Inter Terminal Transport

Captured in an ontology

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Preface:

I am at the end of my years as a student at the Technical University, Delft, and it is time to graduate. It seems like yesterday that I started the bachelor at the faculty of Technology, Policy and Management. After completing my bachelor I volunteered for a year of board duty at the Solar Boat Team associated with the university. At the end of this inspiring year, it was time to start my Masters. After careful consideration I decided to take the Masters in Transport, Infrastructure and Logistics, which is offered jointly by three faculties:

1. Civil Engineering and Geosciences
2. Mechanical, Maritime and Materials engineering
3. Technology Policy and Management

The end of this Masters programme is like all others. A final task needs to be accomplished, namely, the MSc thesis. At first, it was hard for me to find a subject I was willing to undertake. I eventually started under Dr. J.H.R. van Duin, on the subject of Inter-Terminal Transport Ontology.

My thesis committee consists of the following four TU Delft faculty members:

- Dr. J.H.R. van Duin
- Dr.ir. R.M. Stikkelman
- Prof.dr.ir. L.A. Tavasszy
- Dr.ir. H.P.M. Veeke

Thanks to the guidance I received from these committee members, and additional counselling from TNO’s Bakia Bakia, MSc and Laura Danielle, Ph.D., I was able to develop the ontology to the form I present in this thesis.

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Summary

This report is about the transportation of containers between terminals within a port region, from now on, Inter Terminal Transport (ITT). Within the ITT domain, two kinds of issues are considered: the functional issues and the stakeholder issues. The differentiation between functional issues and stakeholder issues may easily be made on paper, but is difficult to achieve simultaneously. The reality is that functional issues and stakeholder issues need to be tackled at the same time to make a difference. Perspective is important.

However, irrespective of perspective, aspects of functional issues and stakeholder issues are intertwined. For a better understanding of the situation an ontology might help. At least if that ontology is able to create clarity in the intertwined mesh of stakeholder and functional issues. This can be formulated in the following Research Goal:

Develop an ontology that is able to depict the inter terminal logistics in a functional way, and that is constructed in such a way that it can also be used in the analysis of multi stakeholder problems.

By developing this ontology several purposes can be served. The ontology can be applied to:

1. Integrating the functional and stakeholder descriptions in ITT: Creating clarity in the mesh of stakeholders and functions
2. Assisting in the development of new ITT alternatives: Providing information and alternatives so that the development process can take place fluently. The ontology can also serve as checklist to see if all alternatives are considered.
3. Acting as a source for the representation of ITT knowledge: The ontology can represent knowledge of the ITT domain so that a person who is interested in a part of the domain can find the knowledge he needs without needing a lot of background knowledge of the domain.
4. Assisting in the validation of Agent Based Models for ITT: In recent years, Agent Based Models are increasingly used in Transport and Logistics (Yang, 2011). The added value of the ITT ontology is that it can become a standard for validation, or be the basis of one, contributing to the development of Agent Based Models for ITT.

While the ontology can add value to all these aspects, it also knows limitations. The ontology is developed for the ITT domain and is not intended to be used outside this domain. This ITT ontology considers only transportation; storage is not included. However, in the future, storage can be implemented into the ontology. It is left out because it was only considered in a later stage of the development of the ontology. Due to the limited amount of time available the choice was made to develop the ontology as it was first intended. Including storage now comes in as a recommendation for expansion. Within this design a certain lay out is followed. To create clarity in the mesh of intertwined stakeholders and functional issues. Both sides have to be represented in detail by the ontology. They can be seen as the first two branches of the ontology, the third represents the tangible aspects like containers, terminals and modes. These aspects are present and part of the complex situation, but only because their owned or needed. They do not form an issue by themselves.

The functional branch is build out of multiple aspects: Mode, Information, Connection, Container. Container is needed as it is the aspect that needs movement. The facilitating of this demand is the
purpose of ITT. In order to move containers they have to be transported by a mode. This mode requires a connection to be able to operate. If the mode is road, it needs a road connection. If the mode is waterborne it needs a water connection. To ensure that the demanded transport takes place on the demanded time, information is needed. Therefore, information also deserves a spot in the ontology.

The stakeholder branch has multiple high level stakeholders

1) Customer: Willing to purchase services because it cannot fulfil its own needs.
2) Mode Operator: Different operators operate different modes
3) Supervision: Ensure smooth operation, fix errors
   a) Chain supervision,
   b) Customs
   c) Overall Supervision
4) Terminal Operator: Different terminal operators operate different terminals.

The customer-stakeholder can be found throughout the ITT system. All stakeholders can become customer if their possibilities do not match their needs. In that case they need to purchase the services they need. These services can be bought by mode operators, (facilitating the mode for the transport) and/or by terminal operators (access to connections and therefore to the mode that requires that connection) The supervision is in place to ensure rules and regulations are followed (overall supervision), no illegal activities like smuggling take place (customs) and to optimise the transportation process (Chain supervision)

The stakeholder, mode operator, is connected to the functional aspect. The stakeholder terminals operator is connected to the functional aspect mode. So many more connections are present in the ITT domain. These relations are taken up in the ontology. To check if the ontology is complete, validation is required.

The first version of the ontology is validated by means of Port Vison 2030. The outcomes of this validation round were used to expand the ontology, improving the coverage of the domain. As a second validation report, Combiroad (Connext, n.d.) is used. This report was far more detailed than the ontology. It could be used to increase the detail of the ontology, but that carries the risk of designing the ontology towards Combiroad. Even if the detail in the Combiroad report is not matched in the ontology than the validation with Combiroad shows that the ontology missed out on the aspects that contribute to the technical development. So, it is recommended to implement the aspects for technical development in the ontology. The last validation round used a wordle of the report by (Diekman & Koeman, 2010). This is the same report where the construction of the ontology is founded upon. By using a wordle, the developer can check if the right aspects in the report were given priority. If an aspect is important for the wordle it should also be important in the ontology. This validation showed that all the relevant aspects mentioned in the report by Diekman & Koeman are implemented in the ontology.

The validation shows that the ontology seems to be complete except for the technical development. Implementing this development is recommended. The ontology is ready to add value to the four different purposes. Using the ontology will show flaws, however these can be fixed. Increasing use will lead to an increase of usability and a higher coverage rate of the domain.
Samenvatting Nederlands

Dit rapport gaat over het transport van containers tussen de verschillende terminals in een havengebied. Dit Inter Terminal Transport zal van nu af aan worden aangeduid als ITT. Binnen het ITT domein zijn er twee soorten zaken die meewegen. De functionele zaken en de stakeholders zaken. Het onderscheiden van deze twee zaken is op papier makkelijk te maken maar tegelijkertijd moeilijk om te realiseren. De realiteit is dat beide zaken tegelijkertijd dienen te worden aangepakt om een verschil te kunnen maken. De keuze van perspectief is ook belangrijk.

Echter ongeacht het gekozen perspectief blijft het zo dat de stakeholder en functionele zaken verwezen zijn. Voor een beter begrip van deze situatie zou een ontologie kunnen helpen. Tenminste als de ontologie er in slaagt om de complexe situatie van verweven zaken te verhelderen. Dit doel kan als volgt worden verwoord:

Het ontwikkelen van een ontologie die de inter-terminal logistiek helder kan weergeven en die op zo een manier is samengesteld dat het ook gebruik kan worden voor de analyse van multi stakeholder problemen.

Door het ontwikkelen van de ontologie kunnen de volgende doelen worden gediend:

1. Het integreren van stakeholder beschrijvingen en functionele beschrijvingen van het ITT domein. Dit resulteert in een duidelijker beeld aangaande de verweven stakeholders en functies.
2. Assisteren bij de ontwikkeling van nieuwe ITT alternatieven: De ontologie kan informatie en alternatieven aanbieden voor het ontwikkelingsproces. Ook kan de ontologie worden gebruikt om te controleren of alle alternatieven zijn overwogen.
3. Dienen als een bron voor de representatie cab ITT kennis. De ontologie kan kennis vertrekken aan personen die daarin geïnteresseerd zijn zonder dat de geïnteresseerde persoon achtergrond kennis van het domein nodig heeft.
4. Assisteren in de validatie van Agent Based Models voor ITT. In de afgelopen jaren worden Agent Based Models in toenemende mate gebruikt met betrekking tot transport en logistiek (Yang, 2011). De toegevoegde waarde van de ITT ontologie is dat het een standaard kan worden voor de analyse van multi stakeholder problemen.

Zojuist zijn de punten aangegeven waar de ontologie waarde kan toevoegen echter het heft ook zo zijn beperkingen. De ontologie is ontwikkeld voor het ITT domein en is dan ook niet bedoeld om buiten dit domein gebruikt te worden. De ontologie beschouwd het transport van ITT opslag is uitgesloten. Echter in de toekomst kan opslag nog worden geïmplementeerd in de ontologie. In het begin van de ontwikkeling van de ontologie was er nog geen sprake van opslag binnen het ITT systeem, tegen de tijd dat het ter spraken kwam was er geen tijd meer beschikbaar om deze toevoeging te implementeren. Het toevoegen van opslag word meegenomen als aanbeveling. Tijdens de ontwikkeling van de ontologie is het doel vast gehouden om helderheid te scheppen in de complexiteit van de in elkaar geweven stakeholder en functionele zaken. Beide dienen in detail te worden geregisteerd in de ontologie. Ze kunnen worden gezien als de eerste twee takken van de ontologie. De derde tak wordt gevormd door tastbare zaken zoals containers, terminals en
modaliteiten. Deze tastbare dingen zijn onderdeel van de complexe situatie maar alleen omdat ze eigendom zijn of nodig zijn. Ze verhogen de complexiteit niet uit zichzelf.

De functionele tak is opgebouwd uit meerdere delen: modaliteit, informatie, verbinding en container. Containers moeten worden opgenomen in de ontologie omdat containers de producten zijn die de behoefte heeft aan transport. Het voldoen aan deze behoefte is het doel van ITT. Om containers te kunnen verplaatsen is er een modaliteit nodig. Deze modaliteit heeft weer een verbinding nodig zodat om te kunnen functioneren. Als de modaliteit op de weg opereert heeft het een weg verbinding nodig. Als de modaliteit op het water opereert heeft het een water verbinding nodig. Om er zorg voor te dragen dat het transport plaatsvind op de juiste tijd is er informatie nodig. Dus ook informatie verdient een plek in de ontologie.

De stakeholder tak heeft meerdere stakeholder op een hoog niveau.

5) Customer: Bereid services te kopen die de stakeholder zelf niet kan vervullen.
7) Supervision: Zorg dragen voor een soepele operatie en het herstellen van fouten.
   a) Chain supervision,
   b) Customs
   c) Overall Supervision
8) Terminal Operator: Verschillende terminal beheerders beheren verschillende terminals.

De klant-stakeholder kan teruggevonden door het gehele ITT systeem. Alle stakeholders kunnen klant worden als hun mogelijkheden niet in overeenstemming zijn met hun behoeftes. Als dit het geval is moeten ze de diensten kopen om hun behoeftes te vervullen. Deze diensten kunnen gekocht worden bij mode operators (faciliteren van de modaliteiten voor het transport) en/of bij terminal operators (toegang tot verbindingen en daardoor tot de modaliteit die deze verbindingen nodig heeft). De supervision is nodig om na te gaan dat de regels en wetgeving worden nageleefd (overall supervision), dat er geen illegale activiteiten plaatsvinden (customs) en om het transport proces te optimaliseren (Chain supervision)

De mode operator is gekoppeld aan de functionele zaken. De stakeholder terminal operator is gekoppeld aan de functionaliteit modaliteit. En nog veel meer verbindingen zijn aanwezig in het ITT domein. Deze relaties zijn opgenomen in de ontologie. Om de ontologie te controleren is validatie vereist.

De eerste versie van de ontologie is gevalideerd middels Port Vision 2030. De uitkomsten van deze validatie ronden worden gebruikt om de ontologie uit te bereiden en het verbeteren van de dekkingsgraad van het domein. Als tweede validatie rapport is Combroad (Connekct, n.d.) gebruikt. Dit rapport bevat meer detail dan de ontologie en zou kunnen worden gebruikt om het detail van de ontologie te verhogen. Maar dit draagt het risico in zicht dat de ontologie zich richt naar het rapport. Als de details niet worden ingevoegd dan geeft het rapport ook nog aan dat de ontologie te weinig informatie bevat aangaande de technische ontwikkeling. Daarom is het een aanbeveling deze technische aspecten alsnog in te voegen in de ontologie.

