these activities, therefore is assumed that half of them does this and half of them not. The number of activities related to sowing is therefore lowered from four to three.

It is no longer allowed to fertilise before February. Therefore is this moment of fertilizing removed, this is not done at another moment (Evert, Gert).

At last the activities relevant to straw pressing is raised to two: the straw pressing machine and the pick-up truck must be brought to the parcel (Gert, Evert, Isaac). How many times the truck has to go back and forth depends on the truck size and parcel size. For these activities this is not taken into account in the model. In this study is assumed that the low estimation of activities for straw package transport is levelled out, because some farmers only cultivate the straw underground.

Flower bulbs

The number of activities for flower bulbs is raised to 43 activities. This is mainly the result of a raise in irrigation activities, this is increased from one to seven times annually. Furthermore flower bulbs are never cultivated in one go. The moment of harvesting depends on the size of the bulbs and breeds and this number is therefore increased to four activities (*Table 4.6, p.28*).

Grassland

For grassland the number of activities is increased from 26 to 33 based on the interviews with Dirk, Jan and Klaas. The numbers are focussed on grassland that is only mowed and not used for grazing. Because there is assumed that the field parcel is too far away to pasture animals. This assumption can change from region to region and farmer to farmer. Furthermore the current estimations are adapted to temporary grassland, instead of permanent grassland. The number of activities needed for temporary and permanent grassland does not differ much, because on permanent grass the farmer can mow a sixth time, but sprays less and does not need to sow and cultivate (Dirk, Klaas).

The mowing related activities were estimated too low. A farmer mows it, shakes it (one or two times), puts it in rows (wiersen) and picks it up. This results in four activities related to mowing and then the transport of the production is not even taken into account. Next to the increase of mowing related activities the number of fertilizing moment is increased. Furthermore several changes are made in the period in which some activities occurred (*Table 4.7, p.28*).

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Potatoes

Within the three potato categories several changes are made (see *Table 4.8, p.28 – Table 4.10, p.28*). For starch potatoes ploughing and soil disinfection are activities that were done in the past, but are no longer performed (Lars) so these are removed.

For seed potatoes the number of planting activities is increased to three. A farmer cultivates several breeds on one lot and these different breeds have to be separately brought to the lot (Aart, Bas, Isaac, Gert). Furthermore the planting machine must be brought.

Consumption and starch potatoes have less different types of breeds, but also for these crops the machinery and the potatoes must be brought. Therefore the number of activities related to planting is estimated at two.

For seed potatoes the number of spraying activities in the summer was too low. Seed potatoes have a shorter growing season in comparison with consumption, but are sprayed more frequent in a short period. While consumption potatoes grow longer, but are sprayed less frequent (Gert). Because of this are consumption potatoes sprayed about five times more (Gert, Isaac) then seed potatoes. This difference did not appear from all the interviews, therefore the number of spraying activities is stated at seventeen for consumption and fifteen for seed potatoes. Starch potatoes are sprayed fourteen times in a year (Lars).

For all potatoes categories accounts that the harvesting machine has to visit the parcel several times. For example because of the weather, different breeds or a divided delivery to the factory. Also the removal of the leaves is done in two times instead of one (Bas, Evert, Gert, Isaac). The number of times a harvesting machine needs to visit a lot depends on the parcel size and the number of breeds. There is no information about the number of breeds on a parcel. Therefore is the number of activities estimated on three times for plant potatoes. For consumption and starch potatoes it is raised to two.

All in all is decided to estimate the seed potatoes on 33 activities, consumption potatoes on 29 activities and starch potatoes on 26 activities.

Onions

Also for onions was the number of spraying activities estimated too low. In the last years a change has occurred in which farmers spray more times with a lower dose (Fons), because less times with a higher dose can result in over dosages. This development also accounts for onions and therefore the number of spraying activities is increased from thirteen to twenty times (*Table 4.11, p.28*).

Furthermore the fertilising moment is removed to spring and plant onions are moved to the 'Agricultural crops' class and therefore the 'Onions' class is specifically about seed onions. All in all this results in 28 activities annually, instead of 21.

Sugar beets

In total the number of activities for sugar beets is increased with five activities (*Table 4.12, p.28*). Because the number of spraying activities was estimated to low and sugar beets are in most cases harvested mostly in two times (instead of one time). The number of spraying moments is increased to ten times in a year. Sugar beets are mostly harvested in two times because it is possible to deliver these in two times to the factory (Aart, Isaac). Otherwise the farmer has to store a lot of sugar beets on his farmyard.

4.3 Access application

The factor quantification can differ per region in the Netherlands. This is a result of regional diversity in the habits of farmers or land consolidation. For example in the Noordoostpolder are the parcels larger and more equally shaped in comparison with some parcels in the province Zeeland. This difference can result in different habits or less production. Therefore an application is made in Access in which it is possible to change the input data (*Appendix 4.3, p.109*). The tool gives the 'default' quantification. The default are the numbers that are estimated within this research (*Appendix 4.4, p.110*; *Appendix 4.5, p.110*). The user of the application is able to change these estimations. This accounts for the production quantifications and the activity quantifications. Furthermore is it possible to add a new crop category and to add factor quantifications to this crop category. At last is it possible to print several statistical results after the model has runned.

4.4 Résumé

Several adaptations are made as a result of the interviews. From the interviews appeared that the chosen factors cover a large part of the motivations to go to a field parcel. Optional other factors can be farm type and crop category independent activities like mowing of ditch sides of control visits. The factors are adapted as a result of interviews within the Noordoostpolder and three in Groningen and Drenthe. Because every region in the Netherlands is different, is decided to make an application which makes it possible to change the factor quantifications for that specific region.

5 Results revised

In this chapter the fifth and last research question is discussed. "*What is the effect of the input data on the model results?*" This chapter first describes the choices that are made with regard to the visualisation of the maps. Thereafter is explained what the effect is of the parcel data and the crop rotation system on the results. Furthermore attention is paid to the different time spectra as well. At the end the geographical distribution of the agricultural traffic intensity in the Noordoostpolder and Zeeland is discussed.

5.1 Visualisation

The model results consist of geospatial data and maps are used to provide an understanding of the geospatial relationship (Kraak & Ormeling, 2010). Among other things maps, help to reveal patterns and relations. In order to create effective maps 'cartographic grammar' can be used. Which are the: *"rules and guidelines (...), based on the nature of the data and the communication objectives (Kraak & Ormeling, 2010, p. 2)"*. Geo-cartographer Bertin has made a structure that makes clear which various representation methods there are and what the rules or guidelines there are for these representation methods. Differences can be made in size, value, texture, colour, orientation and shape (Kraak & Ormeling, 2010) and to these methods are guidelines attached. In this study are dashes or lines visualised. The values are differentiated with symbol size and colour value. On behalf of an easy

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to read map there is maximum number of different classes that can be used for the representation methods (Kraak & Ormeling, 2010). For colour on dashes this is seven (Kraak & Ormeling, 2010), therefore is the maximum of classes in the maps seven. The colours used are tested for both screen and analogue use, so that the differences are visible for both uses.

