Efficiency at Dutch Inspectorates:

creating accountability and transparency with optimal coverage

Erasmus University
Rotterdam School of Management

August 25, 2019 Final

Author: Maurice van Dorp (487836)
Coach: Niels Agatz
Co-reader: Pieter van den Berg

Abstract

Inspectorates have the difficult task to try to keep the Netherlands as safe as possible. They do so with limited resources and continuous involvement of politics, organizations and civilians. Besides those challenges, they almost have to act as a soothsayer: trying to prevent something that has not happened before. How can Inspectorates keep up and fulfill their task?

Different research has been done about *the supervision paradox* and the *risk regulation reflex.* Both phenomena have a considerable impact on the way an Inspectorate functions. To address those phenomena, a more *transparent* and *accountable* way of supervision planning is needed. Therefore, in this research, we propose a new way of supervision planning based on *prospective supervision* and *risk coverage.* We created a model that optimizes the way inspectors, the resources of Inspectorates, are deployed. This creates a more efficient way of supervision planning, with direct impact on the amount of risk coverage and by doing so, aiming to lower the risk in the living environment.

Because of the by default immeasurable attributes of risk, measuring the effects of the optimized coverage is difficult. Instead, the proposed solution and model creates *transparency* and *accountability* for the decision makers to decide on which risk area there should be focus and what the impact is on the current focus. And, if risk coverage is not adequate, what is the impact of a number of new inspectors?

The proposed solution in this research is the answer to the formulated research question: *How can the total risk coverage in a geographic area suitably inspected or visited be maximized by more efficiently deploying available resources?* By doing so, the proposed solution helps ILT with the challenge (business problem) to deploy resources more efficiently and at the same time, this solution assist in a new way of supervision by creating accountability and transparency.

Table of Contents

1. Introduction

In January 2013 the Inspectorate Leefomgeving en Transport (ILT) makes an announcement that a newly taken into use train model, called Fyra, is considered unsafe and ordered to be halted immediately. This happened despite an approved permit and several inspections by ILT. After an extensive research (parliamentary enquiry) findings where that ILT only performed “paper inspections” and did not interfere with the external organization who performed the physical inspections for the NS. ILT inspectors never went physically in a Fyra train to inspect (NOS, 2015). After the parliamentary enquiry, the ILT intensified their inspection process in the domain Rail. They performed more and substantive inspections and interfered in the whole inspection process (ILT jaarverslag, 2015).

Another incident happened in late of July in 2017: a warning from the Nederlandse Voedsel en Waren Autoriteit (NVWA) about the toxic substance fipronil which has been found in eggs. This substance is used to kill blood lice in poultry houses. The with this substance poisoned eggs are a direct danger to the public health and can no longer be eaten. A few weeks later the news reports that in 2016, one year before, an anonymous incident report has been made at the NVWA about the possibility of fipronil in eggs, but after a small investigation by the NVWA no evidence was found to confirm this (NOS, 2018). After incident in 2017, the NVWA shifted its resources to focus on the organizations who produced eggs (NOS, 2018).

More recent in June 2019, the Dutch Research Council of Security published a report with the conclusion that Inspectorates in the food sector mainly focus on risks that already have taken place. Because of this focus, and the therefor slow reaction time when an incident happens, incidents like the Fipronil case have a higher risk of taking place (Onderzoeksraad van de Veiligheid, 2019).

Cut-backs, centralization, shifting responsibilities and deregulation are common practice at Dutch government agencies. Where for example government law enforcement organizations are directly visible to the public and have a broad support in society, Inspectorates are in a constant turmoil of the public opinion. Extremely visible and accountable when things go wrong and not seemingly doing what must be done but considered money spenders when everything is all right (Wetenschappelijke Raad voor het Regeringsbeleid, 2013). How do Inspectorates hold their business afloat while keeping the public interest safe and secure? Not very well. The need to ad hoc respond to incidents is getting larger (Onderzoeksraad van de Veiligheid, 2019), while at the same time the number of inspectors, the core resources of an Inspectorate, is getting lower (Meerjarenplan ILT, 2019). There is change needed at the Inspectorates (Schinkelshoek & Inspectieraad (Den Haag), 2016). Granting more funding because of an incident is a temporary solution and creates a problem at another government institute where the money was supposed to go. Besides, money can buy a lot of things but resources, qualified and available inspectors, is not one of them, because for instance of scarcity on the market (Wetenschappelijke Raad voor het Regeringsbeleid, 2013). Inspectorates have to fulfill their task and excel at it, with the available resources. In the field of Operations management this kind of challenge is everyday business and boils down to one thing: efficiency. Performing maximal with the available resources. Maximizing the output by optimizing the operation. In this research efficiency models from operations management are applied at the work process of an Inspectorate of the Dutch Government: Inspectie Leefomgeving en Transport (ILT). The ILT is chosen because of the accessibility of people and data. The results of this research are possible applicable at similar Inspectorates in the Netherlands. In the different inspectorates there is a real problem concerning the efficiency of the deployment of resources. ILT acknowledges that a change is needed. Shifting from reactive supervision to more data driven proactive supervision is one of the ambitious goals of ILT the coming years. (Meerjarenplan ILT, 2019). To achieve these goals a better, more efficient way of running the operation is asked for. To do so, a change is needed to increase the efficiency today. One of the actions ILT has taken is to focus all the resources they have in designated risk areas. A list with the top 10 of highest risk areas was created, based on past incidents in the domains of ILT: ILT Brede Risco Analyse (IBRA, 2018). But even with a prioritized list, ILT has difficulties to supervise all risk areas. This is considered a high priority problem at the ILT.

This research focusses on a strategic business problem at ILT: ILT cannot inspect all the prioritized risk areas in the Netherlands due to scarcity in resources. ILT wants to explore if a more efficient deployment of inspectors can increase the coverage of risks it can supervise, with the risk areas as described in the IBRA taken into account. Thus, this research is focused on an investigation whether it is possible to increase the effective use of the inspectors to enhance the inspection coverage of the risk areas.

In this research, *coverage* has two meanings. The first is *geographical coverage*: an inspector has to physically visit a location. A location, a certain company, landmark or object has to be inspected. With limited amount of resources, a maximal amount of geographical coverage is needed. Secondly, as many as possible *risk areas* should be inspected (as described in the IBRA). Those risk-areas are not geographically categorized, but on impact on society.

This problem can be viewed from different angles. The Dutch central government asks for reports with an overview of the amount of carried out inspections. The more carried out inspections, the better. They regard more inspections as a way to lower the risk, the location of the inspection does not matter. The management of ILT views this problem as a resource planning problem (Peter Neuteboom, personal communication, 10 dec. 2018). They have to deal with a limited amount of resources but have to perform a target number of inspections. To be able to inspect a sufficient amount of areas to keep risk low (as described in IBRA), more efficient planning is necessary.

The inspectors see the cut backs and limited resources as a management and priority problem. (M. van Wichen, personal communication, 30 jan. 2019). They argue that with more priority for the Inspectorate, more money would be available, more inspectors can be hired and thus the risk is lower. In the meantime, they are doing their work, and are skeptical about planning and schedules. They argue that inspections should be random and based on their own expertise and cannot be planned solely based on optimizing the amount of inspections for a set period of time. Inspection times are variable, depending of the kind of inspection, more or less time is needed (M. van Wichen, personal communication, 30 jan. 2019). This research tries to solve the management perspective of the problem: improve the resource planning at the ILT.

To develop a solution for the business problem of ILT the *problem solving cycle* (van Aken ,2007) is used. The different stages of the problem solving cycle, except the last two (Implementation and Evaluation) will be used in this research (van Aken, 2017). To focus this research a main research question is formulated: *How can the total risk coverage in a geographic area suitably inspected or visited be maximized by more efficiently deploying available resources?* For every stage of the problem solving cycle, there are sub research questions formulated. With the answers of the sub research questions, this research tries the answer the main research question.

Problem definition

R1. What are the root causes of the current business problem?

R2. What is the current performance of inspection coverage?

Diagnose and analysis

R3. What literature is available in the context of the business problem?

R4. What is the impact on performance of a more efficient planning related to coverage of risks?

Solution design

R5. Which model(s) can be used to deploy the available resources more efficiently?

Company profile

The Dutch government has the responsibility to keep citizens safe and make sure businesses work safely within rules (European regulations, national laws and lower regulations) designed by The Dutch government and the European Union. To perform this task, the government supervises and works on safety, security and trust in all kinds of areas. For example, there are fire departments, police departments, hospitals, but also special departments; Inspectorates with a supervising and granting permit task in the environment, focused on different domains.

In the Netherlands, there are ten of those Inspectorates, responsible for different domains. The Inspectorates have a controlling and supervising task in the different domains to make sure that organizations, *Onder Toezicht Staande* (OTS) work by the law and take actions to maintain a safe working environment and have safe products and/or services. An Inspectorate is not directly responsible for the safety or for preventing incidents: safety is the responsibility of the organization. Inspectorates *supervise* the OTS, to *verify* if they put enough effort in the actions to *maintain* a safe working and living environment and to minimize the *risk* of an incident happening. (Schinkelshoek & Inspectieraad (Den Haag), 2016).

Inspectorates indirectly safeguard public interests such as food safety, financial markets, safe transportation, or a clean environment. Despite the different domains, every Inspectorate is similar in the objective and the tasks it has to perform, supervise (carry out inspections) and grant permits. One of those Inspectorates is Nederlandse Voedsel en Waren Autoriteit (NVWA). This Inspectorate focusses on the quality of food and retail products in the Netherlands. An Inspectorate in a different field is Autoriteit Financiële Markten (AFM). The AFM supervises the financial markets in the Netherlands. Another similar Inspectorate is Inspectie Leefomgeving en Transport (ILT). The main purpose of ILT is to ensure a safe (living) environment for civilians and organizations in the Netherlands by working on safety, security and trust (Meerjarenplan ILT, 2019). ILT supervises and grants permits in the environment, transportation and public housing.

There are around 1000 employees working at the ILT. Around 700 of those employees are inspectors. All the other personnel is considered supporting staff. ILT is organized in different divisions, based on type of work. One of those divisions is *Vergunningverlening en dienstverlening*, specialized in granting permits and customer service, another division is *Toezicht en Handhaving*, specialized in inspections. Considering the subject of supervision in this research, we focus on the division *Toezicht en Handhaving*.

The ILT has a strategic vision about when, where and why inspections need to take place, to minimize the risk of possible incidents. In an ideal situation, ILT has enough inspectors to carry out as many inspections as needed. However, ILT has to deal with limited resources due cut-backs: there are not enough available resources to carry out inspections everywhere and anytime. As a countermeasure, ILT identified a top 10 of highest risks in the Dutch environment in relation to the domains ILT has to supervise. The ILT-document ILT Brede Risico Analyse (IBRA) contains a risk-based prioritized list of the areas where ILT should supervise. An area should be interpreted as a location, organization or object. For those areas, year plans are created that satisfy a minimum amount of inspections to be carried out to reduce the risk.