Verder is voor de validatie nog een wordt gebruikt voor een analyse van het rapport van (Diekman & Koeman, 2010). Dit is hetzelfde rapport waarop de eerste versie van de ontologie was gebouwd.
Door het gebruik van de wordle kan de ontwikkelaar controleren of de juiste aspecten van het rapport prioriteit hebben gekregen. Als een aspect van belang is in de wordl zou het ook van belang moeten zijn in de ontologie. Deze validatie slag toonde aan dat dit het geval is voor de ITT ontologie.

De validatie toont aan dat de ontologie compleet lijkt met uitzondering van de technische ontwikkeling. Deze alsnog implementeren is aanbevolen. The ontologie is klaar om waarde toe te voegen aan de vier doelen die eerder in de samenvatting zijn benoemd. Door het gebruik van de ontologie zullen fouten aan het licht komen, maar deze kunnen worden gerepareerd. Een toename in gebruik zal leiden tot een toename van gebruiksmogelijkheden en een betere dekkingsgraad van het domein.
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1 Introduction
The goal of this chapter is to provide some general information on ports, on the concept of an ontology and on Inter Terminal Transport. This information is required to establish the current situation and to find out why the problem is relevant. Once these concepts have been introduced, the research goal and the methodology chosen for the thesis will follow.

1.1 Ports and terminals
Ports have been around for ages. Their function has remained as access points for long distance trade. For millennia, the business at a port has all been rather straightforward. A vessel might call onto a port, the port would allocate a spot on the quay to the vessel and the workforce would start to unload or load the goods. Although these processes have increased in complexity over the years, they still are the basic building blocks of port activity, at least when referring to the port side. On the land side things are getting more complicated with every innovation. Ports are shifting from gateways to logistic hubs, becoming critical nodes in the supply chain. (Pettit & Beresford, 2009). An increasing number of companies are willing to invest in a location in the port or terminal domain. As a result, the number of activities within a port or terminal increases rapidly and the area required for these activities increases as well. As long as space is available, there is no problem for expansion. However, when space runs out, it is up to the port authority to develop a master plan that makes sure that the port can maintain itself and preferably keep on growing in the years to come.

Developing this master plan is challenging. Ports and terminals are situated in a nation and therefore are obliged to operate within the borders that are stated by the government of that nation. Another situation a port or terminal may face is fierce competition from other ports or terminals wanting to take over their trade. There are models available that calculate the effect on market share of some decisions that ports make. (Tavasszy, et al., 2011) (Zondag, et al., 2010). Although such models are still under development, they already show that market share seems to depend on the policy that a port or terminal adopts for its business, on its maritime access, its efficiency and on its inland connections. An ontology contributes knowledge about stakeholders and functions that are needed to develop such a policy within the domain of Inter Terminal Transport (ITT)

1.2 Problem statement
Inter terminal transport facilitates the transport of containers between terminals. The loading and unloading at the mode that facilitates the transport (rail, road or inland waterway) is assumed to be done by terminal equipment.

The demand for Inter terminal transport will increase in size and importance with the increase of containerised transportation. How to deal with this increased demand is not yet clear. A larger flow of containers will have an impact on the functional operations that take place to facilitate ITT (Taneja, et al., 2010). In the current situation the number of containers that arrive at the terminals and the number of containers that the terminals are a able to process are a match. However if the amount of containers that arrive keeps increasing the time will come that the processing capacity will no longer be sufficient. Although changes on the individual way of operating may result in some improvement, cooperation hold options for larger improvements. In order to cooperate the involved stakeholders have to invest in cooperation, admit they can or cannot do certain tasks and have to be willing to invite additional stakeholders if their combined possibilities are not yet able to meet the expected increase in demand. But to know what is needed, one must know what is present. In other
words a system description is required that includes the stakeholder concerns as well as the functional properties of the domain, both are intertwined. There are different possibilities to formulate this description and from this possibilities the ontology is chosen. To help understand this complexity situation the ontology is developed for, an example:

1.2.1 Possible situation:
A stakeholder X wants to transport a container in the port of Rotterdam from a terminal A to a terminal B using Inter Terminal Transport (ITT). The container is temporarily stored in a stack, waiting to be collected by a stakeholder Y in order to be transhipped onto a suitable mode of transport. Possible modes of transport are Road, Rail and Inland Waterway. To select a suitable transport mode, the stakeholder X has to provide information about the time the container has to start its journey (Time of departure) and the time the container should be at its destination (Time of arrival). Based on this information, some transport modes can already be discarded. For example, water transport will take longer than rail or road, and so water transport will be less suitable if the requested time interval between departure and arrival is short. Moreover, the selection of a suitable transport mode depends on the connections that are supported in the terminal of departure and in the terminal of arrival. For example, if terminal B, which is the destination of the container, does not support water transport connection type, then only road and rail transport will be considered as possible modes of transport. Once a suitable transport mode for the container is selected, a stakeholder Y that can fulfil the requirements will place an order for the terminal to move the container from the stack to the selected mode that will perform the transport. Since the activities that take place in the port are related to import and export of goods, customs are included in the activities. The moment the container enters the Netherlands, it needs to be cleared at customs. The location of the border can be shifted somewhat by means of regulations. However, any container movement across the border into the country qualifies for clearance by customs. This can also be seen as movement between terminals.

From this scenario, it becomes clear that the transport is initiated by a stakeholder, that the area where the containers are waiting is owned by a stakeholder and that the different modes represent different stakeholders. Furthermore, we may conclude that the different connection types have to be installed and maintained by stakeholders. Finally, Customs also comes forward as a stakeholder. Furthermore the example also contains functions that have to be prefored. It shows stakeholders cannot perform activities without functions. And that functions need stakeholders to perform them.

1.3 Ontology
An ontology can be built in many ways (Batemant, 1995). Some articles help determine the way to go (Noy & McGuinness, 2001) (Uschold & Gruninger, 1996) and some only provide background information about alternative ways to construct an ontology (Park, et al., 2008) (Yu & Hsu, 2011). For the development of the ITT ontology the definition by Guarino is taken as basis.

1.3.1 General definition of the ontology
"An ontology is a logical theory accounting for the intended meaning of a formal vocabulary, i.e. its ontological commitment to a particular conceptualization of the world. The intended models of a logical language using such a vocabulary are constrained by its ontological commitment. An ontology indirectly reflects this commitment (and the underlying conceptualization) by approximating these intended models." (Guarino, 1998)
In the same paper, a distinction is made between top-level ontologies, domain ontologies, task ontologies and application ontologies. When an ontology is mentioned in this thesis, the reference is to the domain ontology. The domain that will be described is Inter Terminal Transport (ITT).

1.3.2 Ontology for the ITT domain

An ontology is ranked in several layers (hierarchies). Each lower layer inherits the attributes defined in the corresponding higher layer. These can be physical attributes, or relations with other instances. An ontology can be kept fairly general (Hui, et al., 2007) or be made extremely detailed. Either way, one should keep in mind that it might become difficult to link all the different parties, materials, handling equipment, etc. involved (Jenkins & Welty, 1999). A large part of the added value of an ontology is usually captured in a relational database. If an ontology could be linked to problem solving methods, it would lead to active databases. (A.G. Perez, 1999)

The possibility of an ontology to depict relations in a clear manner makes it suited for the task of generating insight into the complex mesh of intertwined stakeholders and functions. Figure 1 shows that stakeholders as well as functions can partly be described on their own. However in the middle of the figure there is a green area. In this area the stakeholders and functions are so intertwined that one can speak of a complex situation. The ontology manages this complexity. It can clearly show the interrelation between Stakeholders and Functions. To place the intertwined area within context, the ontology takes up the Stakeholders and Functions separately as well.

![Diagram of intertwined stakeholders and functions](image)

Figure 1: Intertwined stakeholders and functions

1.4 Research goal

The goal of the thesis is to develop an ontology that is able to depict the inter terminal logistics in a functional way. The ontology is constructed in such a way that it is also suitable for the analysis of multi-stakeholder problems.

To realise this goal, the following research questions need to be answered:

1. What parts are included and what parts excluded for the ITT domain?
2. What are the functions in the ITT system?
3. What stakeholders are present in the ITT system?
4. To what criteria should the ontology comply?
5. What aspects should be taken up in the ontology?
6. How should the ontology be constructed?
7. How will the ontology be validated?

What parts are included and what parts are excluded for the ITT domain
With regard to the development of an ontology it is important to know what the ontology has to cover and what may be left out. Once the construction of the ontology has started, it is tempting to see all kinds of relations and to add these relations to the ontology. However the added value of the ontology is to create clarity in a complex situation. This clarity does not prosper with many side relations that, although they do exist, do not contribute to the domain the ontology is to describe.

Answering this sub question helps to determine whether or not a relation/ entity should be taken up in the ontology, or that it may be left out because it does not fit within the scope.

What are the functions in the ITT system
To be able to construct an ontology for the ITT domain, it is good to identify all the functions that are part of the ITT domain. In the introduction, the differentiation between functional and stakeholder concerns in the ITT domain has been introduced. Due to this differentiation the issues that are relevant for the ITT are also identified in two phases. This question only deals with the functions that can be identified within the ITT system.

Answering this sub question results in a list of building blocks with regard to functions that have a place within the ITT domain. This list can then be used as input to represent the functional part of the ITT system in the ontology.

What stakeholders are present in the ITT system
The previous sub question is about identifying the functions of the ITT system. This sub question has the same intention. However, it is oriented towards the stakeholders that have a roll within the ITT domain. It is important to know the stakeholders involved because they are intertwined with functions. The fact that these stakeholders are intertwined with these functions is what results in a complex situation. All stakeholders are needed, to enable understanding of the situation and creating clarity amidst the complexity.

Answering this sub question results in a list of stakeholders that have a place within the ITT domain. This list can then be used as input to represent the stakeholders of the ITT system in the ontology.

To what criteria should the ontology comply
In the introduction, three different ways were mentioned how the ontology can add value: During the design phase of new alternatives, As a source for knowledge regarding ITT and to assist in the validation of Agent Based Models. To add value, the ontology has to be able to provide the information that is needed by these activities. The different activities have a need for different information that will result in different criteria.

Answering this sub question results in a list of criteria that ensures that all three goals can be achieved. This list will be compiled out of the criteria that flow from the different goals. The list of criteria can be used to check if the ontology is complete and capable of adding value.

What aspects should be taken up in the ontology
Before construction of the ontology can commence, an additional check is required. For the aspects that have been identified in previous parts of this thesis, the following question is asked: what is
known about these aspects, and is this enough or should information be added that lies one level deeper? By asking this question for all aspects and adding information, where needed, the ontology will gain in richness.

**How should the ontology be constructed**
All the information that is acquired by means of the previous sub questions needs to be integrated in the ontology. How is this to be done? The ontology will start as a single class that forms the highest hierarchy. From this high-level hierarchy downward, differentiation between classes will occur and attributes will be inherited. The ontology will list all the knowledge available in a clear and compact picture.

Answering this sub question will result in a clear approach to how the ontology is built, and explain the way the different classes within the ontology are interconnected.

**How will the ontology be validated**
The ontology contains knowledge and this knowledge needs to be validated. How can this be done, what methods of validation might apply? And what is known after validation has taken place? Different kinds of validation will be run on the ITT system ontology. The validation will be based on multiple documents that cover (parts) of the same domain. The validation will be enriched with additional information from the differences between these methods. Answering this sub question results in clear a description of how the ontology is to be validated, and the results of this validation.
1.5 Methodology

The development of an ontology is a highly interdisciplinary activity (Guarino, 1998). Therefore the methodology should embrace the variety of relevant suggestions from the different disciplines.

Also, ontology development is necessarily an iterative process, and there is no single correct way to construct an ontology. (Noy & McGuinness, 2001) Therefore the methodology used should hold the option for iterative processes, and allow for differences from researcher to researcher. From the methodology suggested in the same paper the following figure can be drawn:

![Figure 2: Methodology as suggested by Noy & McGuinness](image)

When this suggested methodology is looked upon critically, some additions are necessary. First, the problem should be analysed. What is the problem, and why is it a problem? What are causes? After the analysis, the problem has to be defined. This definition may help to explain the added value of an ontology. This problem statement, together with the explanation of the added value of the ontology, justify the development of the ontology as a research goal.

From this point onward, the methodology as suggested by (Noy & McGuinness, 2001) can be used. Although it is slightly adapted to fit the requirements of the ITT system developed in this thesis. (See Figure 3).

Thus, there will be no step involving reuse of existing ontologies, as we have none. It is important for our purposes that the ontology be constructed from the ground up, so that the developer’s understanding of the domain can grow together with the ontology.