The data is classified to create a clearer map image. In this study the equal steps method is used for the maps with average workday traffic intensity. This implies that the width of the classes is equal (Kraak & Ormeling, 2010). However the class width sometimes becomes larger for the higher densities, because there is a low number of dense road segments. Furthermore the maps are created in such a way that these are comparable and therefore the class widths are adjusted so this is possible. For the annual maps the class width are equal as well and they become wider if the values are higher. Therefore attention is paid to the number of observations in a class. Consequently not only the 'Equal steps' method, but also the 'Quantile' method is used.

5.2 Analyses results

For both case study areas are combinations made of crop datasets and parcel datasets (*Table 5.1, p.32*), to show the possible differences in traffic intensity as a result of the crop rotation system and the effect of the different parcel datasets. For these combination different statistics are presented and the analysis are displayed in maps. Some combinations are not reality like the combination of owner data of 2014 with crop data of 2013, but are created to show the possible effect of crops on the results.

The owner data of 2014 in the Noordoostpolder is combined with the crop data of 2012, 2013 and 2014. Furthermore the owner data of 2013 is combined with the crop data of 2013 and 2014. At last the user data of 2014 is combined with the crop data of 2013 and 2014. In Zeeland the user and owner data of 2014 are combined with the crops of 2013 and 2014 (*Table 5.1, p.32*).

For all analyse combinations applies that the distribution is right skew (*Figure 5.1, p.33*; *Figure 5.3, p.36*). This is confirmed by the fact that the mean and median values are not equal for any of the analyses (*Table 5.2, p.34; Table 5.4, p.37*) and the skewness statistic is a positive number (*Appendix 5.1, p.111*). While the distribution has outliers in the high values, it can still be seen as symmetric because the skewness standard error is below null (*Appendix 5.1, p.111*). A positive skew, or left skew distribution means that the mass of the distribution is concentrated within the low values and there are outliers in the high values (Vocht, 2011).

The kurtosis shows the curvature of the distribution. A positive kurtosis implies that the curve is more peaked in comparison with the normal distribution, still the curve can be seen as normal because the standard error is below null (*Appendix 5.1, p.111*). Furthermore the analyses results show a wide range of values and all analysis show many outliers in the high values.

Parcel effect

For the analyses parcel user and owner data is used. In this paragraph is described what the effect is of these datasets on the results. In both the Noordoostpolder and Zeeland the analyses with the users of 2014 show a wider value range in comparison with the analyses with the owners of 2014 (*Figure 5.1, p.33; Figure 5.3, p.36*). This means that the maximum of vehicles that annually pass by over a road is higher. Furthermore the average number of vehicles over a road segment is higher. The median is lower for the parcel users of the Noordoostpolder analyses in comparison with the analysis with the owners, while the median is almost two times higher for the Zeeland user analysis in comparison with the Zeeland owner analysis (*Table 5.2, p.34*; *Table 5.4, p.37*).

Furthermore the total number of kilometres that is covered in a year is much higher for the user analysis. In the Noordoostpolder this is almost three times as much as the owner analysis (*Figure 5.2, p.33*). For Zeeland the user results are double as high as the owner results (*Figure 5.4, p.36*).

These results are logical, because more parcels can be taken into account in the case of the user data. The share of parcels in the Noordoostpolder that can be used for route calculation is about 64 percent in the case of owner data and 98 percent in the case of the user data. Therefore the conclusion is that the user analysis shows a better estimation of the agricultural traffic intensity. Consequently in the next paragraphs the focus is on the user results. However also the other results are presented in the tables and figures as well and used as a reference.

Not only the effect of the parcel users and parcel owners is studied. Also the effect of different registration years. This can have an effect because farmers have quit or have bought new land. Therefore the parcel owners of 2013 in the Noordoostpolder are compared with the parcel owners of 2014. Both parcel datasets are combined with the crops of 2013 and 2014. Unfortunately the user data of 2013 was not available

Independent from the crop data the results of 2013 are lower in comparison with the parcel 2014 results. The analyses with the parcel owners of 2013 show the smallest range of values of all analyses done (*Figure 5.1, p.33*). This can be explained (partly), because for the 2013 owner data 383 routes are calculated while for the 2014 data this is 396. Furthermore the number of crop parcels is in all cases higher for the 2014 owner data (*Appendix 5.2, p.112*).

The number of kilometres that is covered in the parcel 2013 analyses is always in comparison with the number of kilometres covered by the 2014 owners. It can be that farmers have quit which results in a less efficient distribution, which results in a higher number of kilometres that must be covered in 2014.

Crop rotation

Not only the parcel database can have an effect on the model results, also the crop data that is used.

The owners of 2014 in the Noordoostpolder are combined with the crops of 2012, 2013 and 2014. For the Noordoostpolder the 2012 analyses are almost similar in range in comparison with the 2013 and 2014 crops. Only the maximum outlier of 2014 differs much with the 2012 and 2013 analyses (*Figure 5.1, p.33*). The crop analyses of 2013 and 2014 for the 2013 owners show even more resemblances.

Furthermore is the number of kilometres covered in the analyses with the owners of 2013 almost similar for both crop years (2013 and 2014). The results with the 2014 crops is even a bit lower. Also for the 2014 owners the number of kilometres that is covered in the analyses with the crops of 2012, 2013 and 2014 differ not much. The number of kilometres in 2012 is a bit higher in comparison with 2013, while 2014 shows more kilometres in comparison with 2012 and 2013 (*Figure 5.2, p.33*).

This also accounts for the analyses in Zeeland, the owner analyses with the crops of 2013 and 2014 show little difference in both statistical numbers as in the number of kilometres (*Figure 5.4, p.36; Table*

5.4, p.37).

As stated in the previous paragraph the user analyses show a larger range in comparison with the owners (*Figure 5.1, p.33; Figure 5.3, p.36)*. Furthermore the analyses with the crops of 2014 show a larger range in comparison with the crops of 2013. This difference is less apparent for the analyses in Zeeland. The maximum outlier of the 2013 crops is higher in comparison with the 2014 crops in Zeeland, though this does not say much because only one busy road is needed to have a higher maximum outlier.

For the user analyses of both region the number of kilometres is higher in 2014. For the Noordoostpolder this raises with forty percent, while in Zeeland this number only raises with four percent. It is possible that the differences in crops is levelled out in the case of Zeeland. This is a bigger area and therefore is the change higher that differences in crops for one farmer are levelled out by crop changes of another farmer. It can imply that the crops cultivated in 2013 were less activity intensive. Another explanation can be that in 2014 there were less farmers over the same amount of land.