2. Literature review

Exploration of practice

The Fyra incident did not happen because of a direct scarcity in resources, but mainly due the view and interpretation of the law and task description of the Inspectorate. The Inspector General (IG) of the ILT at that time, Jenny Thunissen, admitted that the way the law (description of the ILT task) was interpreted should have been better: only inspecting reports is not enough (Parlementair onderzoek Fyra, 2015). ILT created an improvement plan to better reflect the intention of the law and to try to prevent this kind of incident from happening. By doing so, the ILT intensified the inspection process while at the same time ILT got to deal with heavy cut-backs. (Meerjarenplan ILT, 2016). One of the results of the Fyra incident does have a direct relation with scarcity of resources. Less inspectors, to perform the same or more amount of inspections and the inspections itself are intensified, because of the "extra" work an inspector has to perform.

About the Fipronil incident, Mr. Sorgdrager admitted in a television interview in *Nieuwsuur* in august 2014 that a cut-back of one third of the NVWA and performing a fusion of two smaller inspectorates into one, *"probably wasn't a good idea", 2014* (Sorgdrager). The assumption was that with the fusion, the Inspectorate would be more efficient, because of sharing the secondary processes, and thus less budget was needed. In case of the Fipronil incident the result was that there was not enough time to perform an in-depth research, triggered by the anonymous incident report, because of less available inspectors due cut-backs.

The Research Council of Security (2019) recommends in their research to focus on discovering trends in occurred incidents to prevent major incidents from happening. They urge the Inspectorates to learn from past incidents and use historical data to predict possible future incidents.

The mentioned incidents describe an interesting paradox. When there are no significant incidents, like the Fipronil or Fyra incident, society want less rules and interference of the Inspectorates. The results are the deregulation, cut-backs and fusions of smaller Inspectorates, to bigger, on paper more efficient Inspectorates. But when things go wrong and a significant incident occurs, the general opinion is: *Where was the inspectorate? Why were there no, or not enough inspections at chicken farms to prevent poisonous eggs to be distributed among the community?* And, *Why are there even Inspectorates if these incidents keep happening*? (Wetenschappelijke Raad voor het Regeringsbeleid, 2013, p22).

The call for *less* and *more* supervision results in this intriguing *supervisory paradox* (Wetenschappelijke Raad voor het Regeringsbeleid, 2013, p23). This paradox has a few attributes. When everything goes well, society wants less rules and interference of Inspectorates, what results in more self-responsibility, less bureaucracy, and cut-backs. When an incident happens, such as the Fipronil and Fyra incidents, more supervision is called for, what culminates in more extensive, intensive and stricter supervision. And that, of course, is difficult because of the removement of responsibility, less bureaucracy and cut-backs (Wetenschappelijke Raad voor het Regeringsbeleid, 2013, p23).

Another concept is the *risk-regulation reflex*. This is the propensity to create new and additional rules to manage a risk after an incident (Schinkelshoek & Inspectieraad, 2016). This reflex is especially visible after the Fyra incident, creating additional countermeasure in order to try to minimize the risk of this kind of incident to happen again (Schinkelshoek & Inspectieraad, 2016). The Inspection council formulated goals for the period of 2015 – 2018, to address the *supervisory paradox* and the *risk-regulation reflex.* The goals focus on professionality, knowledge and experience, the way supervision is maintained and assured in the society and, relevant for this research, operating *risk oriented, where supervision is needed.* (Schinkelshoek & Inspectieraad, 2016).

As stated before, ILT tries to create risk coverage while dealing with scarcity in resources by focusing on a top 10 of risk areas. The IBRA is used as a decision-making tool to determine where to deploy the resources. This list is based on historical data. That means that ILT only focusses on known risk areas: areas where in the recent past an incident has taken place or has a high potential for incidents based on historical data. The challenge with this approach is that the focus on certain risk areas is influenced by the *supervisory paradox* and the *risk-regulation reflex*. The IBRA is changed regularly, based on the paradox (less and more) and the risk-regulation reflex: if an incident happens, all focus is on that risk area for maximum control and trying to prevent an incident in this area from happening again. The result is that resources intended for other risk areas are redeployed to focus on the new focus area.

But even with the top 10 risks areas defined, there are not enough resources to cover all these areas. The deployment of resources based on the IBRA is not structured on operational level and is a result not efficient. At ILT the deployment of resources is based on best effort: trying to do as much inspections as possible, solely based on the expertise of the inspector (Peter Neuteboom, personal communication, April 2019) and sometimes based on mutual arrangements between inspectors. (Mike van Wichen, personal communication, Feb. 2019).

Exploration of theory

In another similar context, for instance the police, there is a concept called *proactive law enforcement* (Hutter, 1986). When the police are visible on the street (physically present in a location) and seeking out offences, the risk of an incident happening is lower than when the police is not present. (Hutter, 1986). Their planning is based on a location, with a certain distance a police officer can cover. The locations the officers must visit are maximized to have the best possible coverage.

Reactive law enforcement is reacting to an incident, not being somewhere to prevent one. Hutter (1986) makes a connection between proactive law enforcement and inspections by explaining that it is vital that an enforcement agency, for instance an inspector, has contact with the organization instead of sitting across a table with a representative at the inspector's desk (Hutter, 1986). Being proactively on premise as a law enforcement agency is crucial for a good relationship with the OTS, to lower the risk of an incident happening. (Hawkings, 1984)

Proactive and reactive law enforcement is not new for ILT. Beukenkamp (2016) describes proactive law enforcement as *prospective supervision*, to try to prevent escalation of incidents and reactive law enforcement as *retrospective supervision,* after an incident deciding what to do to prevent another incident. The IBRA, the main decision tool for deployment of resources, is mostly based on *retrospective supervision*, because it focusses on incidents happened in the past. Beukekamp (2016) suggest a more *learning* focused way of inspection, where historical data is used to predict possible disasters. This way of thinking is also suggested by the Research Counsil of Security (2019), as mentioned before in the exploration of practice, retrospective supervision is not enough, it has to be combined with prospective supervision, just as Hawkings (1984) described as proactive law enforcement with a physical presence to reduce the risk and improve the relationship with the OTS.

To efficiently perform *proactive law enforcement* and *prospective supervision*, and by doing so reducing the risk in the areas mentioned in the IBRA, *coverage* is needed. Because, as stated before, being physical present lowers the risk of an incident happening. In this research we try to enhance the accountability, transparency and the amount of risk coverage, by maximizing the amount of geographical coverage.

For an inspector, there is a target amount of inspections he or she has to carry out (IBRA, 2018). We aim for the most efficient way to reach this amount with the available resources, taking into consideration the risk and geographical coverage with the goal to maximize the amount of inspections which can be carried out. The risk coverage means performing as much as possible *unplanned* inspections. The geographical coverage means being physically present on a location. By doing so the logic is that with more efficient deployment of inspectors and thus visiting more OTS and thus have more geographical coverage, the risk coverage also goes up, because of the maximized amount of inspections and so the overall risk goes down. Obtaining maximum coverage can be useful in several different context. For instance, when expanding a supermarket chain of stores, it is important to locate a new supermarket store where it can reach an optimal population: the coverage of an area.

The allocating and planning of objects to maintain an optimal coverage is a challenge in a lot of contexts. The context with the most impact on everyday life is emergency response. To determine where to place a fire department or a hospital for instance, is an *operations management covering problem*. To obtain maximum coverage (to deliver relief to people in need on time) several covering models and optimizations techniques can be used (Li, Zhao, Zhu, & Wyatt, 2011).

The most common used techniques described by Li et. al. (2011) are the Location Set Covering Problem (LSCP) and the Maximal Covering Location Problem (MCLP) with different variations like the Maximum Expected Covering Location Problem (MEXCLP) and Maximum Availability Location Problem (MALP) models. There are several recent developments, like hypercube queuing models, dynamic allocation models, gradual covering models, and cooperative covering models, but not much research is yet conducted for these models (Li, Zhao, Zhu, & Wyatt, 2011).

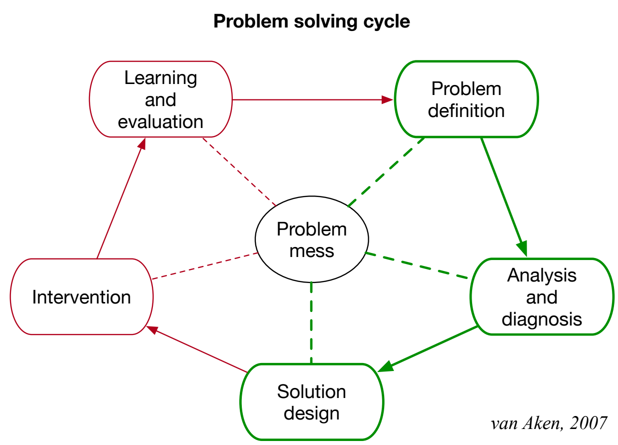
The first covering model to determine where to locate facilities to cover all demand points is the Location Set Covering Problem (Toregas, Swain, ReVelle, & Bergman, 1971). Toregas et. al. (1971) describes LSCP as most applicable to determine the location of for instance emergency services such as fire stations, police stations and medical stations, but also to determine the optimal location of placement for a school or library. In LSCP the special aspect is according to Toregas et. al. (1971) *"that the maximum time or distance that separates a user from his closest service is a crucial parameter."* The main focus for LSCP is to locate the minimum number of facilities that cover all of the demand nodes. Creating total coverage is difficult, because of the lack of limiting resources (Li, Zhao, Zhu, & Wyatt, 2011).

As an improvement over LSCP, Church & ReVelle (1974) proposed the Maximal Covering Location Problem (MCLP). MCLP focusses on choosing a maximum set to cover as many elements as possible. They constrained the problem by a set number of facilities; a resource limit. It is a way of mathematical location modeling, based on a realistic objective and can be quantified. There are two perspectives of using MCLP: searching the maximum population which can be served given a stated service distance and given a limited number of facilities, or from a minimizing perspective, minimize the amount of people that will not be served within the maximal serving distance (Church & ReVelle, 1974). When there is a scarcity in resources and all or as much as possible population needs to be served, MCLP is definitely considered. With MCLP a strategic decision maker can determine what the needed resources are to cover the demands as much as possible. (Fazel Zarandi, Davari, & Haddad Sisakht, 2011).

MCLP is thus also applicable for emergency facilities who need maximal coverage in an area to service the population in that area, where there is focus on coverage with limited resources. A practical application is the most optimal deployment of Automatic External Defibrillator (AED) units, based on the areas where a cardiac arrest had occurred every few years (Tierney et al., 2018). This application has some similarities with this research. Tierney et al. tried to maximize the coverage of AED's in a specific location (where cardiac arrest has occurred). They compared MCLP, described as a fixed location problem, with their own modified MCLP, flexible location problem. The flexible modification added an extra limitation in the problem: the maximum cost of installing a new AED or relocating an existing AED. (Tierney et al., 2018). Another application of MCLP is optimal location of intersection safety cameras on for instance an urban traffic network (Dell'Olmo, Ricciardi, & Sgalambro, 2014) the location of retail facilities (Berman and Krass 2002) or the location of ambulance bases in rural areas (AdensoDiaz and Rodriguez, 1997). For the context of this research, it is shown that the usage covering models and obtaining a higher level of coverage can result in a more *efficient deployment of resources* and a more *accountable and transparent* way to distribute resources in an area.