To be able to enumerate the important terms in the ontology, they have to be known. These important terms are determined from a description of the functions of the ITT system and from an analysis of the stakeholders. So we depart slightly from Noy & McGuinness’s enumeration of important terms to a description of the functions and stakeholder analysis. The remaining steps are then combined together as sub-steps in the explanation of the ontology.

After these steps have been completed, the validation of the ontology is added, as well as the conclusions, recommendation and reflection.
Figure 3: Methodology as used

Build up report

Within a port region competition takes place on multiple levels. It requires careful planning to make sure that a port region can hold on to, let alone expand, its market position while keeping its customers satisfied. One of the things that might help is an ITT system. However such a ITT system has functions and stakeholders that are intertwined. An ontology helps to understand this complex situation since it is able to show the complex relations between the functions and stakeholders.

The methodology introduces the different steps that are taken to develop the ontology. The report is built out of chapters that match the methodology. In Chapter 2, the problem is analysed and in chapter 3 the problem is defined. Following the definition in chapter 3, the different ways in which the ontology can add value are explained.

Chapter 4 is all about the ITT domain. It states the limitations of the ontology and its development. Chapter 5 describes the ITT system for the functional issues as well as for the stakeholder issues. In chapter 6, the different stages of ontology development are explained. Chapter 7 contains information about the validation process and the suggested way to maintain the ontology. The last chapter, chapter 8, presents the conclusions.
2 Problem analysis
Within ITT, two parts are analysed. In the first part of this chapter, the focus will be on the functional problems. In the second part, the focus will be on the stakeholders and the conflicts that can occur between them. Both parts can provide detailed information. However, such information is sometimes hard to access. And connections between the stakeholder and functional details can be hard to realise. This chapter examines some of the reasons for these difficulties.

2.1 Problems in the ITT domain
Within the domain of ITT, six different general problems are encountered. The following structure will be used in discussing them. First, the problem is described. Then the cause of the problem is given (if it is known). At the end of each sub part, the possible consequences of not tackling the problem are given.

2.1.1 Demand for ITT increases, a new solution might be cheaper
The amount of containers that are transported globally is expected to grow. (de Graaf, 2011) Even when the market share of a port stays the same, it still has more containers to cope with. Since not all processes can take place in one location, due to space limitations (Thijs, et al., 2000), the need for Inter Terminal Transport will rise as well. As more containers are moved between terminals, larger and larger investments are required to make these movements possible. When the investment involved has reached the point where an alternative method of transportation becomes economically interesting, it is beneficial for all parties involved to use a new form of ITT to save money. (Port of Rotterdam Authority, 2011)

2.1.2 Space is limited
Within the area of a port the amount of space that is available is limited and expensive (Baird, 1999) Different types of companies have different demands for the space they operate in. Deep sea terminals, for instance, must have access to deep sea quays to be able to operate. Rail Service centres, on the other hand, do not have this need. However, they cannot operate without rail access. Installing access to a certain mode requires space, a limited resource. As a result, the effectiveness (container throughput per unit area, measured in TEU/ha) decreases (Evers, 1994). So, from a functional point of view, different modes should be handled at different locations. Then, each mode can be handled with the highest effectiveness, thereby improving the effectiveness of the port as a whole.

Space limitation is also relevant with regard to increasing vessel size (Montes, et al., 2012). As vessels carry more TEU, the terminal is still able to unload the vessel, but does not have the space to store all the containers. (Jiang, et al., 2012) Alternative space needs to be sought for. The connection between the new space and the existing terminal can be facilitated by ITT. The ITT modes could also be used as buffer (Duinkerken, et al., 2006)

2.1.3 No terminal wants to be dependent
Although the division of modes sounds sensible from the functional point of view, it implies that terminal operators become dependent on one another. To transport a container with a certain mode that the terminal does not have access to, requires the terminal to transport the container to another terminal (ITT) that has access to that mode. But what possibilities do terminals have to ensure that the containers they send to the other terminals are handled with the same care and
urgency as they would handle them themselves? As long as these concerns remain, the issue of dependability will also remain. Terminal operators are compelled to lower their effective use of space in order to stay independent (Wesselink, 2010)

2.1.4 Not all equipment can be integrated
Different terminals have invested in different solutions in the past. By investing in a certain technology, a certain development or business path is chosen. Due to the size and accompanying cost of these investments, it is quite hard (if not irreversible) to change paths. The write-off on the initial investment would be so large that the change to a new system is unlikely to be economically feasible. This diversity between terminals inflicts two demands on the ITT system. The ITT system has to be able to cooperate with the different systems operating on different terminals. Also, the ITT system should not count on vehicles from the terminals participating in ITT.

2.1.5 Future is insecure
The future is insecure. Although all the prognoses and trends indicate that the market for container transport will continue to grow, this still is only a forecast (de Langen, et al., 2012). Unexpected events can change this future trend. What if the growth in the container sector grinds to a halt, or even worse, what if the absolute number of containers that is being shipped decreases? Should this happen, although it is very unlikely, it would lead to a decrease in the funds that are available to research new alternatives. (Taneja, et al., 2010).

So, before deciding to invest in the development of the ITT system, a critical view on future scenarios is necessary. If the current predictions are not convincing, additional future prognoses might be deemed necessary before allocating funds towards the realisation of the ITT-system. In the meantime, investment may be directed at worthwhile strategies, which will eventually benefit a new ITT system. Examples are, introducing trip booking, improving road use and decreasing delays. (Feijter, et al., 2004).

2.1.6 Information is unavailable
In order to organise anything information is required. With regard to the organisation of ITT the needed information takes on the form of an approximation (the model of Voss may help to approximate some of this data) (Tierney, et al., 2012):

- Location
- Destination
- Time Window
- Available modes
- Available Connections
- Cost of movements

However, all this information is usually not available beforehand. (Attempts have been made to improve the information availability in the shipping industry (Lambrou, et al., 2008) (Nielson, et al., 2001)). It is possible in theory to compile the ideal planning whereby all the containers are shipped on time by the mode (from a pool of available modes) that best suits the needs of the customer, and whereby this mode operates at full loading, eliminating losses from inefficient mode use. However this ideal scenario is far from being realised.
One reason is embedded within the logistic chain. Although information is available in the chain, the owner of the information only shares the information at the last moment. (van Schuylenburg, 2013) One reason for this behaviour can be the intention to gain competitive advantage. Another is that sometimes the information is just not known yet. It might happen that the type of transportation that is wished for, or even the time a container is to be delivered, has yet to be decided. As long as the information is unavailable, the container will not be moved and will remain in the stack. If all the participants in the chain could be convinced to provide information well before the transportation needs to take place, planning could be optimised and efficiency increased within the limitations of the free market (competition reduces options to enforce measures).

2.2 Problems with regard to stakeholders
Every stakeholder has limitations of one kind or other. If the stakeholder wants to realize a goal that is greater than his capabilities, he will need to cooperate. But cooperation is difficult, as multiple stakeholders usually compete for exactly the same goal. There will also be stakeholders who are negatively affected if another’s goal is realised. The former might therefore try to prevent this goal from being realised.

In the case where a goal is formulated in which all stakeholders are willing to invest, realisation becomes easier. However, formalising such a goal is nearly an art form, fraught with difficulties of a non-technical nature. This is the realm of conflict and cooperation. In this section, the different possible conflicts are elaborated. If this topic is to be studied in more detail, perception graphs might help (Bots, 2007). That is, however, beyond the scope of this work.

2.2.1 Conflicts within stakeholder group (Competition)
Stakeholder groups consist of multiple members. Consider, for example, the stakeholder group of terminal operators. Although all the members of the group are terminal operators, there is still enough reason for conflict. Some terminals will have the best facilities to facilitate rail transport. As a result they can serve rail cheaper, meaning that other terminals will lose their demand for rail transport. Another example is the need for space. All terminal operators need space. If there are more operators involved, then the available space needs to be divided; another possible reason for conflict. So, when stakeholders are differentiated there is a chance of conflict because they do not want to be dependent. However, when the group consists of similar members, there might be conflict regarding the available resources (space, customers, etc.). Then the conclusion could be that, within the group, there is always a chance of conflict, unless the group only has just one member.

2.2.2 Conflicts between stakeholder groups
There are also a lot of possibilities for conflict between stakeholder groups. The main reason here is that every group wants to improve its own situation. If we assume that there is only a certain value that can be gained, this leads to the result that, what the one party gains, the other will have to lose, a zero-sum game. If the supervisory group applies strict control, the customers will gain (better market performance). However, the terminal operators and/or mode operators will lose. (Sharper prices means less margin.)

2.2.3 Cooperation possibilities
The impression might have risen from the previous paragraphs that stakeholders can only live in conflict, and that knowing the objectives of a stakeholder cannot change that. This is not true. The assumption until now has been that there is only a limited amount of value available to go round.
However, there is also the possibility to add value (Wesselink, 2010). Under this assumption, conflicts may be unlikely or easily overcome, resulting in the system as a whole experiencing an increase in value. It is worthwhile to research how stakeholders can be motivated to pursue conflict-avoidance. (Wang, et al., 2012)

### 2.3 Problems encountered by researchers

The problems arising from the functional and stakeholder perspectives have been described in the previous paragraphs. However, the researcher should not hope to find common ground between the two descriptions to enable him to arrive at a synthesis between them.

An explanation why this is difficult is the lack of common definitions for the terms used for functions and for stakeholders. The one is about technology, the other about people.

Definitions hold information. A lack of common terms or common definitions means that a lot of the functional information and stakeholder information is mutually exclusive, with a gap of uncertainty in between. As long as this uncertainty remains, both functional and stakeholder analysis will have to be used beside each other. (de Bruijn & Herder, 2009). Again, a shift in perspective may help.

### Synopsis

Within the ITT domain, there are two kinds of issues to consider: the functional issues (increase in ITT demand, limited space, no terminal wanting to be dependent, impossibility to integrate all equipment, insecure future, unavailable information) and the stakeholder issues (conflicts within stakeholder groups and conflicts between stakeholder groups). These different issues have been described in this chapter. The main lesson to be learned is that the distinction between functional issues and stakeholder issues may easily be made on paper, but is difficult to achieve simultaneously. However, the reality is that functional issues and stakeholder issues need to be tackled at the same time to make a difference. Perspective is important here. Taking a step back may reveal a whole new problem/solution. An ontology can create clarity amidst the complexity. The shifting of perspective from time to time will improve the ontology.

In the next chapter, the issues identified will be used as input to formulate the problem definition. The chapter also explains how an ontology can add value.
3 Problem definition/ Added value of an ontology

3.1 Problem definition
Global container transport has been growing and the expectation is that this trend will continue. As a consequence, the demand for inter terminal transport is expected to grow as well. (Diekman & Koeman, 2010). Alternative transport ideas, strategies and designs have to be generated today to keep up with the increase in ITT demand in future. As discussed in the previous chapter, two views are needed to develop a good ITT alternative: a functional description of the system and a clear understanding of all the stakeholders involved. This thesis has developed a range of methods for obtaining information on both of these views. The difficulty lies in the integration of the two views. A functional description of the system will not be realised if the stakeholders concerned cannot reach agreement. On the other hand, if the development of an alternative ITT method is first approached from the point of view of the stakeholders, a solution may be found that all the parties involved are happy with. However such an agreement may result in an overly costly or complicated design.

3.2 Added value of an ontology for the ITT domain
By first constructing an ontology from a functional perspective, and then connecting the actors and their problems to this functional description, possible clashes of interest can be identified early on and taken into consideration during implementation. Also, the ontology can form a bridge between the actors and indicators.

A valuable part of the ITT ontology is that the knowledge that it contains is accessible. When a new ITT system is being developed, many choices have to be made. Some of these choices will be strategic, some tactical and some operational. The ITT ontology will transcend these lines, and will contain information at the strategic, tactical and operational levels (5). The fact that ITT transcends all 3 levels is perhaps the single greatest added value of the ontology. The result is an overall picture that has the possibility to show indirect effects, like power relations, that can be identified because the ontology transcends the different levels.

![Figure 4: ProPer Model (Veeke, et al., 2008)](image)

![Figure 5: Ontology transcends all 3 levels](image)
However the way the ontology can be applied differs for these levels. For strategic choices the ontology can be used as a guideline. The ontology can be used to check how the different visions of the decision makers do or do not match. And when the position of decision makers in the decision process become less clear the ontology might be applied to improve the understanding of one another.

On the operational level the function of the ontology is drastically different. On this level it is clear what needs to be done and ideas may exist of how it can be done, but by whom. What stakeholder is best suited to undertake the task that is available. And how can this stakeholder be convinced to undertake this task if he is unwilling? The ontology is rich in relations and these relations can help to answer these questions.

On the tactical level the ontology can assist in both ways described above.