Workday

Next to the annual traffic intensity the average workday traffic intensity is calculated. This is done because it is difficult to interpret the annual number. Assumed is that only on the weekdays is worked (5 days), this results in 260 working days (5x52). This is based on the research of Oosthoek and Pouwer (2014) in the province of Zeeland, in which appears from counts that the main agricultural traffic intensity can be found on the weekdays. *Appendix 6.2, p.150* shows that in the weekends there is a dip in comparison with the weekdays.

The number of agricultural vehicles that drive over a road segment in a workday shows a similar pattern as the annual data shows. The analyses with the owners of 2013 in the Noordoostpolder show the lowest values, the users of 2014 the highest, with a rise for the user analysis of 2014 in comparison with the 2013 crops. The mean number of vehicles on a workday raises from 2.55 to 3.74 (*Table 5.2, p.34*).

For the analyses in Zeeland the workday mean in 2014 and 2013 are comparable for both the user as the owner analyses. Between the two parcel datasets is much difference. In 2014 the users had a workday mean of 4.19, while this 1.80 for the owner analysis (*Table 5.4, p.37*).

Seasons

The annual traffic intensity is divided over the different seasons (*Table 5.3, p.35*; *Table 5.5, p.37*). The seasons are divided in spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February).

In both regions the winter has the lowest traffic intensity. This can be explained because in this season most crops are harvested, or not growing, furthermore the new crops are already sowed or planted or will be in the spring. Therefore the number of rides is low.

Between the number of rides in the spring and autumn some resemblance can be found, mainly when is looked at the owner data. For the user data there is more variance between the spring and the autumn. In general the spring shows somewhat more rides and the number of rides is higher for the crops of 2014.

The analysis of the users of the Noordoostpolder shows a high raise in the spring from 2013 to 2014. In 2013 was 2.89 and in 2014 this was 4.45. In Zeeland it only raises from 3.17 to 3.30. Also the number of rides in the autumn raises for both regions, but this is a lower raise in comparison with the spring in the Noordoostpolder. This can (partly) be explained by the flower bulbs in the Noordoostpolder (*Figure 5.5, p.38*). For flower bulbs are more activities estimated in the spring (20) in comparison with the autumn (2). The difference between 2013 and 2014 can be the result of the increase in surface that is used for flower bulbs. In 2014 was 270 hectare more used for flower bulb cultivation in comparison with 2013. Because this crop is mainly cultivated on rented parcels is the effect of this crop mainly visible in the user analyses. Flower bulbs can only be cultivated once in many years on a parcel. For example a tulip can grow once in the six years on a parcel, gladiolus can only grow once on a parcel. Furthermore flower bulb farming is in many cases a specialisation and therefore the main crop of a farmer. Therefore a flower bulb farmer needs to vary a lot between parcels. This explains why this amount of traffic is not shown in the analyses with the owner information, while it is visible in the user analyses.

In the summer the most agricultural vehicles are on the road. In this season many crops need a lot of attention. Examples of activities are; spraying or crop harvesting. The analysis in the Noordoostpolder of the users of 2014 also shows a high rise with the crops of 2014 in comparison with 2013. From an average of 5.02 to 7.46. This is probably also the result of the increase in flower bulb cultivation. In the summer are 20 fixed activities related to flower bulbs. This is in accordance with the interviews from which appeared that the flower bulb cultivation results in a lot of agricultural traffic in the spring and summer.

5.3 Geographical distribution

For most analyses accounts that the agricultural traffic intensity annually rises for some road segments. With some regional knowledge the patterns can be explained, these are given in the next paragraph.

Noordoostpolder

The results from the analysis are visualised in maps (*Figure 5.7, p.39* till *Figure 5.16, p.41)*. There are maps in which the yearly traffic intensity is visualised, furthermore the average traffic intensity and the intensity in the summer is visualised for several of the analyses. The maps are also displayed in a bigger format in *Appendix 5.2, p.112* till *Appendix 5.18, p.128* to be able to distinguish details.

The classes used for the owner parcels in 2014 are equal for the crops of 2013 and 2014, this makes them easier to compare. Also the classes of the maps with the user analyses of the crops in 2013 and 2014 are equal. In both cases the analysis of 2014 shows more traffic, this is displayed in an extra class. When the owner maps and user maps are compared attention must be paid to the different classes, in fact there are classes combined for the user maps. Therefore it seems like it is less busy, but this is not the case.

For a comparison of the user and owner analyses is it better to use the average working day traffic intensity maps (*Figure 5.11, p.40* till *Figure 5.14, p.40)*. The classes are divided in equal intervals, but also here attention must be paid because for the user maps classes are combined to be able to show all values in seven classes.

The user analyses shows a kind of beltway (ringweg), which goes from Bant via Luttelgeest, Marknesse, Nagele to Creil. For the owner analysis accounts that the geographical distribution shows a high

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traffic intensity in the neighbourhood of Marknesse and Emmeloord (*Figure 5.11, p.40* till *Figure 5.16, p.41*). While the user analysis also show traffic density near Creil and Nagele. In a number of interviews appeared that there are traffic safety issues in Marknesse. For example the agricultural vehicles need to pass through the middle of the city centre.

The traffic intensity for the owner analysis in Marknesse is influenced by only a few farmers (*Appendix 5.8, p.118,* dark red line). The user analyses show less traffic intensity in the middle of Marknesse, but more intensity around the city centre. The amount of traffic in Marknesse can be influenced by the land consolidation. In this area (Marknesse and Luttelgeest) are several small parcels, which leads to a less efficient distribution of the land (*Figure 5.6, p.38*).

The traffic intensity around Marknesse, Luttelgeest and Ens is expected to be higher as shown on the maps because in these areas several greenhouses are located. These crops result in agricultural traffic as well, but they are now not taken into account in the model.

As stated before the user maps show traffic intensity near Creil, while the owner maps do not show traffic intensity in that area. This can be the result of the different flower bulb farmers in this area (*Figure 5.5, p.38*). This is the result of the sandy soils, which is historically the soil type at which flower bulbs are cultivated. Nowadays this also occurs on clay grounds, but only the 'light' clay type mixed with sand for example. The maps with the average working day traffic in the summer show that the increase in traffic in 2014 is mainly located near Creil. What the earlier conclusion that this increase is mainly the result of flower bulbs further confirms.

The traffic intensity as a result of the flower bulbs becomes only present on the maps if the user data is used, because many flower bulb farmers rent parcels to cultivate their flower bulbs. Another difference between the user and owner analyses is the increase in visible roads in the case of user analyses. This can be a result of lot renting. On one parcel several farmers are cultivating and to all these different lots a 'road' is made by the software. Furthermore there are more parcels that could be taken into account.