3. Methodology

The research objective of this research is *problem solving:* solving a real-life business problem of ILT. The research approach is *design study*. When trying to solve a problem, a solution has to be designed. The research strategy is *modelling*. This research is trying to design a new practice based on (existing) model/optimization. For design study type of research, van Aken (2007) describes the *problem solving cycle* as an excellent model for problem solving research. The problem solving cycle is specifically designed to address business problems in an organization. With this approach, the business problem is clearly defined, analyzed and diagnosed resulting in a solution. With the solution for the problem, an intervention can be implemented, and the results can be evaluated. (van Aken, 2007).



By conducting a design study and creating a model, this research contributes to the research object. As stated in the introduction, there is a business problem that needs to be addressed. The relevance is visible in the impact the problem has the Dutch society. Due to the scarcity in resources, not all risks can be supervised. This poses a real-life threat for the citizens and organizations in the Netherlands. If this research can decrease the risk by just a bit, that would already make a difference. The novelty of this research lies in the application of MCLP for a more efficient coverage of risk by obtaining a better geographic coverage. The added value is on strategic level for a decision maker. With this research a more accountable and transparent way of deploying resources is possible. To accomplish that objective, this research aims to develop a workable model, which can be used to simulate different scenarios.

In this research, the focus lies on the first three stages of the problem solving cycle: problem definition, analysis and diagnosis, solution design. The ultimate objective of this research is to develop and present a concept solution, to be used in the business where the problem occurs. (van Aken, 2007). From the perspective of academic research, after the solution design stage, a loop back to the exploration of practice is analyzed to discover whether the designed solution is also applicable in other similar inspections and/or organizations. This could be done in future research. The first stage problem definition contains an extensive exploration of practice and theory. With both explorations, the problem can be clearly defined. After a clear description of the problem, the diagnose and analyze stage can begin. This stage characterizes itself with an extensive research in the context of the problem and the different causes of the problem. The last stage in this research is the development of a solution to address the most important causes. A model is designed to experiment with different scenarios. The results of the experiments are a recommendation and a theoretical model.

During the exploration of theory, a systematic literature review is conducted, based on different relevant keywords. Searching for relevant papers is based on the presumed "gap" in the literature. By using references and citations in those papers, new context related theory can be found. This is called respectively forward or backward snowballing, what refers to using a reference or citation from a paper to identify possible other interesting papers. (Wohlin, C., (2014). The main research location for the literature study is the University Library of Erasmus University and Google scholar.

The object of study of this research is inspectorate ILT. The main focus of this research is maximizing the geographic and risk coverage by deploying resources more efficiently. The unit of analysis is on the level of process units: the effectiveness of activities, in this research inspections is analyzed. (van Aken, 2007). The data collection for this research will be qualitative in the stages problem definition and diagnose and analyze. Formal and informal interviews will be used to get a clearer picture of the problem, context and cause. In the solution design stage, quantitative data collection is used. Input data is collected from the available supporting ICT systems in the ILT. This is historical data related to the context of this research. The output data will be created by the solution and will be compared with the input data. The recommendations are based on the comparison. The object of measurement will be the amount of coverage by a number of inspectors in a set period of time. This measurement will be applied at the input and the output data.

Scope

In scope is the possible defining and modelling of a solution for the business problem, out of scope is the implementation and evaluation of the possible solution. Further in scope is defining the preferences of the business related to resource deployment and the possible solution, out scope is gaining the support of the inspectors for the possible solution. Also, in scope, is the conceptual modelling of the solution, out of scope is a feasibility study of the implementation of the solution in current or new (ICT) systems.

4. Diagnostic story

Inspectorates have the challenging task of keeping the environment, in different aspects, as safe as possible by *supervising* the OTS, to *verify* if they put enough effort in the actions to *maintain* a safe working and living environment and to minimize the *risk* of an incident happening. Based on the different interviews with management, inspectors and business analysts and research from the WRR, the inspection council, and internal ILT documentation, the diagnosis is that ILT has a constantly changing playing field and has to work with the limited resources it has and, in the future, maybe less resources. The *supervision paradox* and the *risk regulation reflex* have a constant impact on where the scarce resource ought to be deployed. The deployment of resources is ad hoc, and is sometimes based on the IBRA, but mostly on the expertise of the inspector. Some attempts were made by ILT to structure the deployments of resources by creating an operational planning, but those attempts failed. There is no real insight in where inspections are performed and neither can the "why there" question be answered.

The IBRA tries to focus the resources based on risk priority, but due to the scarcity in resources, not every risk area can get enough attention from the inspectors. The continuous meddling of the government and society (supervision paradox and risk regulation reflex) and the lack of structure makes it very difficult for ILT to make deployment decisions. This is a *real problem* for ILT, it is a situation that does not meet realistic standards (van Aken, 2007).

An inspector has four different types of inspection work. There are object focused inspections, system specific inspections, inspections based on a theme and administrative control (audits) (IBRA, 2018). An inspection is an *announced* or *unannounced* visit to an organization, object or location. An administrative control (audit) is an announced visit; it is two-sided planned, which means that both the inspector and the inspected organization or object are aware of the inspection. (P. Koetsier, personal communication, March. 2019). An object, system and theme-based inspection is unannounced, based on risk and the expertise of the inspector who is carrying out the inspection. The unannounced aspect of an inspection means that there is a certain randomness involved. To supervise, the object of inspection must be unaware that an inspector is supervising. An inspection can be one-sided planned by the inspector or be initiated unplanned (ad-hoc) based on his or her expertise, by deciding "on the go" where to carry out an inspection. In this research, we focus only on *unannounced inspections*: *one-sided planned* and *unplanned*, because those inspections have the largest impact on risk in a way that with the OTS not knowing that the inspector is coming, and thus we presume that the chance of preventing an incident is higher.

The IBRA is accepted on strategic level but is not actively used on operational level. (Peter Neuteboom, personal communication, 10 Dec. 2018) This means that operational planning is not actively based on the IBRA. There are no planning methods used by ILT which are aiming to cover the risk-based prioritized list where ILT should perform inspections (IBRA, 2018). There are no ILT-wide planning tools to schedule inspections for inspectors. Every team of inspectors has a year plan, with a specific target number of inspections that has to be carried out that year. An inspector reports the amount of inspections he or she carried out to his supervisor. There is no ILT wide report about the achieved risk coverage: there is no transparent accountability on strategic level. The ILT only reports on the amount of inspections to the Dutch central government but has no instruments to create accountability about the risk coverage at the ILT.

To solve the strategic business problem of ILT, a few different solution directions have been explored. A couple of years ago, ILT tried implementing a rigid resource-based planning system tool called Metrix. All inspectors were supposed to carry out inspections based on a work schedule, provided by decentralized planning teams. The work schedule was based on geographical location and inspection time. An inspection was defined as *"an unannounced visit to an organization or location, inspect and report."* (M. van Wichen, personal communication, 30 Jan. 2019) The timeframe of an inspection was calculated based on historical data from the inspection process application: an average inspection took around two hours. The assumption was that with a work day of eight hours, an inspector could perform a maximum of four inspections, with travel time taken into account. The time to travel from the inspector's home to the first inspection location was not considered. On paper, this seemed like a good way to let inspectors carry out their inspections in a more efficient way, allowing the inspectors to perform more directed inspections and thus, as reasoned by ILT, lowering the risk in the living environment.

For several reasons this planning method did not succeed and was abandoned after a short period of time. The most important reason of the failure of the implementation was that two hours is too short to carry out an inspection when an incident occurred. Sometimes an inspector has to manage an incident after an inspection which might take a few days to resolve. In addition, the amount of paperwork related to the inspection can be of such extent that two hours is not sufficient. The result was a continuous pile up of planned inspections that could not be carried out and had to be rescheduled. But most of all, with this way of planning, there is no or less freedom and control for inspectors. An inspector is not able to act on his expertise and feels he has less freedom because of this. The lesson learned with this solution is that inspections are different in every context and are difficult to plan "on paper". There has to be some extent of freedom to "shuffle" activities on a daily and weekly basis. Another lesson is the amount of resistance to implementing a new way of planning inspections. After the failure of the Metrix solution, no other ILT wide efforts were made to improve the efficiency of resource deployment. Currently inspectors plan their inspections individually based on their experience and available time, or in consultation with their direct colleagues. There is no companywide initiative to address the way of supervision.

Changing the way of working of any organization requires time and a lot of perseverance. Especially when the "core" of an organization is changed: in this case the way supervision is planned at an Inspectorate. There is a lot of resistance for a change in supervision from inspectors at the Inspectorates. The inspectors operate as small one-person organizations, to maintain the element of surprise and for flexibility. They claim that a solution to obtain more coverage is not that difficult: allocate more money to the Inspectorates to "buy" more resources, inspectors, and the coverage will be better. Thus, one can argue that instead of focusing on supervision efficiency across the whole organization, another way of obtaining more coverage could be by just adding more resources. That way, a lot of resistance is avoided, and a simpler solution can be relatively easy implemented. But with this approach another problem surfaces: are there available inspectors? The job market is difficult, there are not many available possible inspectors to be found. Therefore, this proposed solution is not a valid solution, considering the time and effort the Inspectorates have to invest in finding new inspectors, if they can be found in the first place.

5. Solution design

There are two concepts important in the solution design with a considerable impact on supervision: *risk* and *expertise*. The first is risk, which is defined by ILT as: "*The amount of damage it conflicts in a certain classification*." (IBRA, 2018) There are five different classifications of damage: physical, health, environmental, economic and institutional. Every risk has a value in euros granted. The risk is rated by probability times effect. With this method, risks are prioritized and have a value (IBRA, 2018). The value is important, because based on that value ILT can determine if action (in this case an inspection) is required for that risk and can be justified in a business case

(IBRA, 2018). Supervision is performed to as a countermeasure to the different types of risk. The solution has to address the risk focus ILT has formulated in the IBRA, and by doing so try to lower the risk.

The second important concept is *expertise*. This is an intangible subject at ILT. Expertise is elusive, sometimes referred to as "gut feeling" and consists of two types: the expertise to *perform* an inspection substantive and expertise to decide *where* to perform an inspection. Thus, sometimes an inspector makes a decision on where to inspect based on expertise. For example, he or she drives to a location, say Schiphol Airport, drives across the airplane platform and sees something suspicious in an aircraft. Based on the expertise of the inspector a decision is made to perform an inspection or drive further. This kind of supervision can be classified as an unplanned inspection: it is not based on any form of planning or historical data. But being in an area, and thus being able to react to an incident at a location, whether or not it is based on expertise, asks for a certain amount of freedom in the way of working of the inspector. Because of this, expertise is important and needs to be addressed in the solution.