The 3 levels do not necessarily have to be explained by means of an ontology. There are many other (perhaps, better) ways available to describe the operational level. For example, the Delft System Approach. The PROPER - PROcess-PERformance - model (Veeke, et al., 2008) shown in Figure 4, is also a very good model to describe the operational level from a functional perspective. PROPER is a model meant for optimizing the design. Due to its structured approach, the real design problems can be systematically detected and solved.

Also the Soft Systems Methodology could be applied. However this methodology makes a clear distinction between the real world en the model. First the real world is analysed and a model is created to learn more about the aspects of the real word that are of interest to the developer. In a later phase the developed model is checked against the real world and if necessary it is expanded and improved. An ontology does not make this this distinction between the real world and the model. It makes a selection of the real world. And only this selection is to be taken up. When this selection is made, in the case of this ontology ITT, this selection is modelled entirely. New knowledge is added when it becomes available and contributes. Another difference is the early formalisation that takes place while developing the ontology. Do to this early formalisation, parties with different backgrounds and different ways to express themselves have access to a shared terminology.
3.2.1 Where the ontology can be used
The ontology can add value in the following 3 ways:

1. As source for knowledge regarding ITT
2. Design phase of new ITT alternatives
3. To assist in the validation of Agent Based Models

3.2.2 As source for knowledge representation regarding ITT
Knowledge is stored in the human mind. It is a shame that once the mind is gone the knowledge is lost. The ontology can help to prevent this. By storing knowledge in an accessible way, the ITT ontology promotes greater understanding of the domain of the ontology, namely, Inter Terminal Transport. All the researcher or developer has to do is open the ontology document and search for the part he or she is interested in. Because the different classes of the ontology are interrelated, all the relevant information related to the item he or she is interested in are listed. If more knowledge about a certain relation is deemed necessary, this information is only a mouse-click away. To develop an idea of the completeness and richness of the ontology the formulas of (Anand, et al., 2013) are applied.

3.2.3 Design phase of new ITT alternatives
Different ITT alternatives can be searched for in many directions or in many disciplines. However, what will guarantee that the different researchers use the same vocabulary and definitions? If different definitions are used, communication between the different parties will become more difficult. The difficulty of integrating the different solutions will increase. An ITT ontology can prevent such issues. It can help to ensure that all the involved parties use the same terminology, improving the effectiveness of meetings and making combined alternative solutions easier to set up and analyse. Once the ITT ontology has been realised, it will store knowledge and make it accessible in future.

Furthermore, the ontology covers all the issues that require attention when new alternatives are being developed. The ontology’s high level of abstraction provides developers with the flexibility they need to design alternatives. The ontology also holds information that the developers can consult to verify or validate their design.

3.2.4 To assist in the validation of Agent Based Models
In recent years, Agent Based Models are increasingly used in transport and logistics (Yang, 2011). The added value of the ITT ontology is that it can become a standard for validation, or be the basis of one, contributing to the development of Agent Based Models for ITT. Especially the definition of the different classes, and the relations that are present between these classes, are of interest. However, in this report the possibilities for Agent Based Models are not explored further.
Synopsis
The ITT system can be described from a functional perspective and from a stakeholder perspective. Each perspective adds value, but cannot cover the entire ITT system. To arrive at a complete picture both perspectives are required. However the two perspectives are partly intertwined. An ontology can help to create clarity in this complex part of the ITT system.

Furthermore, the ontology can be used to:

- assist in the development of new ITT alternatives
- act as a source for the representation of ITT knowledge
- assist in the validation of Agent Based Models for ITT

In the next chapter, the knowledge acquired in defining the problem is used to describe the research goal in more detail.
4 The ITT domain and development perspective

Within this chapter the ITT domain is described from the point of view of the ontology developer. The first paragraph will describe the scope. The second paragraph will elaborate on the position of ITT. The chapter continues with a description of the assumptions that are made in developing the ontology. The last paragraph explains the importance of perspective, and its influence on the development of the ontology.

4.1 Scope visualized

The ontology is developed using Maasvlakte II as reference port. However, it will still be applicable to most other coastal ports. The limitation to coastal ports is depicted in Figure 6: the port area (light blue square) crosses the border between the land side and the sea side.

Within the port area two terminals are shown: Terminal X and Terminal Y. The specific functions of these terminals are not relevant for the scope. However, the terminals are shown in such a manner that all the ITT functions can be fulfilled. The terminals have access to the sea.

An important consideration for the scope is the set of connections available between the terminals. The scope allows for different connections. The road connection is currently the primary connection used to facilitate the inter terminal transport. Inland waterways also contribute to the needs of the ITT. In the current situation, barges hop from terminal to terminal. The rail connection is available as well. It is mostly used for transportation by shuttle services to the hinterland (Thijs, et al., 2000).

The last type of infrastructure within the scope is the New infrastructure. This infrastructure has currently no cargo carrying capacity. It is included in the scope as a place-holder, reserved for the new ITT solutions that will be realized eventually.

Figure 6: Scope visualized
4.2 Position of ITT

ITT is the movement of containers between terminals. ITT is hard to depict, as it can take on many different forms. However, its functions are easy to identify (chapter 6).

ITT facilitates the transportation of containers between terminals. As discussed above, the four enablers of this transportation are:

- Mode
- Information
- Connection
- Container

These four enablers are of course intertwined. For instance, the information on available connections will limit the possibility of modes to select. The 4 enablers, not the transportation, affect the organization of the ITT system. As long as the transportation function is looked at as just a criterion, it would not really matter how the ITT system is organised (if an automated system is considered the control form by (Versteegt, 2004) might be an option, it combines detailed control and with simple rules and freedom.). All that is relevant in the functional view is that the container is picked up and delivered at the right location and on time. However, from an economic viewpoint, it is important that this transportation is done as cost-effectively as possible. Different alternatives are available to reach this cost effective level of operation. The ontology should hold enough information for all these alternatives.

4.3 Assumptions

During the process of building the ontology, certain choices have to be made. Some assumptions need to be made in order to ensure that the work could be completed on time. The downside of some of these assumptions is that the possible use of this ontology is limited. In this paragraph, a list of these assumptions is given, followed by an explanation for each assumption.

1. ITT is only required for container transport
2. There is sufficient road capacity currently and in the foreseeable future
3. Transport on public road is the default alternative
4. ITT takes place between terminals and not on the terminal terrain itself
5. ITT will only facilitate transport within the port region
6. Customs and regulations do not form a problem for ITT
7. Future scenarios provide enough certainty to justify investment in ITT research

4.3.1 ITT is only required for container transport

Within the port, different types of cargo flows can be identified. From the range of cargo flows, only the transportation of containers is interesting for inter terminal transport. The other cargo, like bulk and liquids, have no direct need to be moved around, or have better transportation alternatives. For example, pipeline connections for liquids.

Within the cargo flow of containers, there is quite some variation (TIS, 2013). For the development of the ontology, however, the difference in container type is of no interest. All that is required is the availability of a mode to transport the container. Also required are a connection for that mode
between the origin and destination of the container, and information about the time window, route, etc.

The ITT system will not store containers. Where additional storage or stacking space is necessary, that area will be taken up in the ITT system as just another location where containers can be picked up or delivered.

4.3.2 There is sufficient road capacity currently and in the foreseeable future
An important assumption is that the road capacity is not going to become a bottleneck in the ITT system. Since there are many ways to organise ITT, the system makes use of this flexibility by differentiating explicitly between public and private roads.

A public road is accessible to all legally roadworthy vehicles. As a consequence, vehicles in the ITT system will have to abide by the rules that apply on the public road. Furthermore, they will have to share the infrastructure capacity with other road users, such as employees going to work. A notable assumption is that the capacity of the public infrastructure is sufficient.

Private Road is not a part of the public road system. As a result, the rules and regulations that apply to the public road do not have to be followed. This therefore expands the possibilities for vehicles that can be chosen to facilitate ITT transport demand. Customized vehicles optimized solely for ITT are allowed to operate on this private road. Another advantage of a private road is that it is possible to control the amount of traffic on it. Such increased control results in infrastructure use that can readily be optimized. The assumption is made that the reserved space for the construction of a private road is sufficient to deal with the ITT demand now and in the future.

4.3.3 Transport on public road is the default alternative
Inter terminal transport is already required by the terminals that operate within port. Although new solutions might be generated that can provide the ITT service in a more efficient way, this does not take away the current need for ITT. This need is fulfilled by public road mode. Any ITT alternatives will have to be more cost efficient. When evaluating such alternatives, it should be considered that the public road mode alternative will not remain the same. (Havenbedrijf Rotterdam N.V., 2012).

4.3.4 ITT takes place between terminals and not on the terminal terrain itself
Inter terminal transport handles the transport between terminals. This means that the ITT will not account for any of the processes that occur within a terminal. The mode used to perform the ITT will receive its container from a stack at the terminal, by means of terminal equipment. When the mode has covered the distance between origin and destination, it will be unloaded by equipment present at that terminal. In this form of operation, the efficiency of the ITT system is partly determined by the willingness of terminals to allocate their equipment to the loading and unloading processes of the ITT system. There is then the question of the kind of service the ITT system may expect from the terminal. If a terminal has a higher demand for its equipment elsewhere, there is a risk that the ITT system will be the first to be put on hold. It is conceivable that the larger modes (deep-sea vessels, shuttle trains) will have priority over the ITT system.

The possibilities for further integration of ITT transport and terminal operations are limited. The reason for that is twofold. Firstly, the terminals have invested in different solutions to optimize their processes. Integrating the ITT as carrier and as part of the terminal’s equipment is too much of a challenge. Secondly, the different terminal operators do not want to have to depend on one another
(Wesselink, 2010). If the ITT were to be expanded as to also cope with processes that take place at the terminals, then this unwanted dependency would increase the chance of terminal operators adopting the ITT alternative.

4.3.5 ITT will only facilitate transport within the port region
Space in the port area is limited. In this study, it is assumed that any increase of container flows will most likely be handled in dry ports (Roso, et al., 2009), and that the ITT will only take place within the port region. This assumption implies that travelling time between terminals will remain low.

4.3.6 Customs and regulations do not form a problem for ITT
The moment that a container crosses the border of a terminal, clearance by customs is required. For the development of ITT, the assumption is that this clearance is given before the transportation of the container is needed. Or that the region wherein the ITT takes place has been generalized to one zone. Clearance by customs will only be needed if the container leaves the zone. Hence the assumption that ITT is free of customs intervention.

4.3.7 Future scenarios provide enough certainty to justify investment in ITT research
Investing in ITT research is worthwhile, for the expectation is that the research will lead to change. This change is expected to make further optimization of port operations possible. However, preliminary research (Diekman & Koeman, 2010) indicates that a minimum amount of containers need to be transported by means of an ITT system, for it to be a better alternative than the current way of operating.

There is a tacit assumption that this critical value will be passed somewhere in time. That justifies investing in ITT research. However, it is wise to reconsider the investment in ITT research for the scenario where this critical value of throughput is not attained. Although the development of an ontology holds the possibility to store knowledge, there is still the chance that the knowledge gained will fade away before it can be applied.

4.4 Perspective
When constructing the ontology, choices needed to be made. These are necessarily made from a certain perspective. Therefore, to understand the choices, it is important to know what the perspective is.

The development of the ITT ontology started with the port authority’s perspective. In particular, Rotterdam Port Authority is interested in the possible developments with regard to ITT, since they expect the demand for ITT to increase with the completion of the container terminals at Maasvlakte II (Mes, n.d.). An increase in the demand for ITT would likely mean an increase in the investments necessary to make ITT happen. However, the port authority is interested in limiting these expenses. So, in all probability, the balance will be found by reducing ITT expenditure by investing in new technologies.

Another reason to look towards the ITT case from the port authority’s perspective is the power that the port authority holds with regard to the allocation of space to stakeholders. If the port authority does not stand behind an ITT concept, it will not be realized. For, the space upon which the connections will have to be built cannot be altered without the consent of the port authority. In later stages of the development, other perspectives were selected to expand the ontology. From time to
time the overall perspective was selected, to enrich the ontology with regard to the multi stakeholder issues.

**Synopsis**

Maasvlakte II is used as reference port to develop the ontology. The ontology is developed for the ITT domain and is not intended to be used outside this domain. The ontology may also be applicable to other (coastal) ports, but no guarantees can be given. This ITT ontology considers only transportation. Storage is not included. However, some accommodation is made for additional storage, by treating it as just another location where containers can be delivered or picked up. Other assumptions are that road transport is the default mode and that Customs will not obstruct the development of ITT alternatives.