Zeeland

The province of Zeeland is cut in two pieces; Zeeuws-Vlaanderen and Schouwen-Duiveland / Beveland (*Figure 5.17, p.42* till *Figure 5.36, p.46*). Just like the Noordoostpolder map, the maps are also displayed in a bigger format in *Appendix 5.19, p.129* till *Appendix 5.38, p.148*.

The maps that show the yearly traffic intensity of the parcel owners and parcel users are not easy to compare. This is the result of the large values differences. The maps with average working day traffic are more applicable to compare the user and owner analyses. In the text is referred to the different areas in the province, these are shown in *Figure 5.37, p.47*.

The maps with Zeeuws-Vlaanderen of the owner data show little difference between the different crop years. The tunnel between Terneuzen and Zuid-Beveland is busier in 2013 in comparison with 2014. For the user data this is the other way around. This tunnel is only open two hours at night for agricultural traffic (personal communication, Zeeland interviews), it is therefore questionable how much this tunnel is actually used.

The average traffic intensity in Zeeuws-Vlaanderen with the users shows a high traffic intensity near Oostburg. Furthermore near the village Zaamslag a high traffic intensity is found. This can be a result of the fragmented land consolidation (*Figure 5.39, p.48*). In the analysis results the agricultural vehicles go through the middle of Zaamslag and do not take the somewhat longer route over the N290 (*Figure 5.38, p.47*). In reality it is more plausible that farmers take the route over the N290, because it is probably faster and safer.

The maps of Schouwen-Duiveland and Beveland with the annual results show that a road in the north of Zuid-Beveland is the busiest in the case of the user data (see arrow in *Figure 5.32, p.45)*. While the owner data does not show much traffic over this road.

Another difference between the owner and user analyses is the use of the roads between Schouwen-Duiveland and Tholen, in 2013 and 2014. In the case of the owner analyses the road to Zierikzee is used by between 2000 and 4000 times. While this is only something between the 500 and 2000 times for the user analyses. The road in the west which leads from Schouwen-Duiveland to Tholen is not used in the case of the user analyses, while it is used between the 750 and 2000 times with the owner analyses. It seems like farmers own parcels at the other side, but rent these parcels. Maybe it is used as risk dispersion.

Furthermore the average working day traffic in the summer shows much higher numbers in comparison with the annual maps. From these maps appears that bigger areas, Zeeuws-Vlaanderen and Walcheren/Zuid-Beveland, show higher numbers of agricultural traffic, in comparison with the smaller areas.

5.4 Résumé

In conclusion can be stated that the user data gives a better view on the agricultural traffic intensity in an area. In the Noordoostpolder more parcels are rented in comparison with Zeeland and therefore the effect of the parcel registration is more apparent. Furthermore the larger area of Zeeland seems to have a balancing effect on the crop rotation system. The difference between the results of 2013 and 2014 are lower in comparison with the differences in the Noordoostpolder. This can only be the result of other reasons. With regional knowledge the geographical dispersion of the agricultural traffic intensity can be explained and the various time spans make it possible to estimate the busiest periods in a region. With the maps of the Noordoostpolder becomes apparent that one crop can make a difference in the traffic density. The user analysis of 2014 show an increase in comparison with 2014, which is probably the result of an increase in flower bulb cultivation in 2014.

6 Validation

In the previous chapter the model results of both case studies are described. In this chapter these results are compared with other studies. An important issue during research is if the method used is valid. A method is valid if it measures what it is meant to measure, also the question is if the results can be generalised to other social situations (Bryman, 2012, p. 390). The research question on which is focussed is: *"How can the model be validated?"* **In this study three validation methods are used. Of each validation methods is first the methodology explained and thereafter the results. The validation is tested with three methods; the farmers perception, an agricultural traffic counting in the Noordoostpolder and a comparison with the study of the province of Zeeland.**

6.1 Farmers perception

The first validation method looks at the route farmers take and all interviewees from the Noordoostpolder are asked to draw their perception of the agricultural traffic intensity in the Noordoostpolder.

Shortest route

The farmers with field parcels are asked to draw the routes they take from the home to field parcel. For farmer Evert the route made by the software (*Figure 6.1, p.50; Figure 6.2, p.50*), was almost correct. The start point of one parcel was incorrect, because it was at

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the back of the parcel. This is because some paths along the parcels (kavelpaden) are also incorporated in the network and the software starts the route at the nearest road, which was the path of neighbour. In reality this route is impossible, because it goes over a waterway. Also the route for farmer Hein was wrong because again the back of the parcel was chosen as start point (*Figure 6.3, p.51* and *Figure 6.4, p.51*).

The route made for farmer Gert was incorrect because it went through the city centre of Emmeloord (*Figure 6.5, p.52*). He does not take that route, because it is slow and unsafe. Instead of that he takes the green (highlighted) route (*Figure 6.6, p.52*). Furthermore not all parcels are taken into account, because it depends on the person who does the parcel registration to whom it is coupled or other unknown reasons.

In general the routes seem to fit reality. The start point (from the field parcel) is in some cases incorrect. Furthermore routes that go through the middle of a city centre, while there is another possible route, must be taken with a pinch of salt.

Traffic intensity perception

The interviewees from the Noordoostpolder are asked to draw the traffic intensity in the Noordoostpolder, this appeared to be difficult, because a farmer only uses a small part of the network. Therefore are the locations drawn at which a farmer experiences problems, for example small roads, or round abounds. Referred to as 'bottlenecks'. Farmer Evert had the perception that the traffic intensity in the northwest of the Noordoostpolder is higher than is calculated by the model (*Figure 6.7, p.53*), but this was based on the owner parcels, so it fits that it was less busy. Also the policy employees of the Noordoostpolder had difficulties drawing the traffic intensity. They stated that the traffic intensity in general is equal. It is possible to say that the traffic intensity increases a bit from east to west and that in the northwest the flower bulbs are an important factor in the traffic intensity.

The interviewees from the province of Zeeland are asked to their perception of the agricultural traffic density in the province. The province has defined several roads that are important for agricultural traffic in Zeeland. These roads are compared with the agricultural traffic density as calculated by the model (*Figure 6.16, p.56*). Most of the red coloured roads in the model map, so the busy road, are part of the agricultural network of the province. These roads are thus defined as important for agricultural traffic and this also appears from the model results. One road in the northeast of Zuid-Beveland forms an exception, this road is not identified as an important road by the province, but is important in the model results. Maybe the province expected the traffic in an identified road below the red/purple coloured road in the model.