Based on the previous experiences at ILT, conducted research and the literature study, we endorse the change in the way of *thinking about supervision* suggested by Beukenkamp (2016) and The Research Counsil of Security (2019). We agree that the focus should not only be from a *retrospective* point of view, on an OTS (because an incident has happened), but *prospective* based on geographic locations. Proactively supervising by being on a location, visiting OTS in that area. In this way of thinking, an inspector has a focus on a geographical area, in which different OTS are located. We conclude that to achieve more efficiency with *prospective supervision*, a certain amount of coverage is needed. In the current situation an inspector visits an OTS based on its own expertise and mostly on *retrospective supervision*: an incident has taken place, hence the focus on that OTS. With the limited amount of resources, and the increasing risk areas, resource deployment most be more *accountable* to address the *supervisory paradox* and more *transparent,* to address the *risk regulation reflex.*

We propose a new way of creating transparency and accountability by developing a model to determine where an inspector could go and thus where inspections should take place, based on *optimal coverage* in a designated risk area*.* The inspector is responsible for *servicing* this area in the span of a period of time, in this case one year, because of the mandatory reporting cycle of the IBRA. Beside the administrative reason, one year of time gives an inspector enough time to "shuffle" his or her schedule and thus can address his or her *expertise*. Every inspector has an area where he or she has to perform inspections at the OTS in that area. By deploying inspectors based on locations, a geographical coverage is achieved. Being physically present in a location for a period of time, unannounced visiting OTS, lowers the risk of an incident from happening. To maintain the *expertise* and thus a certain amount of freedom for the inspectors, we suggest a *domino approach.* The first domino, a location, is fixed and based on a coverage-based planning. Because of the fixed starting location and the maximum travel time for an inspector, the rest of the domino's, OTS, will follow. The area an inspector has to service contains a number of OTS the inspector has to visit in a period of time. The inspector has the freedom to make unannounced, one sided planned and two-sided planned visits, based on his own expertise, but his service area, the area he is working in, is fixed. Every inspector's service area is planned based on maximizing the geographical coverage. By doing so and being physical present at a location, the risk coverage is also maximized.

Creating a structured way of deployment based on geographical coverage has besides the risk coverage, a big advantage for the decision-making process. With the geographical coverage visualized, the decision to focus on a different risk area can show the impact it has on other risk areas. It can also act as a rationale to argue why there is need for more inspectors, and thus more funds. The proposed model therefore creates accountability: it shows where inspections are performed. And transparency: it shows where there are no inspections taking place. Both advantages address the supervisory paradox and the risk regulation reflex.

From the Operations Management field of study there are is a valid theory to solve the problem of how to obtain maximum coverage with limited resources. The *Maximal Coverage Location Problem* focusses on achieving the maximum coverage of facilities servicing a population within a certain distance or reasoned from a minimizing perspective: minimizing the amount of people not to be served within a certain distance. Based on MCLP, the objective for ILT would be: *Maximize the amount of OTS within a region inspected within the set time frame, available inspectors and service distance.*

The problem parameters are as follows:

i, I	The index and set of demand nodes
j, J	The index and set of eligible facility sites
a_i	The population or demand at node i
d_{ij}	The shortest distance (or time) from demand node i to facility at node j
S	The distance (or time) standard within which coverage is expected
N_i	$\{j \mid d_{ij} \leq S\}$ = the nodes j that are within a distance of S to node i
p	The number of facilities to be established
X_j	A binary variable that equals one when a facility is sited at the jth node and zero otherwise
Y_i	A binary variable that equals one if node I is covered by one or more facilities stationed within S and zero otherwise.

(Fazel Zarandi, Davari, & Haddad Sisakht, 2011)

To use MCLP in this research there are a few parameters to map to the context of Inspectorates:

i, I	The index and set of demand **OTS** (nodes)
j, J	The index and set of eligible **inspectors** (facility sites)
a_i	The population or demand at **OTS** (node) i
d_{ij}	The shortest distance (or time) from demand OTS (node) i to **inspector** (facility) at **OTS** (node) j
S	The distance (or time) standard within which coverage is expected
N_i	$\{j \mid d_{ij} \leq S\}$ = the nodes j that are within a distance of S to node i
p	The number of **inspectors** (facilities) to be **placed** (established)
X_j	A binary variable that equals one when an **inspector** (facility) is sited at the jth node and zero otherwise
Y_i	A binary variable that equals one if node I is covered by one or more **inspectors** (facilities) stationed within S and zero otherwise.

The mathematical formulation of MCLP is as follows:

$$\text{Maximize } z = \sum_{i \in I} a_i y_i, \quad (1)$$

$$\text{Subject to: } y_i \leq \sum_{j \in N_i} x_j, \; i \in I, \quad (2)$$

$$\sum_{j \in J} x_j = p, \quad (3)$$

$$0 \leq y_i \leq 1 \; i \in I, \quad (4)$$

$$x_j \in \{0, 1\} \; j \in J. \quad (5)$$

In MCLP z is the objective: maximize the coverage of i by j with a specified S. The result is p: the determination of locations for the facilities. Important input parameters are i, j and S. The parameters are *decision variables* in the practical usage of the model for ILT. The dataset of OTS *(i),* the number of inspectors (*j),* and the service distance (*S),* are variable and can be adjusted for specific cases.

Facilities are fixed locations in the original MCLP. We suggest a more flexible MCLP variant, where a *facility* is read as an *inspector* and can be located for a period of time. The use of this model would be in continuous use. If an incident happens, and the *risk regulatory reflex* kicks in, this model facilitates a change of focus by using a new set of i and by doing so adjusting the location of the inspectors (facilities) to shift coverage to a new risk and thus geographical area. This way of usage of the model is only applicable when the data *i* is available and correct. The result can be used as rationale (accountability and transparency!) for the decision maker to decide where to deploy the resources. The OTS are static and can be regarded the population. The service distance is the distance an inspector can travel from his starting point in a workday (8 hours).

There are two possible conceptual solutions that can be designed based on the MCLP. The first has a focus on the practical decision constraint *service distance* (*S*). Proposed solution 1 uses the parameter *service distance* to determine the maximal coverage. This is useful for overall coverage summaries to create transparency and accountability. It shows the complete coverage, based on distance. The not even spread of locations of OTS throughout the Netherlands is not calculated and can create a wrong impression, if it is not recognized.

The second solution has a constraint focused on the maximal number of inspections an inspector can perform in a set period of time. The solution only uses the maximal number of inspections to create coverage and combines it with the *service distance* as practical decision constraint. This is useful when there is need for focus on a specific region. For example, Port of Rotterdam, or Schiphol. When calculation coverage for a specific region, the spread of locations of OTS is important. The distance is less relevant, the amount of OTS an inspector can visit is, because of the high density OTS on a small location.

6. Results

Data retrieval

The available dataset contained 24.821(*i*) inspections for the domains rail, road, shipping and environment. Aviation is not registered in the inspection process application. Every inspection is unique, but there is a possibility that multiple inspections at one location were performed. The dataset needed some adjustments to be used in the model: all incomplete data (no address) had to be removed from the set, after this adjustment 19.897 valid records remained. ILT performs inspections abroad, all the countries except the Netherlands where removed, to get focus on one area. Off course, in the definitive model an option to choose an area is needed. After this adjustment 14.047 valid records remained. Therefor $|I| = 14.047$. All the remaining records needed their addresses to be converted into longitude and latitude data. To convert the address to coordinates, the *excel-geocode-tool* was used. It took approximately 3 hours and 35 minutes to convert the data. After the conversion, the coordinates where imported in the R development environment and implemented in the code of the model. In this research we use the *domino approach*, which suggest that the first inspection is the starting position. This is a choice: any location in a geographical area could be used. In this research, we created a subset of $|I|$ for *j,* thus $j \subseteq |I|$.

To operationalize one of the proposed solutions in a workable model, we used the programming language R, with the open source library *max_covr* (NJ. Tierney, 2018). The library uses open source solvers *glpk* and *lpSolve* to solve the MCLP problem. The results can be displayed in data outputs and visualized on a geographical map. The R code for the model is available in the appendix. The library uses *service distance* (*S*) and *number of inspectors* (*j*) as input parameters. There is no option to add a constraint on the maximal number of inspections. Therefore, based on practical and scoping arguments, *proposed solution 1* is used in the experiments. Proposed solution 2 could be used in further research to operationalize the solution for Inspectorates.

Experiment set-up

To test the model, we created three experiments. The assumption in the experiments is that ILT wants to perform 66.000 inspections in 2019 (Meerjarenplan ILT, 2019). ILT has a resource capacity of 700 inspectors. In this research, we have 14.047 confirmed locations of OTS and thus |I| is 21,28% of the 66.000 needed inspections. For that reason, we use 21,28% of the resource capacity, the number of available inspectors (*j*) is 21,28% of the available 700 inspectors thus *j* = 149. Due to the fact that OTS-locations are not evenly spread in The Netherlands, this assumption might deviate from reality: there is no linear correlation. But with this experiment we can see if the proposed solution works, and what the coverage would be (with an error margin) when using the model. The parameter service distance (*S*) is also used in the model. This parameter is difficult to determine. An inspector has a certain distance (km) he or she can travel on a day from home to the OTS. Rationally this could be any km ranging from 0 to around 100 km one way, 200 km two way. When arrived at the OTS, the model assumes that there are more OTS clustered around the starting location, hence the *domino approach*, where the model selects the most optimal OTS to start. The service distance, essentially the coverage from the first OTS, cannot be that big considering the time it takes to travel and because of the need to perform multiple inspections a day. Besides the time, there is not an even spread of locations of OTS in the Netherlands. A service distance of 5 km in the Port of Rotterdam can contain 100 OTS, while at Groningen, there are only (for instance) 2 OTS within the service distance of 5 km. Therefore, the parameter *service distance* is variable. It should be adjusted per region. For this experiment, we choose 7,5km (diameter of

15km) for the base case, and 5km (diameter of 10km) for the sensitivity analysis. This seems like a realistic service distance, but it should be adjusted based on real data of the actual spread in the region. Besides the logic of travel time and spread, computing power is also a factor taking into consideration in this research. Using the 7,5 km service distance, it took the available computing power over 1 full day to run the experiment. When using 50km, the experiment did not finish.

The first experiment, exp1, is the *base-case,* this experiment uses |I| (14.047) with *j* (149) inspectors with *S* of 7,5km. The second experiment, exp2, is a sensitivity analysis with *S* adjusted to 5km. With these two experiments the model shows wether the *service distance* parameter is correctly calculated. The third experiment, exp3, is a sensitivity analysis based on the calculations of exp2, with 15 extra *added resources*. This experiment is important for the decision-making process. ILT regularly tries to hire more inspectors, but the consequence of more inspectors is not clear. With this experiment we can show what happens with the coverage when more inspectors are deployed and where they should go, with a more *transparent* and *accountable* way of deployment of resources as a result. To run the experiments a virtual server running Microsoft Windows Server 2016 with an Intel Xeon 5118 2,3GHZ CPU and 128GB of ram was used.

