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INTEGRATION OF PIPELINE TRANSPORT IN THE DUTCH NATIONAL FREIGHT TRANSPORT MODEL: A COMPREHENSIVE ANALYSIS

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ABSTRACT

This paper presents the integration of pipeline transport into the Dutch national freight transport model BasGoed.

This paper first provides a general overview of freight transport in the Netherlands. This overview covers all modes of transport, shipping, road transport, rail transport, inland navigation and pipelines. This overview is followed by a more detailed description of pipeline transport. We address the current use of pipelines, looking at the operational range, the existing infrastructure and the types of goods currently transported via pipelines, such as liquids and gases. With a SWOT analysis, we evaluate the strengths, weaknesses, opportunities and threats of pipeline transport. This analysis helped to prepare the functional and technical design of a pipeline module for BasGoed.

We then present the conceptual design and technical implementation of the pipeline transport module in BasGoed. The considerations behind the architecture and design are described. Modelling challenges include limited data availability, forecasting potential modal shift and potential demand for new transport due to energy transition (hydrogen, CO2). Use cases have been developed to ensure that the model properly reflects these developments in pipeline transport demand.

We further describe the technical integration into BasGoed, addressing the aspects of data integration and ensuring data accuracy and consistency. The paper discusses how the integration of pipeline transport leads to a better representation of freight transport within the Netherlands, by improving the BasGoed model.

The paper ends with some conclusions, recommendations and a discussion on including freight transport via pipelines in freight transport models.

1. INTRODUCTION

The integration of pipeline transport into the Dutch national freight transport model (BasGoed) represents an improvement in the modelling of freight transport in the Netherlands. Pipelines are often overlooked in broader discussions on freight logistics and supply chain management, but they play an essential role in the efficient and safe transportation of liquids and gases. This paper highlights the importance of including pipeline transport in freight transport models.

The primary objective of this paper is to describe a framework for including pipeline transport in BasGoed. This includes a description of the current state of pipeline transport, the challenges involved in modelling it and the benefits it brings to the overall freight transport model. By integrating pipeline transport, we aim to enrich the existing model to provide a better picture of freight transport in the Netherlands. This is innovative because it better captures the often-underestimated importance of transportation via pipelines within freight logistics.

To provide context, the paper starts with an overview of freight transport in the Netherlands. This overview includes all major modes - sea, road, rail, inland waterways and pipelines. This insight is essential for a better understanding of the role of pipelines and understanding their advantages and challenges compared to other transport modes. It forms the basis for a more in-depth description of transport via pipelines and provides insight into their development, current use and future potential.

Pipeline transport, although less visible as other modes, plays an important role in the Dutch freight transport system. The country's extensive pipeline network facilitates efficient and safe transport of various goods, especially liquids and gases. This paper describes the characteristics of the network, looking at the types of goods transported, its operational size and the existing infrastructure. A SWOT analysis has been included to describe the strengths, weaknesses, opportunities and threats of the pipeline transport to provide a clear picture of its potential.

We then describe the conceptual design and technical implementation of pipeline transport in BasGoed. We provide the architecture of the module and address the challenges encountered during development. Issues such as limited data availability, forecasting modal shifts and accommodating new transport needs due to the energy transition are discussed. The paper outlines how these challenges were addressed through use cases, designed to accurately reflect of pipeline transport demand.

The integration of the pipeline module into BasGoed is an important topic of the paper. It describes data integration, ensuring data accuracy and consistency and addressing technical challenges. By integrating pipeline transport, BasGoed provides a better representation of freight transport in the Netherlands. This improves the overall effectiveness of the model, making it an even more valuable tool for policymakers.

The inclusion of pipeline transport in BasGoed not only improves the overall understanding of freight transport, but also provides important insights into the pipeline sector. This addition broadens the operational scope of BasGoed and contributes to the advancement and innovation of freight transport models in general.

2. OVERVIEW OF CURRENT FREIGHT TRANSPORT IN THE NETHERLANDS

The Netherlands is an important hub in global freight transport due to its strategic location, advanced infrastructure and efficient logistics systems. The country's freight transport system comprises several modalities - sea transport, road transport, rail transport, inland navigation and pipelines - each of which plays an important role in the transport of goods, both nationally and internationally. This chapter provides a general overview of these modalities and forms the basis for an in-depth description of pipeline transport.

Maritime transport is a cornerstone of the Dutch freight transport system, with the port of Rotterdam as one of the largest seaports in the world. This port handles large volumes of goods, including containers, bulk and general cargo, and serves as a gateway to Europe. The efficient operation of maritime transport is supported by port facilities, regulations and strong relationships with other modes of transport. The role of maritime transport is important for both imports and exports and makes an important contribution to the Dutch economy.