Bottlenecks in the Noordoostpolder

For farmer Evert is the new parallel road next to the Marknesserweg safer, but still quite small in combinations with the cyclists who also use the road. The centre of Marknesse forms a bottleneck for Evert, because a lot of bends, speed bumps and a narrow road (*Figure 6.2, p.50*). Furthermore he experiences problems when he has to go to the left to go to his parcel. Other commuters sometimes have to pass by before he can go to the left.

Several commuters use sixty roads, as Evert lives at, to be quicker at their location. This can lead to irritations for both users, because the commuters want to drive fast (and most of the time faster than allowed) and the agricultural vehicles with for example turning to the farmyard. Therefore it is perhaps better to only allow destination traffic to these roads. Furthermore it is better to 'lead' the traffic to specific roads (Evert).

Farmer Gert has not a lot of trouble with the network in the Noordoostpolder. He has drawn a bottleneck at the 'Hannie Schaftweg' (*Figure 6.8, p.53*). At this road there are several round abounds and there is a lot of traffic and different vehicle types. Isaac encounters also problems at the 'Hannie Schaftweg' (*Figure 6.9, p.53)*.

Farmers Hein and Fons name the 'Weg van ongenade' because it is small, busy and has unsafe bridges (*Figure 6.3, p.51*; *Figure 6.10, p.53; Figure 6.11, p.54*). The 'Weg van Ongenade' is specifically named because of the small bridges, just like 'Karel Doormanweg' (*Figure 6.12, p.54*). Also the 'Sluitgatweg' and 'Voorsterweg' are small (*Figure 6.13, p.54; Figure 6.14, p.54*).

Parcel renting

During the interviews the crop flower bulbs are mentioned as a crop that results in a lot of rides. This product is mainly cultivated on rented land, as a result of the long 'waiting' time. Therefore the flower bulb parcels are sometimes far away from the home parcel. This results in a lot of (trailer-trucks) traffic on the road (Fons). The interviewees of the policy employees in the municipality of the Noordoostpolder mentioned that not only flower bulb farmers exchange and rent parcels. Also other farmers are more and more specialised and therefore rent their land and rent from others.

6.2 Counting Domineesweg

The second validation method is the comparison with a counting of agricultural vehicles in the municipality Noordoostpolder. This counting is done for two days at the Domineesweg (*Figure 6.15, p.55*), by Meetel in commission of RoyalHaskoningDHV on October 2013 (personal communication, employee RoyalHaskoningDHV). These counts were done to estimate the usefulness of the agricultural pass-by strip. Currently the strip is no longer in use, because it does not work (Omroep Flevoland, 2013).

The counts were done for two days; Tuesday 8 and Thursday 10 October 2013, with similar weather conditions. On 8 October 27 agricultural vehicles are counted from 5.30 to 22.43. On 10 October nine agricultural vehicles between 7.09 to 22.42. Between 5.30 and 7.00 o'clock on Thursday were seven vehicles counted. This can imply that on Thursday the number of vehicles must have been sixteen.

In this study the numbers are a lower. If the specific count location is compared with the owner data of 2013 and crop data of 2013 the number of vehicles per workday is four for the entire year and autumn. These results do not change if is looked at the analysis with the owner data of 2014 and crop data of 2014. The results do change for the user data of 2014 and the crop data of 2014. In that case the number of vehicles per workday is nine, annually. In the autumn this is still four vehicles in one working day.

In this study only the traffic between the home and field parcel is researched. Agricultural traffic for industry or work activities are not taken into account. This can partly explain the lower estimation. Furthermore the conclusion can be made that the estimations in this study may be (too) low.

6.3 Provincial study Zeeland

The third validation method is the comparison of the model results with the study from the Province Zeeland (Oosthoek & Pouwer, 2014).

The provincial study introduced

The province of Zeeland researches movements of agricultural traffic in the province (Oosthoek & Pouwer, 2014). Because there is a need for reliable information about the movements of agricultural traffic (Oosthoek & Pouwer, 2014). Therefore are tests done with mechanical counting devices, because visual counts are expensive and therefore can these only be done for short periods which leads to possible unreliable results. The tests with the mechanical counts in 2011 were successful and therefore eight permanent locations are made at which is counted for the entire year (Oosthoek & Pouwer, 2014) (*Appendix 6.1, p.149*).

Comparison methodology

Several statistical outcomes of the two studies are compared, furthermore a visual comparison is done. Thereafter the strength and orientation of the relation is examined with the Pearson's product-moment coefficient. Because the user data analyses are most probably more accurate these are compared with the study of the province Zeeland. Furthermore the analysis of 2013 are used, because the Zeeland study shows the agricultural traffic in 2012 and 2013.

The dataset of the province of Zeeland exists of road segments to which the result of a counting point is attached (*Appendix 6.2, p.150; Appendix 6.3, p.151*). There is no information of the exact counting point, therefore the dataset of the road segments is used. It is possible that the number of vehicles that is attached to the road segment is not correct for all locations along the road segment, because the counting is only done at one point along this segment.

The road segments of both studies do not have the same size. Therefore two methods are used to compare the results (*Figure 6.17, p.57*). The first method, called 'multiple pair', has the same number of values as there are road segments in the model. This implies that all small road segments of the model are combined with the result of the provincial study. The second method calculates the average of the model on a road segment of the provincial study and combines this with the provincial study and is called 'average pair'. Therefore is the number of values equal to the number of road segments in the provincial study.

Correlation presumptions

The results of both studies are compared with the Pearson product-moment correlation. This is done for all areas as defined in *Figure 5.37, p.47* and for both the annual and summer results. Before the Pearson correlation can be calculated three presuppositions must be met; the relation is linear, there is a bivariate normal distribution and the values must be interval or ratio (Vocht, 2011). The data of both the provincial study as the model are at least interval, so this presupposition is achieved.

If there are more than thirty values can be assumed that the presumption of a bivariate normal distribution is achieved (Vocht, 2011). When there are less than thirty observations the Kolmogorov-Smirnov test and Shapiro-Wilk test are used (Vocht, 2011).

For the multiple pairs method accounts that all areas have more than thirty values. The test for bivariate normal distribution is therefore not necessary (Vocht, 2011). For the 'Average pair' method the following areas had less than thirty values: Schouwen-Duiveland fifteen, Tholen fourteen and Noord-Beveland twelve pairs. For these areas the Kolomogrov-Smirnov and Shapiro-Wilk test are done. These tests examine one variable at the time (and is therefore not bivariate). These tests show a significance level higher than 0.05, the null hypothesis that the values are normally distributed is therefore not reprobated. Therefore is assumed that for all three areas the different variables, both for the summer and the annual values, are normally distributed (*Table 6.1, p.62*).