Current situation

To evaluate the experiments, we tried to use the available data (|I|) and visualize the actual coverage of inspections in 2018. The dataset of |I| inspections carried out in 2018 are shown in illustration 1.

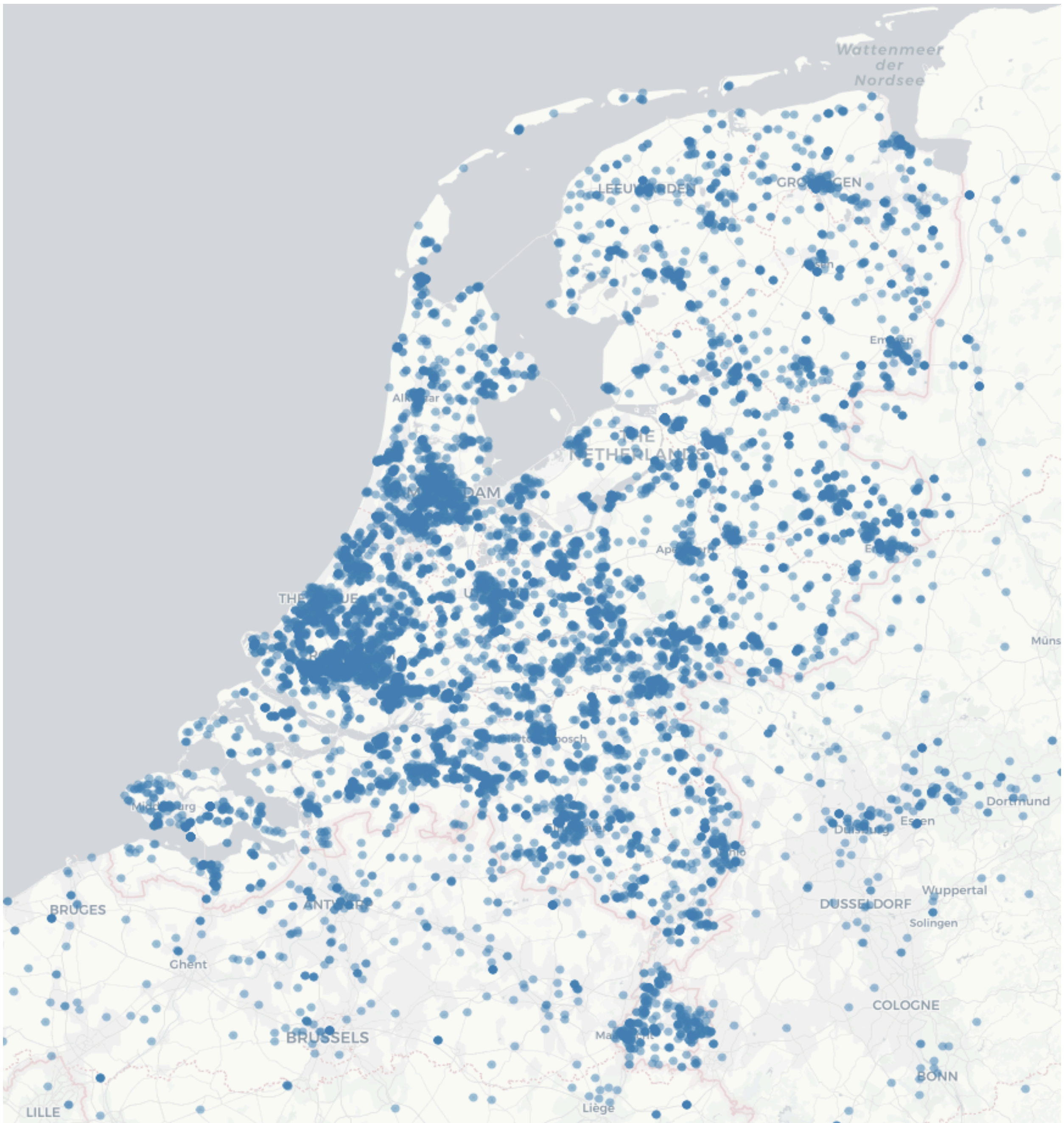


Illustration 1 - *Current situation (inspections carried out in 2018)*

Illustration 1 displays the inspections carried out in the Netherlands in 2018. There is no data available of all the known OTS locations, therefore we only see the actual inspections and not the OTS where no inspection has taken place. What is visible though is the concentration in the western part of the Netherlands (Randstad) and the more sporadically performed inspections in the remaining parts of the Netherlands. That seems logical; there are more OTS located in the western part of the Netherlands. We don't know exactly how many inspectors performed the inspections, so there is no real conclusion to be made about the efficiency of the supervision in the current situation. What we can conclude is that inspectors operate nationwide, and that there is a certain degree of coverage. What the percentage of coverage is and how many OTS are left uninspected is unknown. If that data is available, the model can be used to display this information.

Exp1: base case

In exp1 the to be supervised area by 149 inspectors (*j*) is determined by the most optimal coverage, with a *service distance* of 7.5km (*S*), what results in a total coverage diameter of 15km. In illustration 2, the focus areas and the coverage of OTS |I| by inspectors is visualized. There is transparency and accountability: it is clear for the decision maker where the available resources are deployed. This insight contributes to the efficiency of supervision.

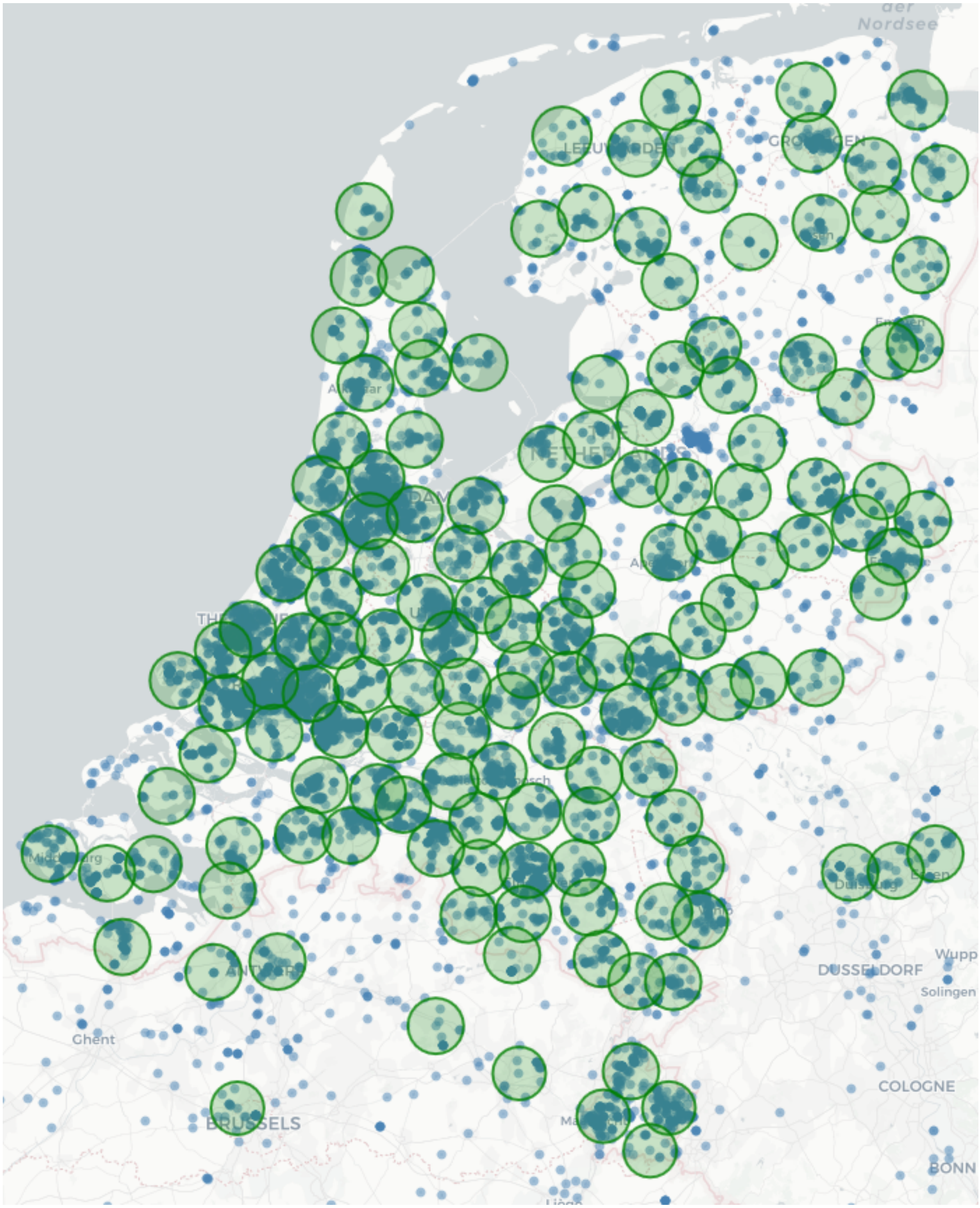


Illustration 2 – *exp1 (resources to be deployed based on optimal coverage with 149 resources and 7,5km distance)*

Illustration 2 shows, on the eye, a high percentage coverage on |I|. Summary of exp1 in table 1 shows that with 149 inspectors, 13.479 OTS are inspected; a coverage of 95,9%. This is without taking into consideration where the inspector lives, how long an OTS takes and if an incident occurs. This coverage must be interpreted in the context of a one-year timeframe.

Summary coverage

	n_added	distance_within	n_cov	pct_cov	n_not_cov	pct_not_cov
1	**149**	**7.500**	**13.479**	**0.9592**	**568**	**0.0408**

Table 1 – exp1 (*resources to be deployed based on optimal coverage with 149 resources and 7,5km distance*)

The original data output contained two rows. The first row showed the situation with 1 resource. This is a constraint in the experiment due the fact that the R code does not run with zero resources, it needs a minimum one (1) value to function. The second row showed 148 resources. Both rows are added in table 1 as totals.

Exp2: sensitivity analysis service distance (S)

In exp2 the parameter *S* is adjusted to 5km, what results in a total coverage diameter of 10km. Illustration 3 shows a different coverage vis-à-vis illustration 2, with smaller coverage areas. In the data summary a decrease in percent coverage is visible: 85% for 5km vis-à-vis 95,9% for 7,5km. The number of OTS covered also dropped: 11.948 for 5km vis-à-vis 13.479 for 7,5km.