The next chapter describes the different functions that take place within an ITT system.
5 Description of the ITT system
In this chapter the ITT system is described. The first part describes the functions that can be identified by functional analysis methods. The second part of the chapter describes the stakeholders and the way they are related. This information can be acquired by means of stakeholder analysis.

5.1 Description of the functions
Figure 7 shows functions within the ITT domain. The figure is a simplification, such that the ITT processes take place between two locations: Location X and Location Y. Only the processes that take place at location X and Y, and that are happening in the transfer area, are taken into consideration as part of the ITT system. This decision is based on the assumption that the ITT system will remain separate from the terminal system, and therefore a transfer is required for transport between the ITT system and the terminal. The reason for the existence of an ITT system is the need to transport containers. A container therefore has a function within the ITT system. Furthermore, a mode of transportation is needed to transport the container. This mode needs infrastructure to be able to operate. Therefore, a connection between location X and Y is required, as a function within the ITT domain. In order to transport the correct container to the correct location at the correct time, information is required. Hence, the function of information is also taken up in the ITT ontology. So the following functions need to be represented within the ontology: Container, mode, connection between location X and Y and information.

Figure 7: Functions within ITT
5.1.1 Mode
The mode used for the ITT can be freely chosen. Of course, all the modes have their own demands that need to be fulfilled before they can successfully operate. A mode can be used for ITT only if all of its demands are fulfilled. Once the modes that are available are known, a selection between these modes will have to be made. The simplest criterion for selecting a mode is the cost of operation. This cost will change with regard to the utilisation rate of the mode, and the total amount of movements over which the initial investment can be divided. A mode has many attributes. Some are relevant for ITT, some are not. A selection of relevant attributes will be placed within the ontology. These attributes will be applied to the modes as early as possible.

5.1.2 Information
To organise the transport between terminals using ITT, information is required. To start with, it is good to know where the transport will start (Origin) and where the transported container will have to be delivered (Destination). Attaching a specific time to the transport will certainly add value to the information. The constraint on time is that it has to be within the time-window attributed to the container. Before the transport can commence, the route has to be known. This can be generated by a planning system. Such a system takes into consideration all the transportations that are taking place or are being planned, and the capacity of the available infrastructure. (Gunter & Kim, 2006)

5.1.3 Connection
In order for a mode to be selectable to facilitate the transport between location X and Y, it is necessary that the mode can actually reach location X and Y. Therefore, the infrastructure needed by the mode has to be in place. The relatively high handling cost (Diekman & Koeman, 2010) and the fact that the distances travelled do not surpass the break-even point for intermodal ITT are usually reasons for not considering intermodal ITT as an option. Therefore, when designing the ITT-system, it is necessary to investigate what kind of connections are necessary for different terminals. During this investigation, one should consider the functional use of the connection as well as the behaviour of the stakeholders in the system when they are faced with no connection. Much information can be gathered from the stakeholders’ choices and preferences.

5.1.4 Container
A container is the item that is in need of transportation. If the container is not yet ready to be transported, the system will have to wait until it is.

5.2 Multi Stakeholders
In this sub chapter, multiple approaches are applied to identify stakeholders and their relations. The first method was devised with the collaboration of Dr. Laura Danielle of TNO, Netherlands. We started by assuming the existence of a fully operational ITT system. The result is a true-to-life scenario in which a stakeholder transports a container in the port of Rotterdam from one terminal to another, using Inter Terminal Transport (ITT).

The second part of the chapter contains an actor relation diagram. Within this diagram, the relations between different stakeholders are identified and explained. These relations are a part of the complex system comprising intertwined stakeholders and functions.

The third part of the chapter contains a Power-Interest diagram. Within this diagram, different stakeholders are identified, and their relations are shown. A stakeholder more interested in ITT is
placed further to the right. A stakeholder who has more power with regard to ITT is placed higher in the diagram. The attributes, power and interest, are assigned to the stakeholders by ranking them relatively among themselves. So, there are no absolute values. When the ranking is complete the stakeholders can be found in one of the four quadrants, Monitor, Keep informed, Keep satisfied and Manage closely.

In the final part of the chapter, the stakeholder terms that will be used in the ontology will be introduced and explained. The number of stakeholders in the ontology might be less, due to the high level of aggregation.

5.2.1 Stakeholder relation diagram

![Stakeholder relations diagram](image)

Stakeholders have relations with one another. In Figure 8, these relations are shown by means of arrows. Two kinds or arrows are used. The arrows with a solid line indicate relations with direct effect on the ITT domain. The dashed arrows indicate a relation with an indirect effect on the ITT domain. The categories, Terminals and Mode operators, are divided into sub categories. Relations that apply to the complete category also apply to its parts.

To understand the figure, we shall start at the stakeholder ITT operator. It has relations with all the sub categories of the stakeholder terminals. Indeed, the ITT operator has to facilitate the transport between these different terminals.

Furthermore the ITT operator also has a relation with the Netherlands Competition Authority [Dutch: Nederlandse Mededingingsautoriteit (NMA)]. The function of the ITT operator to facilitate all the transport between the different terminals offers the opportunity for unfair pricing, as there is no competition. It is up to the NMA to make sure the pricing remains fair. What kind of behaviour is fair and what kind of behaviour is allowed, is determined in cooperation with the Government. Hence
the relation between NMA and governement. Since citizens are responsible for selecting the government, that relation is taken up as well. The final relation of the Governement is with the port authority, as the port authority has to comply with the rules and regulations stipulated by the Governement. The relation between the Port authority and the Industry in the port is based on the availability of the port authority to indicate the use of different port areas for different kinds of industry. Therefore the Industry in the port region is dependent on the port authority. Since there is no relation between the industry in the port and the ITT operator, the relation between the industry in the port and the port authority is indirect. Although many activities that take place within the port region require employees, the choice is made to limit the relation to those between employees and port authority and between employees and mode operator. The relation between the employees and the port authority indicates that employees are needed. The relation between employees and mode operators is added, since the amount of employees needed may differ per mode and may influence the mode selection. Mode operators have an additional relation with carriers, who have a coordinating function. The carriers are related to the end users of the containers, since the end users generate the demand for container transport, and therefore for ITT.

All these different classes of stakeholders have their own power and interest with regard to ITT. This is described next.

### 5.2.2 Power Interest diagram

![Power Interest diagram](image)

Within the Power-Interest diagram (Figure 9), stakeholders can be found that were also present in the scenario or stakeholder-relation diagram. Different clusters are located within the diagram. The cluster in the top right has high power and high interest. It consists out of the Port Authority, Ocean vessel operators, the ITT operator and the deep sea terminal. Ocean vessel operators and deep sea terminals deserve a different position from the other operators/terminals, since they have a key role.
in the logistic chain. The remaining terminals are interested in the ITT system, but have a limited amount of power. So, they end up in the lower right of the diagram. The power of the remaining operators is also low, as is their interest in the ITT system. So they are located in the lower left.

Depending on the location within the power-interest diagram, a different kind of classification is attached to the stakeholders. These different classifications are printed in light grey within the different quadrants of the power interest diagram. They are Monitor, Keep Informed, Keep Satisfied, and Manage Closely.

5.2.2.1 **Monitor (low power, low interest)**
- Citizens should be monitored since they can unite and demand action from the government
- Employees should be monitored since they can unite and organise a strike
- Operators should be monitored since they can try to realise a shift in the dominant mode

5.2.2.2 **Keep informed (low power, high interest)**
- Clients should be kept informed so they are aware of the options that come with ITT
- Cargo brokers should be kept informed so they are aware of the options that come with ITT
- Non deep sea terminals should be kept informed so they are aware of the options that come with ITT

5.2.2.3 **Keep satisfied (high power, low interest)**
- NMA should be kept satisfied otherwise they may intervene, stagnating the development of ITT

5.2.2.4 **Manage closely (high power, high interest)**
- Government should be managed closely because they have the power and the money
- Ocean vessel operators should be managed closely because they provide the cargo for ITT
- ITT operators should be managed closely because they have to organise and execute the ITT
- Deep sea terminals should be managed closely because they need to cooperate to make ITT a success

**Synopsis**

The ITT system only performs the movement between different terminal locations. Therefore, items that need to be available to make transport possible are: Mode, Information, Connection, Container. In the next chapter the stakeholders involved in ITT are discussed.

Stakeholders are involved in all the parts of ITT they own, operate or control. Stakeholders all have a certain amount of interest in ITT, and a certain amount of power with regard to it. When developing a new ITT alternative, the power and interests of the stakeholders involved should be known. ITT developers should take these powers and interests into account.
6 Towards the design of the ITT ontology

6.1 Requirements
In chapter 0, the ITT system was described. As the ontology is to represent the ITT system, it is logical that the items that were mentioned in the description are also input for the requirements. The information provided here comes from the processes described in the previous chapters.

The added value of the ontology is generated by its ability to match the requirements. The list of these requirements is as follows:

- Functional description of ITT
- Connections possible between terminals
- Mode selection for transport
- Information needed for transport
- Stakeholders involved in ITT

6.1.1 Functional description
The functional description can be seen as the framework on which the other requirements are based. The layout of this framework is rather simple. It consists of only four functions: Transfer, Transport, Stack (taken from Ottjes, et al., 2006)) and Control. With these four functions, it is possible to cover all the activities that are relevant for ITT.

Input for ontology:
- Transfer
- Transport
- Stack
- Control

6.1.2 Connections possible
The first part to be considered in the general ITT framework is the part of connections between terminals. Locations in the port area have a limited amount of connections available to other terminals. Some terminals will have the ability to arrange transportation by all means of transport present in the port area. Other terminals might only have access to one kind of transport connection. The number of connections that are available has an impact on the next phase of mode selection. If a mode is available, but there is no connection between the origin and destination of the container to be shipped for that specific mode, then the mode will be useless. To be able to determine what connections are possible, the ontology needs a list of terminals, and their access to the different connections. For each connection type, the ontology has to cover what modes it can handle. Thereafter, it is possible to state, for all terminals, which other terminals they can reach, and by means of which connections. From this point onwards, individual connections are possible. These connections are best depicted in separate Origin-Destination (OD) Matrices for each mode. In the next phase, attributes like travel distance, travel time, cost of movement, effect on congestion, peak times, etc., can be added to these specific connections.

Input for ontology:
- List of terminals ➔ their access to connections as attributes
- Define what modes can be handled by what connections.
- Enrich the connections on an abstract level with attributes.

6.1.3 Mode selection
The second connection that is made with this general framework is the part of mode selection. For containers to be moved, a certain mode is required. Depending on the kind of movement/transportation that is required, the kind of mode that is the best option can differ. What is needed is information on the different kinds of modes that are available, and the tasks that they can perform. When this structure is in place, it can be filled up with attributes that might help in the selection of the mode. These are attributes like cargo-carrying capacity, utilization rate required for efficient operating, availability of sufficient personnel, etc.

Input for ontology:
- Modes available ➔ Tasks they can perform ➔ Attributes

6.1.4 Information needed
Information needed is a separate part that can be attached to the functional structure of the ontology. Although the information listed in this category is needed all over the ontology, the choice was made to write it down as a group, making it better accessible. When information is needed, referring to this group will suffice. The information is divided into three categories: Time, Location and priority. In the Time category, all the information with regard to time will be listed. If the Location is important, it can be searched for in the information part called Location. The third category, Priority, requires a bit more explanation. In this category, information can be listed that may help to select the activities that have to take place when the available capacity is too low to fulfill all demand.

Input for ontology:
- Information needed ➔ Time, Location, Priority

6.1.5 Stakeholders involved
Stakeholders are the people behind the system, the human factor. Human behaviour is hard to capture. Nonetheless, an attempt is made. The first step is to identify the stakeholders that are having an effect on or are effected by ITT. Once this list is compiled, the stakeholders can be connected to the (now already expanded) framework. Stakeholders may have connections with multiple classes of the ontology, and classes of the ontology might be connected with multiple stakeholders. This interconnectivity will look rather messy, but it has to be to approach reality. Stakeholders may represent a group that is not really a unit, and may be in competition with one another (example: Truck Operators)

Input for ontology:
- List of stakeholders, their relations and objectives
- A stakeholder may represent a group that is in competition with one another
6.2 Criteria for the ontology
In this paragraph the criteria are compiled for the ontology with regard to its use during the design phase of new alternatives. Also information is provided regarding the use of the ontology as a source of knowledge regarding ITT.

6.3 Design phase of new ITT alternatives
In order for the ontology to add value in the design phase of new ITT alternatives, it needs to contain information that can assist in making design choices. The technical information of the design process need to be integrated into the ontology and this technical knowledge should be well defined. Also, the ontology has to be flexible enough so that it can deal with design decisions. The ontology should not be designed for a situation, as it is, but it should contain the different design options. If this goal is realised then the ontology can be consulted during the design phase to see what alternatives are available. And due to the relations within the ontology, the effect of choices can be estimated as well.