Furthermore the linearity is checked with scatterplots. Therefore are the annual and summer results of the model and provincial study combined. If the point cloud does not show a specific pattern like a parabola or exponential curve the relation can be seen as linear (Vocht, 2011). The scatterplots show no clear pattern and therefore is the relation seen as linear (*Appendix 6.6, p.154* till *Appendix 6.29, p.159*). Therefore the Pearson's correlation coefficient has been calculated for all areas with both methods (multiple and average pair).

Results comparison with provincial study

The provincial study and the model results are compared in three different ways. Several statistics are compared, thereafter are the values visually compared on maps and at last the correlation between the values is calculated.

Statistical comparison

In the study of the province of Zeeland a mean index is made of the permanent counts in which the distribution over the seasons in 2013 becomes clear (*Appendix 6.5, p.153*). In the model the winter has the lowest traffic intensity (December, January and February). Also in the provincial study these three months had the lowest indexed number of vehicles per workday (Oosthoek & Pouwer, 2014). The busiest time of the year is August and therefore these results are shown separately from the annual results (*Appendix 6.3, p.151; Appendix 6.4, p.152*).

From the research in the province of Zeeland (Oosthoek & Pouwer, 2014) appeared that the autumn is busier than the spring (*Appendix 6.5, p.153*). While in this study the spring is a little bit busier than the autumn (*Table 5.5, p.37*). Also in this study the summer is the busiest season with a maximum of 116 rides in 2014 and 120 in 2013. This is higher than the results from the study of the province Zeeland in August, with a maximum of 91 rides.

Also for these analyses the workday maxima are calculated with the same methodology as the study by the province of Zeeland (Oosthoek & Pouwer, 2014). In the study of Zeeland the maximum number of vehicles that pass by annually is seventy. In this study this maximum is fifty in 2013 and forty-six in 2014, according to the analysis with the user data (*Table 5.4, p.37*). It is logical that the model estimations are lower, because in the provincial study a selection of roads are researched at which agricultural traffic is expected, while in this study all roads are examined.

Visual comparison

Furthermore the results are visual compared with *Figure 6.18, p.58* and *Figure 6.19, p.59* in which the differences in intensity estimations are shown annually and for the summer.

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The annual results show in general a higher estimation by the provincial study (*Figure 6.18, p.58*). For example in Tholen only one road segment has a higher estimation by the model. In Zeeuws-Vlaanderen are the most road segments located that are busier estimated by the model, this are not more than fourteen vehicles. The road segments that have an higher estimation by the provincial study show a wider range, the highest difference is 53. The interviews revealed that there is a potato collect point is located. This agricultural traffic is not counted in the model, while it is counted in the provincial study. This can also be the explanation of the difference on the road in Walcheren at which 41 more vehicles are counted by the provincial study. There is a large mechanic company located, which also generates agricultural traffic that is not counted in the model.

In the summer more road segments are higher estimated and the range is larger. Also here the biggest differences are found in Zeeuws-Vlaanderen. The provincial study has looked at the number of vehicles in the busiest month of the year, August, while in the model is looked at the traffic density in June, July and August. These different methodologies can explain the larger differences in comparison with the annual results.

Correlation results

As stated the presumptions of the Pearson's product-moment coefficient are satisfied. Therefore this coefficient has been calculated for all areas four times; the annual and summer results, both with the 'Average pair' and 'Multiple pair' method. The results can be interpreted with *Appendix 6.30, p.160*. The determination coefficient or R-square shows how much is explained and the correlation coefficient or 'r' shows the relation and direction (Vocht, 2011)

For the correlation the null hypothesis is that there is no coherence between the variables. If the significance level is lower than 0.05 this null hypothesis is discarded with a 95 percent reliability, is the significance level lower than 0.01 than the null hypothesis can be dismissed with 99 percent reliability.

The value combinations of the multiple pairs are all significant with a reliability of 99 percent (*Table 6.2, p.63*). The average pair method only the combinations for the entire province, Schouwen-Duiveland in the summer and the combinations in Tholen are significant with a 99 percent reliability (*Table 6.3, p.63*). Of the significant combinations the correlations can be interpreted (with *Appendix 6.30, p.160*) and the R-square is calculated.

The determination coefficients and correlations are lower for the multiple pair method in comparison with the significant results for the average pair method. Less of the relation is therefore explained in the cases of the multiple pair method. For the average pair method the correlation for the entire province is significant both with the annual data as the summer data, but the relation is weak and only 0.07 percent is explained. For the multiple pair method only 0.04 percent is explained (*Table 6.2, p.63; Table 6.3, p.63*).

In Tholen the relation is strong for the multiple pair method and explains about 52 percent. For the average pair methods this relation is very strong and explains between 62 and 70 percent. For this area a lot of road segments are researched by the province, furthermore this is a small area surrounded by water on several edge. This can partly explain the high correlation.

For both methods the correlation for Schouwen-Duiveland, in the summer, is negative. This relation is negative which means that if the provincial study counts high values the model calculates low values and the other way around. This relation is strong and thirty percent is explained. As stated this can be the result of other companies that result in agricultural vehicles that are not included in the model. Walcheren/Zuid-Beveland and Zeeuws-Vlaanderen show no significant correlation for the average method, in the multiple method these are significant, but the relations are weak.

In this study more values lead to more significant relations, but the relations are less strong. Furthermore less of the relation is explained. The results of this study are not in complete compliance with the results of the province. While there is a relation, this relation is weak.

Disadvantages comparison

As already stated in the previous paragraph the methodologies of both studies differ. In this study the rides between the home and field parcels are researched and for example rides for mechanisation purposes are not researched. In the study of the province all uses of agricultural vehicles are researched. Which explains the in general higher estimations. Furthermore the interview revealed that the counts at roads with a maximum speed of 80 kilometers an hour are the most reliable, because the speed difference between agricultural vehicle and cars is more apparent. The counts done at roads with a speed limit of 60 kilometers are less reliable, while these are done in the provincial study. Also is assumed in the provincial study that the counts at a point can be used for a larger road segments, this does not have to be the case.

Furthermore in the province of Zeeland there is a policy in which they 'lead' the agricultural traffic (personal communication, Paul Peter Kuiper). For example the 'Landbouwweg' is made (Agricultural road), at which only agricultural vehicles may drive (Stok, 2012). This can be an incentive for farmers to drive a longer distance, so they can use the Landbouwweg. In this research is assumed that farmers take the shortest route and no further preferences are taken into account. Furthermore, in this research all roads (on which agricultural vehicles are allowed to drive) are taken into account. All in all the location of the agricultural traffic intensity in this study can differ from the location in the provincial study.

6.4 Résumé

From the interviews appeared that farmers do not always take the shortest route, but that there are also other incentives leading to a route choice. Furthermore it has been proven to be difficult for the interviewees to estimate the traffic intensity, it was easier to locate problem locations.