Summary coverage

	n_added	distance_within	n_cov	pct_cov	n_not_cov	pct_not_cov
1	**149**	**5.000**	**11.948**	**0.8501**	**2.099**	**0.1499**

Table 2 – exp2 (*resources to be deployed based on optimal coverage with 149 resources and 5km distance*)

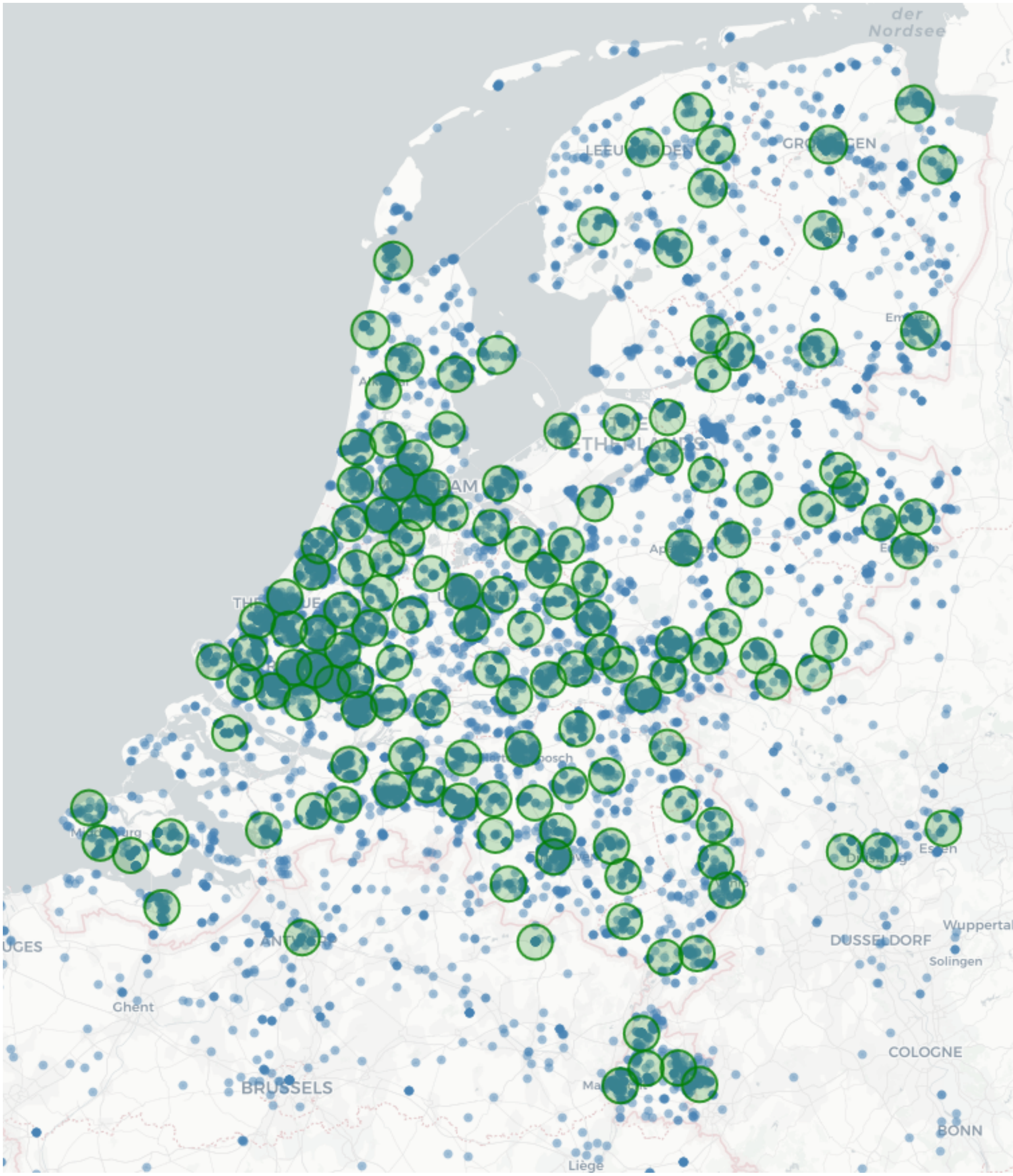


Illustration 3 – *exp2 (resources to be deployed based on optimal coverage with 149 resources and 5km distance)*

Exp3: sensitivity analysis extra resources

There is also the possibility to add more resources to increase the current coverage. The model is flexible; any number of inspectors (*j*) can be added. To show what happens when additional resources are available, we used the results of exp2, and added 10% resources. 10% of *j* (149) = 14,9 -> 15 extra resources. We choose 10%, because 10% growth of the current workforce is a realistic percentage. Therefore, in exp3, *j = 15* and is added to the original exp2 *j = 149*

Summary coverage

	n_added	distance_within	n_cov	pct_cov	n_not_cov	pct_not_cov
Exp2	149	5.000	11.948	0.8501	2.099	0.1499
Exp3	164(*149+15*)	5.000	12.206	0.8692	1.841	0.1308

Table 3 – exp3 (*resources to be deployed based on optimal coverage with 15 added resources*)

Exp3 shows that with the additional 15 inspectors, 1,91% more coverage is achieved, and 258 more inspections are performed at OTS vis-à-vis exp2. This data can be used when deciding if hiring extra inspectors is useful. In illustration 4 the results are visualized. Exp2 is plotted in the green circles and the extra 15 added resources (exp3) are plotted in the red circles.

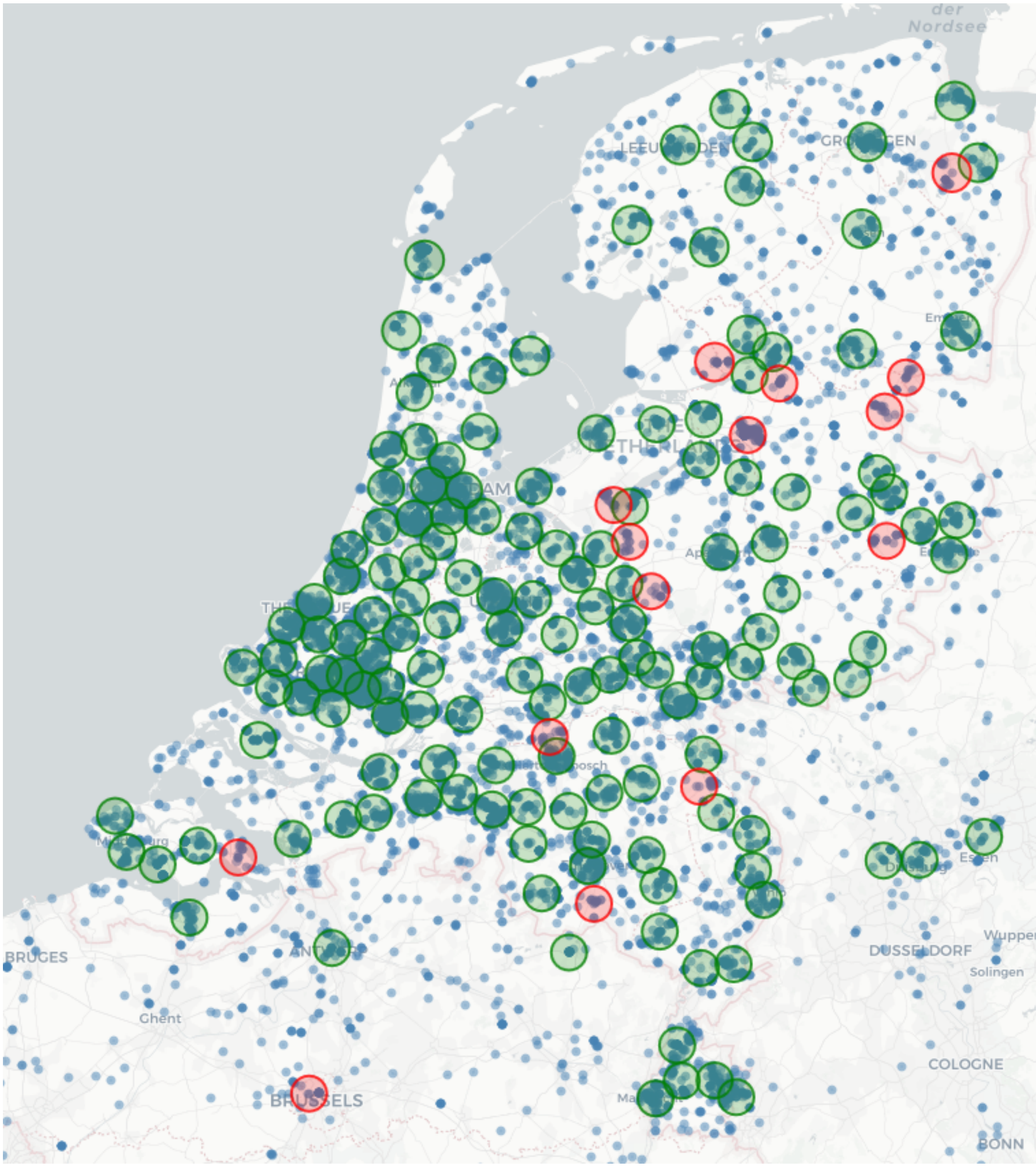


Illustration 4 – *exp3 (additional 15 resources for more coverage)*

In exp3 we added 15 extra resources on top of the already calculated deployment of resources. It could be interesting to see what happens if we recalculate the total of *j, 149 + 15 = 164* again in its totality. The decision maker could use this data to see if relocating existing deployed resources has impact on the coverage. This data can be useful when deciding *when* to deploy additional resources: in the middle of the year by adding the extra resources to the already calculated resources, or at the start of the year and calculate the new number of resources as one. For this extra experiment, epx3.1, we used total of 164 resources in the model.

Summary coverage

	n_added	distance_within	n_cov	pct_cov	n_not_cov	pct_not_cov
Exp3	149 + 15	5.000	12.206	0.8692	1.841	0.1308
Exp3.1	164	5.000	12.220	0.8701	1.827	0.1299

Table 4 – exp3.1 (*resources to be deployed based on optimal coverage recalculation with 164 resources*)

The data summary shows that when recalculating with all the 164 resources, there is a minimal increase in percentage coverage of 0,09. In this case, the advantage of redeploying all the resources is minimal, but, with larger numbers redeployment can be advantageous. Especially when focusing on a specific area. The results are visualized in illustration 5.