6.4 As source for knowledge regarding ITT
The ontology can add value as a source of knowledge regarding ITT, if it is constructed in a way that is easily accessible. Furthermore, no detailed knowledge of the domain is necessary to understand the ontology. The more information the captured in the ontology, the better it can represent the domain. The difficulty lies in the borders of the domain. What knowledge is part of the ITT domain, and what knowledge is part of a larger domain? When is the domain sufficiently covered? Those are interesting questions for a follow-up study.

An ontology is never finished and can always be enriched. To achieve this goal the ontology will be constructed using the software program Protégé. This development will lead to an OWL file, enriched with comments.
6.5 Explanation of the ontology

In this paragraph, the way the ontology is constructed is explained. The ontology has multiple parts and layers that are interconnected. The ontology is explained from top to bottom. The first and largest division in the ontology is the division into Functional, Physical and Non-functional categories.

**Functional:** Activities and information

**Physical:** Classes with physical dimensions

**Non-functional:** Stakeholders and objectives

See Figure 10. In the paragraphs that follow these main categories will be explained further. The division of the ontology into multiple parts will be made even clearer by showing these divisions as a collection of images. Within the images, classes are shown, together with arrows connecting the classes. If the square representing the class name contains a +, this means that the ontology can be expanded. Additional classes and relations are available. Showing all the relations would make the figures more complex than necessary.

![Figure 10: Screen shot thing](image)

Figure 11 shows a list of the different arrows that are present, their colour and meaning. This paragraph will elaborate on the different meanings. Has individual connects a class to an individual. ‘Has subclass’ connect a superclass to a subclass. ‘Has capability to perform’ connects stakeholders to the activities they can perform. ‘Has connection to’ connects a terminal to a connection type. ‘Has control over’ connects mode operator to mode. ‘Has objective’ connects stakeholder to objective. ‘Is able to facilitate mode’ connects connection type to mode. ‘Is able to perform task’ connects activity to stakeholder. ‘Is connecting’ connects connection type to terminal. ‘Is controlled by’ connects mode to mode operator. ‘Is objective of’ connects objective to stakeholder. Finally, ‘Is performed by’ connects activity to stakeholder.

Furthermore the relations in the figure are assigned to stakeholders and functions. If on the right side of the relations name a blocked square is depicted the relation is applicable to both stakeholders and functions within the ontology. If the square is plain blue it is a functional relation and if the square is red it is a stakeholder relation.
6.6 Functional

The functional part is divided into three sections. Activity, Connection type and Information needed. They are clustered under the functional category because they all fulfil a certain function (Activity, connection type), or are needed so that the function can be fulfilled (information needed).

6.6.1 Activity

Within the ontology, four types of activities have been taken up. Three of the four activities have been defined by (Ottjes, et al., 2006), namely Stack, Transfer and Transport. Control is added to the
selection. Control takes place, and is needed, in the ITT domain. Giving it a place in the ontology makes it possible for stakeholders to recognise themselves in this function.

Figure 13: Screen shot Activity
6.6.2 Connection type

Four different connection types have been taken up in the ontology: Road, Rail, Water and New. Road, Rail and water speak for themselves. The class of New holds a connection form that is not dependent on any of the other forms. As an example, magnetic levitation could be considered as alternative connection type that can be used for ITT.

![Connection type diagram](image1)

Figure 14: Screen shot Connection type

6.6.3 Information needed

The information that is needed to perform an activity is also divided into categories. The first category holds information about the type of cargo. The second category is time. Here information can be stored regarding the Time of Arrival, Time of departure, time of stay and time when needed. The third category is priority. In this group, information is stored about urgency of activities. When only a limited number of activities can be completed, this information can be used to construct priority rankings, to ensure that the available capacity will be used for the activities with the highest priority. Locations can be determined by means of GPS. The law and regulations contain information about what is legal and what is not.

![Information needed diagram](image2)

Figure 15: Screen shot Information needed
6.7 Physical

In the category, Physical, of the ontology, information can be found on concrete, tangible items. Container is the category that can be moved. Although a container is a standardized form of transport, there have been many additions to the range of forms a container can have. For mode, there are some options. These options match the different options for connection type. On a Road connection, a road mode can operate, on a rail connection, a rail mode, and on a water connection a water mode (for an overview of vessel types: (Konrad, 2011). A new mode can operate on a New connection type, or at one of the existing connection types, if the new mode is able to do so. For instance, if automated guided vehicles that can carry two containers stacked one upon the other became available, this would be a new mode. However, they would still operate on the road. Terminals will be explained in the next paragraph.

![Diagram](image)

**Figure 16: Screen shot Physical**

6.7.1 Terminals

The terminals that are relevant for ITT have been classified into 4 categories. The names are selected from the Inter Terminal Report (Diekman & Koeman, 2010). Container Service Centre (SC) off-dock applies to a terminal that does not have a deep sea connection, but has the facilities to handle one or more of the other modes effectively. An example of a container SC off-dock could be a dedicated train terminal. Container terminal on-dock refers to deep sea terminals that have a deep sea connection and have the connections and facilities to handle all modes on their own terrain. Non containerized cargo also moves through the port. Although it is not up to ITT to facilitate this transport, ITT is confronted with the cargo flows these terminals generate. Especially when the same infrastructure is used. Due to the fact that all infrastructure has a limited capacity, the capacity available for ITT will decrease when more capacity is used by non-containerised cargo. Supporting activities is a collective name for those activities that have to take place, but do not necessarily focus on the identified activities of stack, transfer, transport and control. Supporting activities add value in a different way. Examples are: storage of empty containers, distribution centres and customs.
6.8 Non-functional

The Non-Functional branch of the ontology is smaller than the functional branch, but is nonetheless just as valuable. Within the branch, the stakeholders are introduced on a general level. Also, the general objectives are taken up in the ontology under the header of policy.

There are four main categories of stakeholder in the ontology, the first of which is the terminal operator. In the previous paragraph, the diversity of terminals was explained. All of these terminals are operated by operators. The second group of stakeholders are the mode operators. They compete among each other to increase their market share. The stakeholder group, Supervision, can be seen as the group that regulates all the behaviour within the port region. One of the reasons they do this is to maintain a fair market for the final stakeholder group, the customers. Customers is a broad group that can be applied at different levels. Even ignoring the level in the ontology where the customer group is applied to, one can safely assume that an unsatisfied customer will look for another service provider.

Stakeholders each have objectives. The objectives are also (on a general level) taken up in the ontology. An attempt is made in this work to capture all objectives under seven general descriptions.

The first objective is to acquire needed service. The second objective is to increase the market share. If the stakeholder already controls a large part of the market, the second goal might be to decrease uncertainty or to increase influence over the market. The third objective taken up in the ontology is to make profit. The fourth goal is to regulate the market. The concept of a free market is not always a success. Sometimes some measure of control is required to ensure fair operation. The fifth and sixth objectives relate to the handling of cargo and, hence, directly to the main function described at the start of this chapter, namely, transfer of cargo between modes and transport of cargo. The seventh objective is presence in port.
The objectives that have been identified in the ontology are dually loaded. They can lead to conflicts as well as cooperation. The biggest conflicts can be expected between acquiring needed services and making profit. To acquire services, one needs to spend, and spending on services, in general, has a negative effect on profit. Assuming there are two or more parties, the objective to regulate the market might influence market share. Such regulation might disadvantage certain stakeholders (negative effect), while favouring others (positive effect). The objectives to transport and transfer cargo will result in conflict when the amount of containers that need to be transported dwindles below the available transport capacity. On the other hand, if the number of containers requiring transportation reaches the system’s maximum, this might motivate cooperation. After all, a jammed system is far worse than sharing some customers with the competition.
6.8.1 Detailed view stakeholders

Figure 19: Screen shot Detailed view stakeholders

Figure 19 shows all stakeholders and their relations. None of the stakeholder classes can be expended further. Their relations are shown. Also + signs are shown in the figure. These + signs belong to classes that are not categorised as stakeholders. Expanding them would not add value to the figure. From Figure 19, it becomes clear that stakeholders are trying to achieve objectives by means of activities. Multiple stakeholders can have the same objective, and stakeholders can have multiple objectives.

Synopsis

In this chapter, all the different building blocks for the ontology are introduced. This is followed by an explanation why they have to be in the ontology and how they can add value. A trend that occurs throughout the chapter is that the attributes are added last. This makes sense, since it is easier to add the attributes to all the relevant classes once the structure of the ontology is clear and complete. The building blocks all contribute, enabling the ontology to comply with the following criteria:

- Functional description of ITT
- Connections possible between terminals
- Mode selection for transport
- Information needed for transport
- Stakeholders involved in ITT

This chapter explains the ontology. The explanation is supported by screenshots from the program, Protégé. The explanation starts at the top of the ontology, and is explained step by step. The figures show a selected amount of available relations that help explain the way the ontology is constructed. The ITT domain has such a complex mesh of interrelations that a picture with all the classes and relations cannot be shown in an understandable way. No matter how the classes are organised, the picture will be a giant mesh of intersection lines that cross each other so densely that the meaning of the lines can no longer be deciphered.
7 Evaluation
In this chapter different issues are addressed. First, some calculations are laid over the ontology, providing an indication of its completeness. Secondly the ontology is validated by new reports. Thirdly some thoughts are introduced how the ontology is to be maintained. The last part of the chapter is about the interrelation of these steps and about how some of these steps can be automated.

7.1 Checking the ontology structure
In the paper by (Anand, et al., 2013) a method is provided to check the structure of an ontology. Figure 20 depicts a graph that will help in understanding the paragraphs that follow. The light blue circles are the nodes. The green connections between the nodes are called links. The purple line that runs from the top of the graph to the bottom, joining consecutive links, represents a path.

The nodes represent the classes in an ontology. There is a special kind of node called a leaf node. A node is a leaf node if the graph does not continue after it. In reality, it indicates a class that does not have a sub-class. For example, the middle node in Level 3 and all the nodes in Level 4 are leaf nodes.

Using these definitions, it is possible to calculate the different properties of an ontology. The values of these properties give an indication of the structure of the ontology. These definitions are applied to the ITT ontology. By all formulas a part of the ontology is showed for clarification.
7.1.1 Depth

The depth of the ontology is an indication of the amount of detail that is contained within the ontology. The value for the depth of the ontology can be determined by dividing the number of links by the number of paths. The result of this calculation is the average number of links for a path in the ontology. For the ITT ontology the number of paths is equal to the number of leaf nodes. (41)

The number of links can be determined by multiplying the number of leaf nodes by the level on which they are located and then sum up all the values that are obtained at different levels.

- Number of leaf nodes on level 1: 0
- Number of leaf nodes on level 2: 1
- Number of leaf nodes on level 3: 25
- Number of leaf nodes on level 4: 15

So the number of links is \((1\times0)+(2\times1)+(25\times3)+(15\times4) = 137\)

The average depth of the ontology is therefore 137/41 = 3.34. This means that, on average, the ontology has 3.34 levels.

Since every node represents a class in an ontology, the depth therefore represents the average number of steps involved in the sub-classing. In this way the depth of an ontology tells us the level of detail to which the ontology explores concepts in the domain for which it is developed. We will again refer to Anand et al for the definitions of Breadth, Relationship Richness, Inheritance Richness, and Attribute Richness. These parameters say little about one particular ontology. As will be shown later, they are useful guides in the comparison of two or more ontologies. For example, given two ontology designs for a given domain, the ontology with the greater depth could, in general, be assumed to explore the domain in greater detail.

![Figure 21: Physical branch depth](image)
7.1.2 **Breadth**

The value for the breadth of the ontology can be determined by dividing the number of nodes by the number of levels. The number of nodes in the ITT ontology is 56, the number of levels, 4.

The average breadth of the ontology is therefore $\frac{56}{4} = 14.0$.

So, on average, each level in the ITT ontology has 14 classes. Breadth, like depth, is only a rough estimate of the data. It is more likely that on lower levels more classes are present, due to the tree structure of the ontology. The breadth of an ontology indicates how many unique classes are included at each level, hence how much the ontology spans the domain.

![Physical branch Breadth](image)

**Figure 22: Physical branch Breadth**

7.1.3 **Relationship Richness**

The value for the Relationship Richness of the ontology is determined by dividing the number of non-IsA relationships by all relationships. The value of the Relationship Richness therefore varies between 0 and 1.

Since every class in the ITT ontology has an IsA relationship with the class above it, and all the classes have only one ancestor, the number of IsA relationships is equal to the number of classes, namely, 56.