Both the counting at the Domineesweg and the study of the province Zeeland shows in general higher agricultural traffic density results in comparison with the model results. This can be explained because this study only focusses on agricultural traffic between field and home parcels.

7 Conclusion and discussion

In this chapter the research questions are revised and is tried to give an answer to the main question. This main question was: *"The creation of a model that estimates and shows the spatial and temporal distribution of agricultural traffic density on the Dutch road network".* **In this chapter is explored if this objective is reached. At first are the five research question answered in close relation to the literature, quantitative and qualitative empirical results. This section is concluded with an overall conclusion. Thereafter several recommendations for further research are given and some applications of this study.**

7.1 Research question revised

Little is known about agricultural traffic intensity in the Netherlands, while an increase in agricultural traffic intensity is expected. Therefore is the study objective to research the agricultural traffic density in the whole of the Netherlands.

With the first research question is focussed on the factors that influence the number of rides: *"Which (parcel) factors determine the number of rides with an agricultural vehicle between home and field parcels?"* Through a literature study, several factors are defined that influence the number of rides, like farm type. In the model are several factors taken into account: crop type, soil type, parcel size, production and dump truck size. Of which the crop type is the most important factor, influencing both the fixed and bulk activities. Some factors are not taken into account in the model because data is missing, they are not quantifiable or their influence is limited.

The second research question has focussed on the implementation: *"How can the determined factors be included in an agricultural traffic density model for the Netherlands?"* Therefore are the factors classified in different categories, because the model would be too complex when all crops and soil types are taken into account. The most important crop types are used as a starting point for the classification. The remaining crop types are added based on their cultivation method. The crop categories are quantified, based on literature about the production per hectare and the number of activities per season. The soil type can make an important difference in the production related activities, while it has less influence on the fixed activities. During the interviews appeared that this is influence is so small that is decided to not further implement this in the model.

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The quantifications and parcel choices affect the model's results, which have been tested in the following research question: *"To what extend is the model implementation in coherence with expert judgement?"* The model implementation is mainly tested with expert interviews in the Noordoostpolder. Because the method had to be generic for the entire Netherlands, the behaviour of individual farmers can deviate from the model results. The interviews for example revealed that the start point of the route is not always correct and that farmers do not always take the shortest route, for example because of other traffic density.

The interviewees suggested to add farm type and crop independent rides to a parcel in the model. The agricultural traffic density in the model is mainly based on the type of crop. Consequently some crop independent activities are not included in the model and other activities are counted double. An example is mowing the ditch sides, which is not included in the model. Ploughing is an activity which is sometimes double counted, because some farmers combine this activity for several crops. Furthermore the salesman problem is not taken into account, while some farmers combine activities of several nearby parcels. In conclusion there are differences on the micro level, but in general the assumptions of the model fit reality.

The quantifications made in the previous research question appeared to give a good overview of the number of activities in reality. The development of agricultural techniques over the last years led to some changes. An example is the sugar beets production, which has grown enormously in the past years because of seeds improvements. Also, farmers currently spray a lower dose more frequent instead of a higher dose less frequent.

The quantification is based on the crop and parcel data, which also influence the model results. The fourth research question tests this influence: *"What is the effect of the input data on the model results?"* From the analyses appeared that there is a difference in agricultural traffic density between the analyses with the parcel users and parcel owners. Analyses with parcel users show more agricultural traffic because more parcels could be taken into account. For the parcel owner dataset it is not always possible to combine home and field parcels and these parcels are therefore not taken into account in the traffic density estimation. It is therefore strongly recommended to use the user registration of the parcels, because this gives a more complete and real image of the agricultural traffic intensity.

Furthermore from the interviews in the Noordoostpolder appeared that some farmers have parcels at different locations as a risk dispersion related to the weather. From the analyses in this study the phenomenon appeared also to be present in Zeeland. Farmers own parcels in different regions, but do not use them because they rent these to other farmers within that region.

Not only the parcels have influence on the model results, also the crops have. From the literature appeared that more and more farmers specialise in a specific crop type (Jaarsma & Hoofwijk, 2013), interviews with farmers confirm this. Because the crop rotation system farmers still have to rotate parcels, the specialisation in one product leads therefore to more parcel renting by farmers. This effect is already visible for flower bulb farmers. In the Noordoostpolder the effect of the flower bulbs cultivation is only visible with analyses with the parcel user, because these are mostly cultivated on rented parcels as it is a specialisation.

At last the size of the researched region seems to have a balancing effect on the effect of the rotating crops. The Noordoostpolder analyses showed a higher difference between the traffic density as a result of the crops in 2013 and 2014, in comparison with the analyses in Zeeland. Zeeland is a larger area and over a larger area it is more likely that changes in crops at one parcel are balanced by other crop changes at another parcel. Because only two years are compared it is difficult to conclude whether this difference in traffic density is a coincidence, or if this development can be expected in the future.

The last research question has focussed on the validation of the model results and is therefore: *"How can de model be validated with the perception of the farmers and the results of a study in the Province of Zeeland?"* The results are validated with three methods; the expert interviewees, an agricultural traffic counting in the Noordoostpolder and the study in the Province of Zeeland. The interviewees found it difficult to draw their perception about traffic density, because farmers use only a few roads. The municipality also had difficulties explaining the traffic density. They stated that in general it is the density of the agricultural traffic is high in the entire municipality of the Noordoostpolder. Also the interviewees identified flower bulbs as a crop that results in a lot of traffic.

The counting in the Noordoostpolder was only done for two days and showed more traffic in comparison with the model results. Also the results of the study of the Province Zeeland (Oosthoek & Pauwer, 2014) are compared with the model results. In general there is a weak correlation between the results of the model and the provincial study. However there are some regional differences. In Tholen there is a very strong positive correlation, while in Schouwen-Duivenland this is strong negative. Tholen is a small island where little alternative routes are available and therefore are the researched routes of both studies similar. In Schouwen-Duivenland is a large company located that results in agricultural traffic, but traffic that is not included in the model. This can explain the negative correlation.

The conclusion from the validation is therefore, that on average the model estimations are lower than the reality is. Although the model explains a part of the agricultural traffic on the road. Furthermore the province of Zeeland has identified several roads that are important for agricultural traffic, within the model results most of these roads were indeed busy.

Overall conclusion

The model is created because not much is known about agricultural traffic on the road, it is therefore difficult to validate the results. In the next paragraph is further attention paid to this. The objective of this study has been accomplished to a certain extent. The model can be used to estimate and show the spatial and temporal distribution of agricultural traffic density in the Netherlands between home and field parcels. It is possible to look at the seasonal differences, the annual density and the amount of traffic on a workday. In combination with regional knowledge the results can be used to get insight in the patterns of the agricultural traffic density. Furthermore the model methodology can be used for the whole of the Netherlands. The methodology is not only applicable for the whole of the Netherlands, the general methodology in which motives or factors are used to estimate the amount of traffic is useful for other traffic density studies.