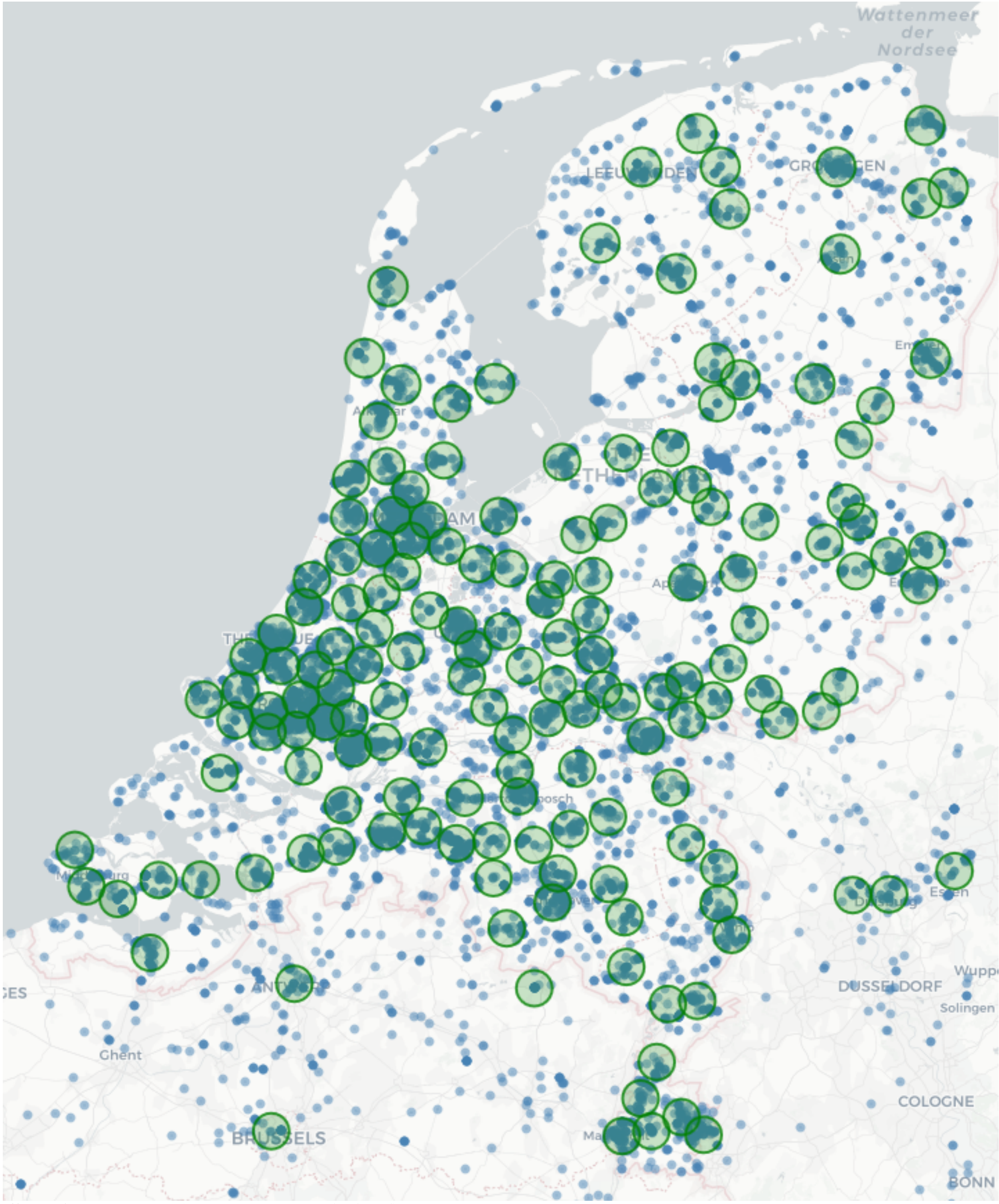


Illustration 5 – *exp3.1 (164 resources recalculated)*

For additional rationale when making a decision to add resources or to create insights about the current coverage, a graph which showing the percentage of coverage that can be created when adding or removing resources was visualized. This also adds to the transparency and accountability of the decision-making process. Illustration 6 shows the prediction of percentage coverage in relation to the available resources. This can be useful when there is need for more coverage and the amount of resources that is needed is not clear. Or when the central government asks: *how much do you need?*, this graphic can give additional insight about the current situation and the change in coverage when adding new resources. This graphic is based on the data from this research and it does not display the actual coverage of the ILT inspectors.

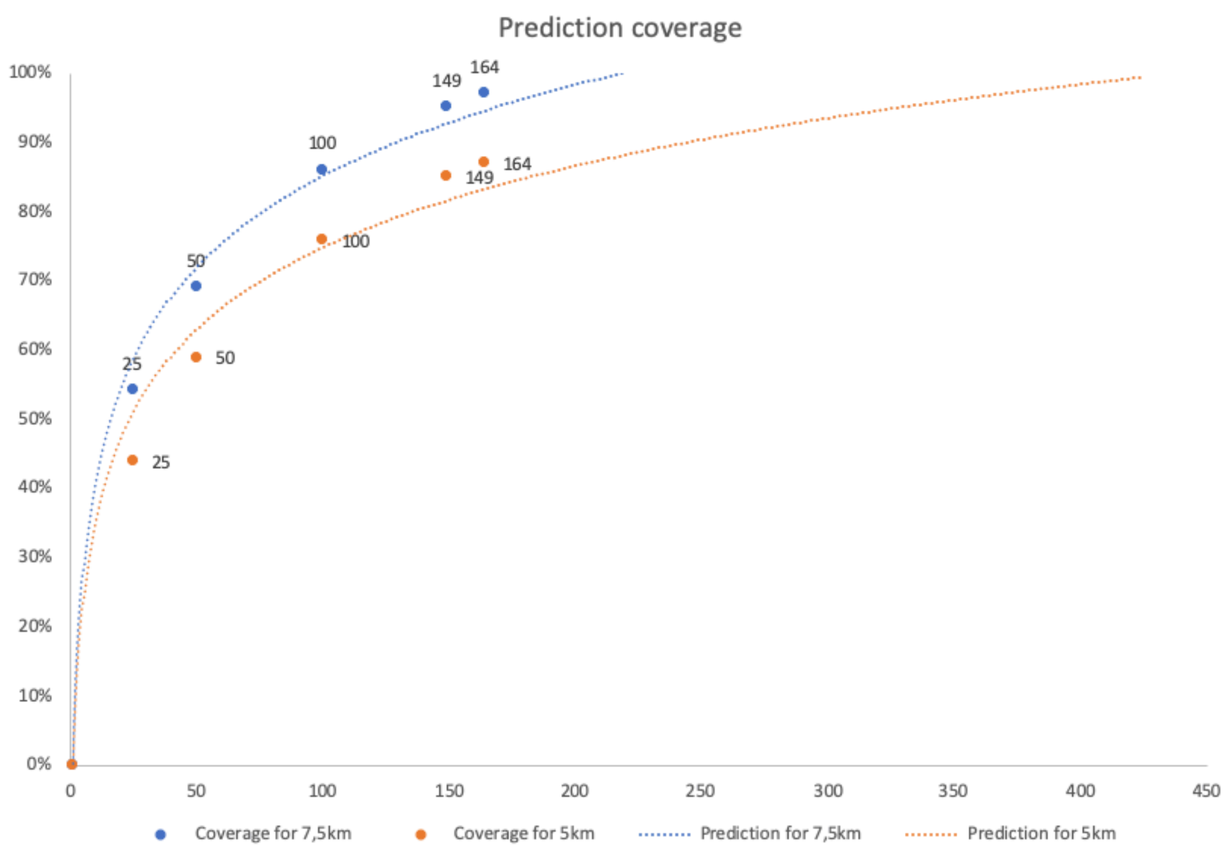


Illustration 6 – *Prediction coverage*

7. Conclusions

With this research we tried to answer the following research question: *How can the total risk coverage in a geographic area suitably inspected or visited be maximized by more efficiently deploying available resources?* To answer this question, we proceeded through the first three stages of the problem solving cycle.

R1. What are the root causes of the current business problem?

The root causes of the business problem (efficiency in deploying resources) are the supervisory paradox and the risk regulation reflex. Both causes have impact on the amount of available resources and the constant struggle to keep incidents from happening.

R2. What is the current performance of inspection planning?

What can be concluded is that:

1. There are inspections carried out.
2. The inspections are taking place spread across the Netherlands (and beyond),
3. and thus, there is a certain amount of coverage of in the Netherlands.

There is not much data available to analyze the current performance. This has to do with the unstructured way of working at the moment. Also, there is no available data with the locations of all the OTS in the Netherlands.

R3. What literature is available in the context of the business problem?

There are two types of literature available. The business literature (exploration of practice), based on research by government research facilities, and literature from the field of operations management (exploration of theory). The two sources of literature combined with desk research and company interviews confirms the problem and supports the proposed solution.

R4. What is the impact on performance of a more efficient planning related to coverage of risks?

The biggest impact is the creating of more accountability and transparency with the proposed solution. Besides those two advantages, more insight in the current performance and a structured way of deploying resources have an estimated performance increase in the efficiency of the coverage of risks. But data has to prove this. There is no valid way to measure the current performance against potential new performance, because of the new way of working.

R5. Which model(s) can be used to deploy the available resources more efficiently?

To deploy the resources more efficiently and create (more) accountability and transparency, the Maximal Covering Location Problem Model (MCLP) is used. MCLP is programmed in R programming language library (Max_covr) and is operationalized in the development environment of R. By using this model, performance can be measured based on the gathered data from the model. With the several data outputs as used in this research, the performance can be measured, and the results can be used in the one year administrative reporting cycle.

With the answered sub questions in this research, the main research question can be answered. The proposed solution makes it possible to give insight in the total risk coverage in an area and can determine how to create the most optimal coverage. The used model is capable of displaying current coverage, optimal coverage and can be used as a rationale when considering more or less resources. The proposed solution is a practical addition to the suggested new way of *prospective supervision* and adds a *transparent* and *accountable* way of more efficient resource deployment for Inspectorates.

8. Discussions and recommendations

The focus in this research is on efficiency in the deployment of resources in the context of supervision. This research treats all the supervision (inspections) performed by ILT the same. In practice, there is a difference in the subject of the supervision based on different domains (Rail, Aviation, Road, Environment). For every domain, there are specialized inspectors. Further research can be done on the efficiency of the combination of the different domains in relation to supervision. For instance, the possibility of cross domain training where one inspector can inspect multiple domains. (a train, the surroundings of the train and the truck that passes by). This can be done by creating different sets of *i*. Another possible efficiency gain can be found in optimizing the route the inspector takes in the area and the possible combination of multiple inspectors in one vehicle. This is a routing problem and can be a valuable addition to the proposed solution.

This research proposes a model to improve the accountability and transparency of the coverage of supervision by Inspectorates. It is an addition to the suggested new way of supervision, based on a combined retro- and prospective approach. Both the model and the approach have a relation with the *supervision process*, not the actual prioritization of risks in an area. Further research on how to determine what risk areas need focus (risk regulation reflex) based on gathered data (retrospective) and experiences on location (prospective) could be complementary to the proposed solution. This has a direct relation with and influence on the IBRA, which is the current ILT model for risk prioritization.

Furthermore, more research can be done on the measurement of the effect of the presence of an inspector on a location. In this research we use the work of Hawkings (1984) in the context of law enforcement. Future research can focus on the supervision context, possible in relation to the supervisory paradox, where being visible can have a positive influence on society, and or the risk regulation reflex, where increased supervision in a specific area might lower the risk.

Supervision consists of a few different tasks. In the proposed solution, only unplanned and one-sided planned inspections are in scope. In relation to efficiency, more research can be done concerning the other tasks an inspector has. For instance, the proposed model can be used to plan a percentage of work time of an inspector: unplanned and one-sided planned inspections. The remaining time can be spent on other tasks in relation to retro- and prospective supervision. For instance, doing thematic research to further enhance the quality of inspections. Besides the different tasks there is also the scenario where a geographical area has limited OTS vis-à-vis an area with a lot of OTS. The inspector in the low-density area (limited OTS), has more time to spend on other tasks then an inspector in a high- density area (a lot of OTS). The partitioning of tasks for the inspectors has the potential to further enhance the efficiency and the quality of supervision of the Inspectorate.