The total number of relationships is the sum of the number of IsA relationships and non-IsA relationships. The other unique relationships in the ontology are the object properties (18). The total number of relationships becomes $56 + 18 = 74$.

The Relationship Richness is therefore $\frac{18}{74} = 0.24$. 
The IsA relationships are fundamental, in that they are the basic connections between classes. However, non-IsA relationships are just as important, in that they indicate relations outside the inheritance hierarchy. A very low value of Relationship Richness, say, less than 0.1, would have indicated that the ontology provides little information about how different class groups relate to each other. However, a value of 0.24 indicates that the ontology provides modest information about how the different class groups relate to each other.

### 7.1.4 Inheritance Richness

The value for the Inheritance Richness of the ontology is determined by dividing the number of IsA relationships (58) by the number of non-leaf nodes. The number of non-leaf nodes is equal to the difference between the number of nodes and the number of leaf nodes. (56-41=15)

The Inheritance Richness of the ontology is therefore 56/15 = 3.73

So, a class inherits on average 3.73 relationships from its ancestors.
7.1.5 **Attribute Richness**

The value for the Attribute Richness of the ontology is determined by dividing the total number of data properties (30) by the total number of classes (56)

The Attribute Richness of the ontology is therefore \( \frac{30}{56} = 0.53 \). So, on average, one out of every two classes has some data attribute. It should be mentioned that the average value only gives an indication. It is quite possible that the data properties are not evenly divided among the classes. The expectation is that a class on a lower level should have a higher number of data properties. An addition to this method could be to calculate the value for each level and try to determine a trend in that data.

7.1.6 **Evaluation Checking the ontology structure**

The formulas described above have their limitations. The calculation of the different values gives some insight into the construction of the ontology. The downside of the method, however, is that the output is given in averages. If the ontology that is validated by this method is relatively small, as is the case for Inter Terminal Transport, one path that is different from the rest will have a large impact on the output values. The biggest impact is from the number of levels. For, suppose the entire ontology is built up around level 4, and one path extends to level 8. Then the output will give a value for the breath of the ontology that is only half the reality. Furthermore, it might be helpful if the output data could be compared to a table or list that states what values are acceptable for an ontology. However, the compilation and applicability of such a list would be difficult due to the wide range of possible field ontologies that the list could be developed for.

7.2 **Validation**

The validation of the ontology takes place in multiple rounds. First, the ontology is validated with the document, *Port Compass Vision 2030* (Port of Rotterdam Authority, 2011). While reading this document, a list is compiled of all the relevant terms that should be available in the ontology. This forms the first column of a table. When the list is complete, a second column is filled with the respective classes in the ontology that cover these terms. The terms that are not covered by classes are looked at once more. If there is no justification for their absence from the ontology, they are added. After this addition, the ontology is validated by means of a wordle and the Combiroad report.

7.3 **Validation with Port Compass Vision 2030**

Port Vision is chosen as a case for validation because it describes the wishes for the future of the Port of Rotterdam. It also helps that the case was available and not yet used in the development of the ontology. The document covers a lot more than just ITT. Therefore it has to remain generic, as the ontology is meant to be. During the validation one needs to be aware that there is no complete understanding of the Port Vision report. So some terms may be interpreted ambiguously.

In Table 1 a comparison is made between the terms that are selected from Port Compass Vision 2030 (Port of Rotterdam Authority, 2011) and the ontology. Not all terms that were selected from the Port Vision document could be found in the ontology. The terms that could not be found are discussed in the next paragraph. Where there was no justification for the absence of a term, it was added to the ontology.
<table>
<thead>
<tr>
<th>Term Port Compass</th>
<th>Class Ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container</td>
<td>Container</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>-</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Connection type</td>
</tr>
<tr>
<td>Traffic management</td>
<td>Supervision</td>
</tr>
<tr>
<td>Economy</td>
<td>Cost</td>
</tr>
<tr>
<td>Government</td>
<td>Supervision</td>
</tr>
<tr>
<td>Laws and regulation</td>
<td>-</td>
</tr>
<tr>
<td>Market share</td>
<td>Increase Market share</td>
</tr>
<tr>
<td>Want presence in port (strategic reasons)</td>
<td>Objective/ -</td>
</tr>
<tr>
<td>Employees</td>
<td>Personal</td>
</tr>
<tr>
<td>ICT applications</td>
<td>Information needed</td>
</tr>
<tr>
<td>Logistic functions</td>
<td>Activity</td>
</tr>
<tr>
<td>Largest ships</td>
<td>Mode/Water mode/ Deep sea</td>
</tr>
<tr>
<td>Store</td>
<td>Stack</td>
</tr>
<tr>
<td>Road</td>
<td>Road</td>
</tr>
<tr>
<td>Inland waterway</td>
<td>Water/Inland waterway</td>
</tr>
<tr>
<td>Rail</td>
<td>Rail</td>
</tr>
<tr>
<td>Pipeline</td>
<td>-</td>
</tr>
<tr>
<td>Choice of transport modes</td>
<td>Mode</td>
</tr>
<tr>
<td>Hinterland terminals</td>
<td>-</td>
</tr>
<tr>
<td>Sea terminals</td>
<td>Container terminal on dock</td>
</tr>
<tr>
<td>Carbon footprint</td>
<td>-</td>
</tr>
<tr>
<td>Depth of port</td>
<td>-</td>
</tr>
<tr>
<td>Throughput</td>
<td>-</td>
</tr>
<tr>
<td>Road network</td>
<td>Road</td>
</tr>
<tr>
<td>Sustainability</td>
<td>-</td>
</tr>
<tr>
<td>Partnerships</td>
<td>Attitude</td>
</tr>
<tr>
<td>European regulations</td>
<td>Sub category of rules and regulation</td>
</tr>
<tr>
<td>Dutch regulations</td>
<td>Sub category of rules and regulation</td>
</tr>
<tr>
<td>Productivity land use 20K 30K TEU/ha.</td>
<td>-</td>
</tr>
<tr>
<td>Container transfer point</td>
<td>Transfer</td>
</tr>
<tr>
<td>Multi-user terminals</td>
<td>Objective/ -</td>
</tr>
<tr>
<td>Growth</td>
<td>Increase market share</td>
</tr>
<tr>
<td>Nature</td>
<td>-</td>
</tr>
<tr>
<td>Living environment</td>
<td>-</td>
</tr>
<tr>
<td>Human Resource</td>
<td>Personal</td>
</tr>
<tr>
<td>Innovation</td>
<td>New</td>
</tr>
<tr>
<td>Industrial transition (Objective)</td>
<td>Objective/ But too specific</td>
</tr>
<tr>
<td>Efficient SC in a European Network (Objective)</td>
<td>Objective/ But too specific</td>
</tr>
<tr>
<td>Improving accessibility (Objective)</td>
<td>Objective/ But too specific</td>
</tr>
<tr>
<td>Improving quality living environment (Objective)</td>
<td>Objective/ But too specific</td>
</tr>
<tr>
<td>Innovating (Objective)</td>
<td>Objective/ But too specific</td>
</tr>
<tr>
<td>Reserve land</td>
<td>Control</td>
</tr>
<tr>
<td>Reduce traffic on highways</td>
<td>Control</td>
</tr>
<tr>
<td>Expand infrastructure and solve bottlenecks</td>
<td>Control</td>
</tr>
</tbody>
</table>
Table 2: Missing terms and the reason why

<table>
<thead>
<tr>
<th>Missing terms</th>
<th>Reason that is not taken up in the ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental impact</td>
<td>Not encountered in sources before, will be added (Data properties)</td>
</tr>
<tr>
<td>Law and regulation</td>
<td>Not encountered in sources before, will be added (Information needed)</td>
</tr>
<tr>
<td>Want presence in port (strategic reasons)</td>
<td>Not encountered in sources before, will be added (objective)</td>
</tr>
<tr>
<td>Pipeline</td>
<td>Not suitable for container transport</td>
</tr>
<tr>
<td>Hinterland terminals</td>
<td>Outside the scope: Terminals within the port</td>
</tr>
<tr>
<td>Carbon footprint</td>
<td>Not encountered in sources before, will be added (Data properties)</td>
</tr>
<tr>
<td>Depth of port</td>
<td>Not encountered in sources before, will be added (Data properties)</td>
</tr>
<tr>
<td>Throughput</td>
<td>Not encountered in sources before, will be added (Data properties)</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Not encountered in sources before, will be added (Data properties)</td>
</tr>
<tr>
<td>Productivity</td>
<td>Not encountered in sources before, will be added (Data properties)</td>
</tr>
<tr>
<td>Nature</td>
<td>Should be handled on a higher level than ITT</td>
</tr>
<tr>
<td>Living environment</td>
<td>Should be handled on a higher level than ITT</td>
</tr>
</tbody>
</table>

Consider the Port Vision 2030 document. When looking at the total number of terms that should be in the ontology (45) and the number that was not yet in the ontology (8) this means that the ontology covered 82.22% of the document. This is an acceptable level. Adding the missing part to the ontology will increase the number of classes from 56 to 58, an increase of only 3.6%. The other terms may be added under the data properties.

7.4 Value calculation (second time)

In Table 3 the outcomes of the first calculation run are presented. The table compares the old values of the ontology parameters with the new values calculated after the validation by means of Port Vision. It shows that the values only shift by a modest amount, the absolute values of the relative changes varying from 1%(Relationship Richness) to 17%(Attribute Richness). This is an indication that the ontology did not need a lot of modification after the validation by Port Vision.

Table 3: comparison values before and after case validation

<table>
<thead>
<tr>
<th></th>
<th>Old input</th>
<th>Old value</th>
<th>New Input</th>
<th>New value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>137/41</td>
<td>3.34</td>
<td>143/43</td>
<td>3.32</td>
</tr>
<tr>
<td>Breath</td>
<td>56/4</td>
<td>14.0</td>
<td>58/4</td>
<td>14.5</td>
</tr>
<tr>
<td>Relationship</td>
<td>18/74</td>
<td>0.24</td>
<td>18/76</td>
<td>0.24</td>
</tr>
<tr>
<td>Inheritance</td>
<td>56/15</td>
<td>3.73</td>
<td>58/15</td>
<td>3.86</td>
</tr>
<tr>
<td>Attribute</td>
<td>30/56</td>
<td>0.53</td>
<td>36/58</td>
<td>0.62</td>
</tr>
</tbody>
</table>
7.5 Combiroad

Combiroad (Connekt, n.d.) is a project that designed an automated form of transport between terminals by means of a dedicated lane. The development of the project lead to a prototype and a test track. The test showed that most of the systems worked or could be adjusted by means of some modifications. Because the project had the intention to lessen the load on infrastructure surrounding the port region, and has the ability to handle containers on different modes, these criteria made Combiroad suitable for validating ITT.

It is clear within the Combiroad report that the choice was made to exclude the operation on transfer stations (terminals) from the automation part. This supports the decision to limit the ITT ontology to the movement of containers between terminals.

![Figure 25: ITT is limited to the transport between terminals](image)

Since Combiroad is a land modality the report does not contain information to validate the part of the ontology that is about the barges and feeders. Nonetheless valuable lessons can be learned especially since the report also describes the technical design in detail.

Within the report of Combiroad there are three aspects that stand out:

1. Transfer stations
2. Control system
3. Technical development

All three aspects are partly covered in the ontology but on a general level. The report of Combiroad can be used to increase the detail of the ontology. In Table 4 the three topics are listed and for each topic several suggestions are placed to increase the detail of the ontology. If terms already match classes that are available in the ontology then these classes are listed in the right column. The table shows clearly that the Combiroad report is more detailed than the ontology. A recommendation is to generalise the design criteria listed in the report for Combiroad. If generalisation does not take place the ontology would lose its generic character and lean strongly towards the Combiroad report. The developer can stop generalising the information if the information is applicable to many technical design choices. For example an need for a steering system can be taken up in the ontology but the selection of a specific steering mechanism is to detailed. After generalisation the new information can be added to the ontology in order to improve it. The control system can be integrated under supervision and the technical development can be integrated in mode and connection type.