Although the model does not show all agricultural traffic in the Netherlands. Also the quantification can differ for each region and it is therefore recommended to use the application to adjust the quantifications to a specific region.

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7.2 Recommendations

Spatial model

The model is created in several GIS programmes and is therefore specifically a spatial model. The spatial factors therefore has an effect on the results. For example it seemed like there is an edge effect. This implies that on the edges of a research area the traffic intensity is lower than it should be. This can be explained because farmers who live outside the borders are not taken into account. The chosen borders of the case study are arbitrary to the researched system so some parts of the system fall outside the case study area. It is advisable to take a larger area than the actual case study area, to overcome or decline these edge effects.

Home to field route

As stated in the previous paragraph the route between the home and the field parcel is calculated on the base of the shortest-route algorithm. In the model a farmer visits each parcel one by one, even if these parcels are in the neighbourhood of each other. The salesman-problem is therefore not taken into account. In future research it may be interesting to research the motives to combine parcels and to implement this in the model.

Furthermore some activities are depending on the parcel size, while these are not parcel dependent in this study. In this study only the production is made parcel size dependent. This is the result of a lack of time and an increase in complexity. Activities that are for example parcel size dependent in reality, but not in the model: organic fertilizing, or harvesting. For further research it would be interesting to make these activities parcel size dependent.

Furthermore the routes taken by contractors can be calculated and implemented in the model. Also is it possible that farmers have several home parcels at which machinery is stored, 'satellite' parcels. With the ongoing increase in scale this may become more commonplace. It is therefore interesting to extend the model with the possibility of having more home parcels.

The model is tested within two areas in which agricultural crops are the most common. As researched in Rienks et al (2009) an increase in scale of dairy farms can also result in less traffic, because the transportation of fertiliser and milk can be done more efficient. One truck for milk can be filled at one farm. These effects are not included in the model, because these agricultural vehicle uses are not taken into account. For further research it is interesting to extend the model with these uses.

Farmer’s motives

Within the Noordoostpolder thirteen interviews are done and the results of these interviews are taken into account with the factor quantifications. While these interviewees are experts and able in explaining what the average farmer does, there are differences in habits. During the interviews in the Noordoostpolder the most attention is given to farmers who produce agricultural products, because grassland and breeding farms are less commonplace. For future research it would be interesting to pay attention to activities related to grassland and animals.

Next to this the quantification of flower bulbs can be given more attention. These are now mainly based on one farmer and literature. Because the flower bulb category consists of a diverse group of flower bulb types it is not possible to further specify this. If this category becomes more specified in the parcel crop data (BRP) it is possible to further specify the quantifications to these crops. Additionally greenhouse cultivation is not taken into account, because this farm type mainly results in movements of trailer-trucks of the road of which the route differs from time to time. The application made in Access can be used to adjust the quantifications of the factors to a specific region.

Furthermore the model of the Kadaster can be extended with other motives. For example by adding costs to roads that are less attractive, for example roads with round abounds. This can result in a better estimation of the location of agricultural traffic intensity.

Validation

The model is created because there is not much known about agricultural traffic. A direct effect is that the model is difficult to validate. There are not many sources that can be used for validation and verification. In this study the research of province Zeeland is used, but this comparison has some disadvantages. It researches all agricultural vehicles, so also those used by others than farmers. Furthermore in the study results of one point are aggregated to a bigger road segment which can result in wrong conclusions. A recommendation is therefore to research for other validation methods and improve the model. In the future it may become possible to use GPS tracking system of agricultural vehicles for this. For now these systems are specifically created for on-field use and in many cases not applicable for on-road use. The data is for example not saved, but only used for precision cultivation. Driving in a straight line for example (Lehman, Reiche & Schiefer, 2012).

In short are the recommendations focussed at the extension of the motives for farmers to go to a field parcel, the extension of the motives to take a route and the extension of the model with other agricultural vehicle uses, like the traffic as a result by contractors. Furthermore the validation methods should be extended. For example in the future it may be possible to use GPS tracking systems of agricultural vehicles to follow their movements. For now these systems on the researched agricultural vehicles are not yet commonplace and not suited for on-road tracking

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7.3 Application of this study

In the following paragraph is attention given to the application of this study. From the interviews several applications are mentioned and the most important are shortly described here.

Land consolidation incentive

The visualisation of the agricultural traffic can be an incentive for policy makers or farmers to use land consolidation to improve the parcel distribution and to decline the amount of traffic. With the activity quantifications is it furthermore possible to calculate the costs of a field parcel. For this study this is already done in an Excel sheet, but this needs further examination with experts (*Appendix 7.1, p.161*). Within this sheet is calculated what the activities to a field parcel cost in fuel, salary and reduction in value of the machinery (afschrijving). In the sheet a difference is made in the speed of an agricultural vehicle with a dump truck and without. Furthermore it is possible to add activities with a car, for example to control the state of the crops. The farmer has to type the size of his parcel, the distance to the parcel and the crop on the parcel.

During the interviews appeared that farmers are eager to know the costs of a field on distance and therefore it is really interesting to further examine the costs related to a field parcel. Such a calculation can make farmers more aware of these costs and may change their buying habits or their views on land consolidation. Some farmers have field parcels on purpose, because this spreads the risks. If it rains in a specific area it does not have to rain in another area, so that the farmers can still do something on the dry parcel.

Land consolidation can result in less agricultural traffic, but the development of specialisation results in renting of parcels and this cannot be solved by land consolidation. Farmers still need to rotate with the parcels and if they specialise on one product, they need more different parcels. This development must be kept in mind with future land consolidation projects. Additionally some farmers rather have a number of parcels scattered over an area, because this spreads risks. Also in Zeeland this seems to be the case. Farmers own parcels at different areas, but do not use them. Other farmers would like to have their parcel near their home. The costs related to a field parcel can be a stimulant to collaborate in a land consolidation project.

Test network adaptations

Secondly is it possible to use the model to calculate the effect of new road or a road block. Farmer Fons works at a large agricultural organisation which has several parcels in Flevoland. He explained that his organisation has made their own paths between the different parcels. Earlier these parcels were reached over the public road, now they can go over their own paths. This organisation furthermore has chosen for this option because most of the machinery is too large to drive over the road (or an exception must be requested). If this option is more financial attractive more farmers may construct a new path to their other parcels.

Furthermore municipalities can test network adaptations and see how much agricultural traffic will use a new road if this is added. This simulation can prevent wrong investments in the network and it can help to look in consultation with the farmers and inhabitants for a good solution.

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