For the model to be used in the operation, functionality should be expanded. For instance, the possibility to adjust an area where the coverage needs to be calculated could be implemented. But also, a way to make different kinds of inspections in different domains. With added value, the coverage can be more detailed and specific for risk areas. Other functionality could be the implementation of more solvers and optimization of the R code to enhance the performance of the calculations. The creator of the R *max_covr* library made the code public for others to contribute. Besides the functionality, the performance of the model should be optimized. It takes approximately 8 hours to calculate a greenfield situation with the setup from this research (~14000 OTS and 700 inspectors) on the used computer system.

9. Limitations

There are a few limitations in this research. The first limitation is related to the implementation of the designed solution. There is a lot of resistance with the inspectors against every way of planning, loose or strict. This research focusses on the solution, makes recommendations about the implementation, but does not take into consideration how the resistance during the implementation stage with the inspectors can be lowered.

Second, there is the possible combination of an unannounced inspection, a planned audit and the granting of a permit. This combination might influence the amount of risk in an area. With an increase in planned audits, risk might decrease. Especially in combination with unannounced inspections. Further research on this combination and the impact on risk is advised.

Thirdly, the available data from ILT, which contains the locations of OTS, the amount of inspections and where the inspections have taken place is of poor quality. The dataset from 2018 was incomplete and not usable in the model. Besides the quality of the data, there are a lot of inspections carried out outside of the Netherlands. These inspections are outside the scope of this research, but the same solution can be used for those inspections. To counter the poor quality of the dataset, this research uses additional fake locations of OTS and an estimated amount of resources to prove the proper functioning of the model. To make the proposed solution valid in practice, ILT needs to organize a complete data set with at least the locations of the known OTS and the available inspectors.

Fourthly, in this research the focus is on efficiency in regard to the deployment of resources. The quality of the inspection, the way an inspector performs an inspection, is not part of this research. And, this research treats all supervision (inspections) performed by ILT as one. In practice, there is a difference in the subject of the supervision based on different domains (Rail, Aviation, Road, Environment). For every domain, there are specialized inspectors. This difference is not incorporated in the proposed solution.

Fifthly, in relation to the proposed solution, the designed model has a few limitations in functionality. There is for instance no way to calculate the coverage for a certain risk area. There is also no option to make a demarcation between the different sorts of inspections, what can be useful when further optimizing the efficiency. And, there is no input parameter to configure a constraint on the maximum inspections an inspector can perform.

Lastly, there are ten Inspectorates in the Netherlands. All the inspectorates supervise, but not all inspectorates supervise outside and thus do not require some form of geographical coverage. For instance, the AFM supervises mostly based on desk research and planned audits. They "follow the money" by supervision paper trails and processes. The proposed solution in this research is likely to not be valid for the AFM.

10. References

Berman O, Krass D (2002) The generalized maximal covering location problem. Computer Res 29:563–581

Church, R., & ReVELLE, C. (1974) The maximal covering location problem. Papers of the Regional Science Association, 18.

Beukenkamp, W. R. (2016). *Securing safety: Resilience time as a hidden critical factor* (Delft University of Technology). https://doi.org/10.4233/uuid:3dec02ac-c659-4741-980f-85619f2c4da6

Dell'Olmo, P., Ricciardi, N., & Sgalambro, A. (2014). A Multiperiod Maximal Covering Location Model for the Optimal Location of Intersection Safety Cameras on an Urban Traffic Network. *Procedia - Social and Behavioral Sciences*, *108*, 106–117. https://doi.org/10.1016/j.sbspro.2013.12.824

D.S. Hochbaum, Approximation Algorithms for NP-hard Problems, PWS Publishing Co., Boston, MA, USA, 1997.

Fazel Zarandi, M. H., Davari, S., & Haddad Sisakht, S. A. (2011). The large scale maximal covering location problem. *Scientia Iranica*, *18*(6), 1564–1570. https://doi.org/10.1016/j.scient.2011.11.008

Hutter, B. M. (1986). An inspector calls the importance of proactive enforcement in the regulatory context. British Journal of Criminology, 26(2), 114-128.

IBRA (2018), ILT-Brede Risico Analyse (IBRA) 2018

ILT (2018), Meerjarenplan 2019-2023 Inspectie Leefomgeving en Transport

Li, X., Zhao, Z., Zhu, X., & Wyatt, T. (2011). Covering models and optimization techniques for emergency response facility location and planning: a review. *Mathematical Methods of Operations Research*, *74*(3), 281–310. https://doi.org/10.1007/s00186-011-0363-4

NOS (2018). Retrieved from https://nos.nl/artikel/2238297-fipronilrapport-voedselveiligheid-stond-voor-niemand-voorop.html on 11 June 2019

NOS (2015). Retrieved from https://nos.nl/artikel/2065619-wat-mankeerde-er-aan-de-fyra-treinen.html on 11 June 2019

Onderzoeksraad van de Veiligheid (2019) *Opkomende voedselveiligheidsrisico's*. Den Haag

Parlementaire enquête Fyra(2015) *Parlementaire enquêtecommissie Fyra-rapport*. Den Haag Retrieved from https://www.tweedekamer.nl/sites/default/files/atoms/files/rapport_dereizigerindekou_enquetecommissiefyra_kst-33678-11.pdf on 3th of June 2019

Schinkelshoek, J., & Inspectieraad (Den Haag). (2016). *Toekomst van toezicht: een verkenning van wat nodig is*.

Tierney, N. J., Reinhold, H. J., Mira, A., Weiser, M., Burkart, R., Benvenuti, C., & Auricchio, A. (2018). Novel relocation methods for automatic external defibrillator improve out-of-hospital cardiac arrest coverage under limited resources. *Resuscitation*, *125*, 83–89. https://doi.org/10.1016/j.resuscitation.2018.01.055

Tierney, NJ (2018). Retrieved from https://github.com/njtierney/maxcovr/ on 2nd June 2019

Toregas, C., Swain, R., ReVelle, C., & Bergman, L. (1971). The Location of Emergency Service Facilities. *Operations Research*, *19*(6), 1363–1373. https://doi.org/10.1287/opre.19.6.1363

Wetenschappelijke Raad voor het Regeringsbeleid (Ed.). (2013). *Toezien op publieke belangen: naar een verruimd perspectief op rijkstoezicht*. Amsterdam: Amsterdam University Press.

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering - EASE ’14 (pp. 1–10). London, England, United Kingdom: ACM Press.

van Aken, J. E., & Berends, H., & van der Bij, H. (2012). Problem solving in organizations Cambridge, United Kingdom: Cambridge University Press.

11. Appendix

R-code max_covr

```
library(maxcovr)
library(dplyr)
library(leaflet)

leaflet() %>%
  addCircleMarkers(data = data_ilt_ots,
                   radius = 1,
                   color = "steelblue") %>%
  addCircles(data = data_ilt_inspector_new_5km,
             radius = 5000,
             stroke = TRUE,
             fill = NULL,
             opacity = 0.8,
             weight = 2,
             color = "green") %>%

  addCircles(data = data_ilt_inspector_new_5km_15,
             radius = 5000,
             stroke = TRUE,
           fill = NULL,
            opacity = 0.8,
            weight = 2,
            color = "red") %>%

  addProviderTiles("CartoDB.Positron") %>%

  setView(lng = median(data_ilt_ots$long),
          lat = median(data_ilt_ots$lat),
          zoom = 5)



library(maxcovr)
# {r show-time-taken-maxcovr}
# {exitsting= now, proposed= new, user= is current proposed=same as user}
system.time(


  mc_5_15 <- max_coverage(existing_facility = data_ilt_inspector_new_5km,
                          proposed_facility = data_ilt_ots,
                          user = data_ilt_ots,
                          n_added =15,
                          distance_cutoff = 5000)
)


data_ilt_inspector_new_5km <- bind_rows(mc_5$facility_selected)

data_ilt_inspector_new_5km_16 <- bind_rows(mc_5_16$facility_selected)

names(mc_20)

library(purrr)
n_add_vec <- c(5, 10, 15, 20, 25)

system.time(
  map_mc_model <- map_df(.x = n_add_vec,
                          .f = ~max_coverage(existing_facility = ilt_data_ots,
                                             proposed_facility = ilt_data_insp
                                             user = ilt_data_ots,
                                             distance_cutoff = 100,
                                             n_added = .))
)

map_cov_results <- bind_rows(map_mc_model$model_coverage)

library(ggplot2)
bind_rows(map_mc_model$existing_coverage[[1]],
          map_cov_results) %>%
  ggplot(aes(x = factor(n_added),
             y = pct_cov)) +
  geom_point() +
  geom_line(group = 1) +
  theme_minimal()
```

Code exp1

<u>Code</u>

```
library(maxcovr)
# {r show-time-taken-maxcovr}
# {existing= now, proposed= new, user= is current proposed=same as user}
system.time(
  mc_148 <- max_coverage(existing_facility = data_ilt_inspector_1,
                         proposed_facility = data_ilt_ots,
                         user = data_ilt_ots,
                         n_added =148,
                         distance_cutoff = 7.500)
)
```

<u>Runtime</u>

User	System	Elapsed
13070.88	47.03	13118.14

Code exp2

<u>Code</u>

```
library(maxcovr)
# {r show-time-taken-maxcovr}
# {existing= now, proposed= new, user= is current proposed=same as user}
system.time(
  mc_001 <- max_coverage(existing_facility = data_ilt_inspector_1,
                         proposed_facility = data_ilt_ots,
                         user = data_ilt_ots,
                         n_added =148,
                         distance_cutoff = 5000) <- adjusted distance to 5km
)
```

<u>Runtime</u>

User	System	Elapsed
37646.84	188.09	37846.08

Code exp3

<u>Code</u>

```
library(maxcovr)
# {r show-time-taken-maxcovr}
# {existing= now, proposed= new, user= is current proposed=same as user}
system.time(
  mc_002 <- max_coverage(existing_facility = data_ilt_inspector_new_5km, <- using results of sim2
                         proposed_facility = data_ilt_ots,
                         user = data_ilt_ots,
                         n_added = 15, <- added 15 inspectors
                         distance_cutoff = 7.500)
)
```

<u>Runtime</u>

User	System	Elapsed
6.89	0.27	7.18

Code exp3.1

Code

```
library(maxcovr)

# {r show-time-taken-maxcovr}

# {existing= now, proposed= new, user= is current proposed=same as user}

system.time(

  mc_002 <- max_coverage(existing_facility = data_ilt_inspector_1,

                         proposed_facility = data_ilt_ots,

                         user = data_ilt_ots,

                         n_added = 163, <- recalculation of exp3 with 164 resources

                         distance_cutoff = 7.500)

)
```

Runtime

User	System	Elapsed
14702.11	81.25	14803.39