<table>
<thead>
<tr>
<th>Term Combiroad</th>
<th>Class Ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer stations</td>
<td>Terminals</td>
</tr>
<tr>
<td>Operational hours</td>
<td>Information-needed → time</td>
</tr>
<tr>
<td>Projected volume of the cargo flow</td>
<td>Information-needed</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Location of the station in the supply chain</td>
<td>Information-needed→Location</td>
</tr>
<tr>
<td>Location of buffer space</td>
<td>Information-needed→Location</td>
</tr>
<tr>
<td>Dwell time of containers in port</td>
<td>Information-needed→Time</td>
</tr>
</tbody>
</table>

**Control system**
- Supervision
  - Handling transport assignments
  - Management transfer stations
  - Transport control
  - Transport planning
  - Vehicle control system

**Technical development**
- Absent
  - Demands on vehicle design
    - Chassis
    - Suspension
    - Guidance of the axels
    - Braking system
    - Steering system
    - Lighting system
    - Electrical system
    - Hydraulic system
    - Pneumatic system
    - Energy supply

**Track design**
- Connection type
  - Geometry
  - Type of material
  - Type of construction
  - Safety
  - Loads

| Table 4: Terms in Combiroad report |

### 7.6 Wordle of *(Diekman & Koeman, 2010)*

*Figure 26: Wordle by *(Diekman & Koeman, 2010)**
A wordle is a scientifically sound way to validate an ontology (McNaught & Lam, 2010). The Dutch wordle shown above is for the report of Diekman and Koeman (Diekman & Koeman, 2010). The report describes different alternatives for ITT at the Maasvlakte 2. This is the same report that served as the basis for the ontology. But the terms that are used to construct the ontology were selected by humans. The wordle eliminates the human factor. If the terms listed in the wordle match the terms in the ontology then the selection was made correctly. If words that stand out in the wordle do not feature in the ontology, then not all the information available in the document has been used. The missing terms should be identified. The reason for their absence in the ontology is to be looked for. If no good reason is found (scoping, for example, counts as a good reason), then it is recommended that the missing terms be taken up in the ontology.

The wordle shows that ITT is the main term used in the report. The other terms that jump out are containers and GTR. The important role of containers with regard to container transport speaks for itself. GTR however requires some explanation. GTR stands for ‘Gesloten Transport Route’, which means closed transport route. In the report, this term is used to refer to infrastructure that is closed to the general public and is only open to specific vehicles. Within the ontology, this term is covered within the class ‘new infrastructure’.

Furthermore, the wordle shows that some groups are more relevant than others. For example, terminals are prominent. Classes in the ontology associated with terminals are found throughout the wordle. Also terms relating to the groups truck, train and barge occur. This shows that such groups are relevant as well. It is possible to identify attributes in the wordle, too. The attributes are: Costs, Capacity, volume, and sensitivity. Though volume and sensitivity are not yet part of the ITT ontology, they can be added as data properties.

Finally it is interesting to classify the terms in the wordle as mainly stakeholder or mainly functional orientated. This way it becomes clear if the document in general is stakeholder of function orientated. As an orientation only the larger words are placed in the table.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centra</td>
<td>Uitwisseling</td>
</tr>
<tr>
<td>Depots</td>
<td>Weg</td>
</tr>
<tr>
<td>Terminal</td>
<td>Containers</td>
</tr>
<tr>
<td>Hartelhaven</td>
<td>Truck</td>
</tr>
<tr>
<td>Douane</td>
<td>Spoor</td>
</tr>
<tr>
<td>marineterminals</td>
<td>Transport</td>
</tr>
<tr>
<td>Distripark</td>
<td>Barge</td>
</tr>
</tbody>
</table>

Table 5: Classification of terms in wordle Diekman
7.7 Maintaining the ontology

An ontology is never complete. The information it contains can be made more detailed, and the detailed information can be made even more detailed, etc. Also, an ontology is constructed for a domain, and the domain can evolve. This leads to the question of how to maintain the ontology.

If the ontology is made openly available for maintenance, different people will add different things, according to their needs. This works well in the short term (the ontology fits their needs). However, the goal of the ontology to provide a standard set of definitions will then be lost. It therefore seems to be better to make the ontology free to use, but not free to change. If users run into limitations, then they can make these known to the person/institution managing the ontology. That person/institution will then study the suggested modification and, if needed, integrate it into the ontology. As the ontology matures, it will approach complete coverage of the domain, and so the need for maintenance will decrease. However, if changes occur within the domain, the need for maintenance and modification will likely increase as well.

The maintenance can follow the steps described in this chapter. It starts with the latest version of the ontology. The values that follow form the calculation to give an indication of the ontology's completeness are known as well. Then additional reports are used to fill up the gaps that have been identified. Each gap should be covered by a report for each branch. The new terms that follow from these reports can then be integrated in the ontology. The final step is to redo the calculations and to interpret the differences.

Figure 27: Maintaining the ontology

7.8 Automatisation

The development of an ontology is a process that requires a lot of time of the developers. A large part of the needed time is invested in reading and understanding reports about the different activities.
that take place within the domain. Time can be saved if part of the ontology development process can be automated. A wordle as used in this report might provide an outcome.

In this report a wordle is primarily used to check if the developer had used all the important information the Gesloten Transport Route-report (Diekman & Koeman, 2010) had to offer. The wordle showed all the important terms that the developer had identified as well. This lead to the thought that it might be possible to use a wordle for the screening of reports, generating a selection of terms that can add value to the ontology. If the terms are selected in this way the development time can be reduced, as there is no longer a need for the developer to read the report in detail. The identification of the relation between the different classes within the ontology and the definition of new classes will remain tasks for the developer. However if these tasks can be automated as well, the ontologies can be kept up to date more easily.

7.9 Evaluation validation

Validation gives an impression how far the ontology covers the expected changes in ITT operations. Validation by means of Port Compass Vision 2030 was helpful, as it gives an approximation about the port operations in 2030. However, for proper validation of the ontology, additional cases will have to be studied. The report of Combiroad helped to show that that ontology is constructed on a general level, but can be enriched with more detail. This detailed information is available in the Combiroad report. However during validation, there is a risk to fine-tune the ontology too much towards the validation case. So, while expanding the ontology it is important to bear in mind the goals the ontology is intended for and to make sure that the additions to the ontology contribute to these goals.

Another concern that arose while validating with the Combiroad report was the possibility that one pillar of the ontology would grow more than the other, causing the ontology to get out of balance. The Combiroad report is oriented towards a functional design. Validating with this report resulted in an increase of the functional branch of the ontology. When the new found terms are integrated the functional side will be more detailed than the stakeholder side. Therefore, it is recommended to validate the ontology with a report for all branches. Then all these reports are used for input and the new terms are identified. All these terms can be integrated in one go, too. In this way the ontology remains as balanced as possible.

Synopsis

This chapter puts the ontology into context by means of calculations of its depth, breath, relationship richness, inheritance richness, inheritance richness and attribute richness. The values enable us to make qualitative statements about the characteristics of an ontology and, perhaps more importantly, to compare between alternative ontologies. It is essential to realize that the values calculated are only averages and that they would hold more meaning if some list was available to help interpret the values calculated.

The ontology is validated in three ways. First, by means of Port Vision 2030. After this validation round the ontology is altered. The second round was by means of Combiroad (Connekt, n.d.) and the third round was by means of a wordle of the report by (Diekman & Koeman, 2010). After the last two validating rounds the ontology is not altered, but the lessons learned are taken up in the recommendations.
8 Conclusions, recommendations, reflection

8.1 Conclusions

ITT is a domain where an ontology can add value in multiple ways. One way is to assist with the development of new alternatives for an ITT system. Within the domain there are multiple choices that impact the final design choices of the ITT system. The first one is the lay out of the port, namely, which facilities, resources and services there are and how they are distributed. Is the lay out defined and already present? If so, the ITT system will have to deal with the situation as is. Or is the port still being designed? If that is the case, then that what would be the ideal setting for using the ITT ontology.

After the layout has been handled, the available connection types are up for consideration. In the case where the port has already been built the infrastructure is most likely already present and fixed. This limits the possibilities for using ITT ontology to improve the connection lines and infrastructure. However, even in this case, the system can be redesigned and the existing infrastructure altered, using the ontology. If the plans for the port region are still on the drawing table, then it will be wise to consider what terminals need connection to what transport modes and why. Terminals that are dedicated to modes can handle more TEU/ha, but are dependent on one another. An additional ITT-terminal could function as buffer and eliminate this interdependency. Although this was scoped out in the beginning of this study this alternative may turn out to be rather effective. Due to the increase in containers that is being transported the funds involved in this transport increase as well just as the complexity of the task. Terminal operators might not be able to deal with this task by themselves. Cooperation might hold the answer and an ITT terminal may hold the key. Further research into this direction is recommended. The concept of an ITT terminal has been researched before an example can be found in the FAMAS report (Thijs, et al., 2000).

To construct an ontology, knowledge of the domain is required. As the list of consulted documents grows, the amount of knowledge that is available also increases. When this knowledge is placed within the ontology there is a chance that new insights arise. Clear connections may appear in the ontology, that were originally not encountered in the consulted literature. Therefore, the more knowledge placed within the ontology, the greater the chance to develop new knowledge. However, this has not happened for the ontology on ITT. A possible explanation is that the ontology is developed on a general level. Whereas, relations or new knowledge are easier to discover on a more detailed level.
8.2 Concerns
The ontology is development with the purpose in mind to aid. However aid needs to be accepted and there may lay the foundation to difficulties. Although the ontology offers the information in a new format and although the information is more accessible through that format. It only adds value if the information actually gets accessed. And being accessed it not something the ontology or its developer have influence on. It is up to the possible users to choose to use the ontology. Before they can choose to access the ontology they need to know the ontology is there. If the possible users know the ontology exists they need to let go of the old ways and accept the new. This requires change and change is difficult to realise. Change requires conviction, determination, endurance and becomes easier if results are acquired, in the case of the ontology the aid is experienced. But if the ontology is consulted on an area where it is not yet complete, since it is can always be expanded, the aid may not be experienced and the ontology may be seen as useless, not to be used again. Every source that is taken up in the ontology reduces the chance that the ontology as a whole will be rejected. Deciding when the ontology is ready to be used, is a difficult question with large consequences.

8.3 Recommendations
The ontology on ITT is built around assumptions. For example, the ITT system is limited to transport. Customs and regulations do not form a problem, and ITT will only facilitate transport within the port region. Following the work in this thesis, the next phase would be to check if the ontology could be expanded in such a way that the assumptions can be relaxed or left out. Another recommendation would be to find alternative cases to validate the ontology with. The more the information put into the ontology, the more the information that will be obtained using the ontology. It is important to keep in mind that the information that is added should directly enrich the domain of ITT. As the purpose of an ontology is to capture knowledge of a domain, a good way to start is by gathering input from the domain. But the job of processing the input is subjective, and depends on the view of the one processing the input (Batemant, 1995). So, by its very nature, an ontology will always have some measure of subjectivity. The essence is for the developer to be as objective as possible and to be faithful to the requirements of his domain.

8.4 Reflection
8.4.1 Methodology
When reflection on the methodology used it needs mentioning that the first and the last phase went rather well. Analysing the problem and defining the problem is crucial for the development of the thesis and the ontology. The steps that lead to the ontology were meant to be iterative and that happened in the end. The fact that the developer can get to enthusiastic and drags in all kinds of irrelevant items should be prevented with the scope. However after the scoping has been completed, the ontology still needs expanding, an additional check of the relevance of the items in the ontology could prevent needless work and therefore accelerate the development of the ontology. The validation has taken place in different ways. This worked well, each approach showed strengths and weaknesses. The variation in validation methods showed the weaknesses and compensated for them. Furthermore the strengths can be accumulated resulting in a strong ontology and a well-defined method for its use and further development.
8.4.2 Overall process
Looking back at the development of the ontology, what stands out is that it involves a lot of different disciplines and perspectives; from terminal operations and management to economics, port policies, design and stakeholder analysis. An ontology has so many branches that, with a bit of imagination, everything can be connected and taken up in it. The trick is to know what to leave out. The result is ontology with a limited amount of data that is actually directly related to the domain (ITT). Even when you are aware of the risk of complexity, it is still easy to fall for the temptation. So, the guiding rule is, when you realise that more than the relevant information is taken up in the ontology, then it is time for resolute measures. Trim it down to the essentials, as early as possible in the design process. If the error is discovered too late it might even mean starting over and building a new ontology from scratch. However, even this solution carries a risk. The longer the developer works on the ontology, the stronger the domain (ITT) settles in his mind. When he starts afresh, it is likely the new ontology will inherit design choices that were made in the old design. Even with the best intentions, a good ontology can only be built from plenty of practice and experience (Jackson, 1999).
9 Appendix

Figure 28: List data properties
Figure 29: Overvieuw ontology 1/2
Figure 30: Overview ontology 2/2
10 Works Cited


Hui, W., Chen, Y. & Fu, C., 2007. *Study of the Port’s Concept System Based on Knowledge Ontology*. Harbin, Dalian Maritime University, pp. 129-134.


van Schuylenburg, M., 2013. *Introduction meeting* [Interview] (3 April 2013).