Road transport is another key component, characterised by an extensive road network that allows fast and efficient movement of goods across the country and beyond. The flexibility and convenience of road transport make it the first choice for short and medium distances. It connects major industrial areas, distribution centres and urban markets and ensures timely delivery of goods. However, road transport also faces challenges such as congestion, environmental problems and high maintenance costs. Most of the road transport in the Netherlands is domestic and consists for a large part out of construction materials and distribution of end products.

Rail transport complements the road network and offers an efficient and sustainable alternative for freight transport over longer distances. The Netherlands has a well-developed rail infrastructure that connects key industrial areas, ports and neighbouring countries. Rail transport is particularly advantageous for bulk, heavy freight and intermodal transport, mainly international transport. Integrating rail with other freight transport systems improves efficiency and reduces the environmental impact of freight transport. An important part of the transport of freight is carried out by using the ‘Betuweroute’ between the port of Rotterdam en Germany.

Inland shipping is an important mode of transport in the Netherlands, using the extensive network of rivers and canals within the Netherlands and the connections to the rest of Europe (via the Rhine). This mode of transport is very efficient for transporting bulk goods such as sand and gravel, agricultural products, coal and ores. Inland shipping offers several advantages, such as reduced road congestion, lower environmental impact and the ability to transport large volumes of goods. The integration of inland ports with sea and rail transport further enhances the efficiency of the Dutch freight transport system.

Pipeline transport, although less visible, is an essential part of Dutch freight transport. The extensive pipeline network in the Netherlands mainly transports liquids and gases, including crude oil, natural gas and chemical products. Pipelines provide a safe, reliable and efficient way to transport these substances over longer distances. Pipeline transport in the Netherlands reflects its importance in the wider freight transport system.

The importance of pipeline transport is shown in the figure below. The figure gives an overview of land transport of hazardous goods by mode. This is dominated by pipelines. Rail and road transport occupy a minor position, while inland shipping still has a substantial volume. The figure shows a decrease in transport by pipeline (especially natural gas). This is caused by the energy transition and by the closure of natural gas fields.

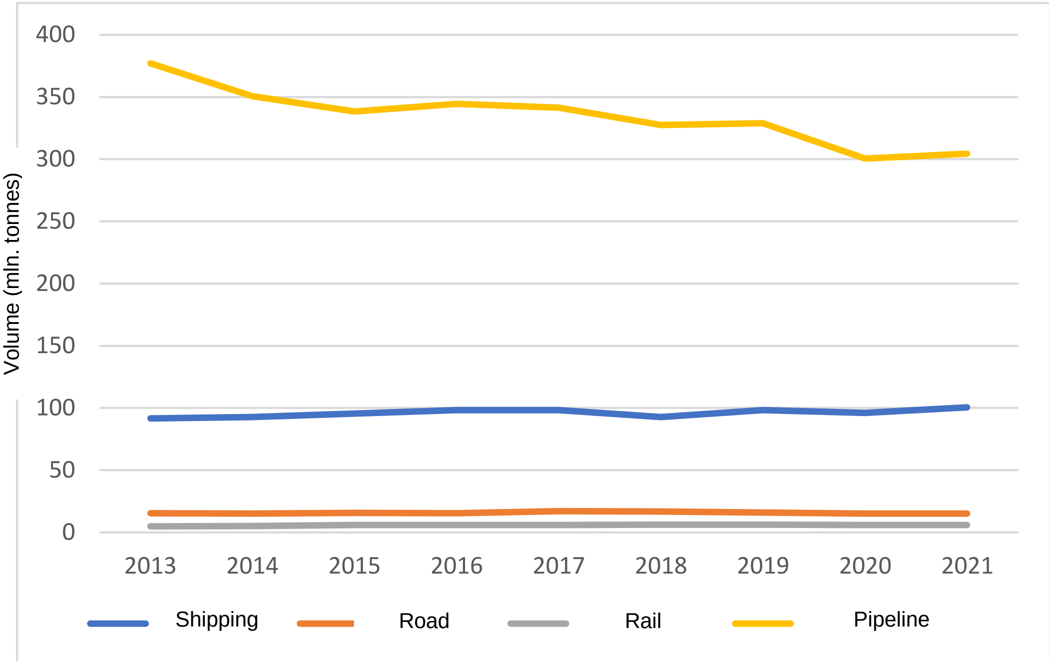

Figure 1: Land transport of dangerous goods (mln tonnes).

3. GOODS TRANSPORT BY PIPELINE

Pipeline transport plays an important but often undervalued role in the Dutch freight transport system. The extensive pipeline network in the Netherlands facilitates the efficient and safe transport of liquids and gases. This chapter examines the specific characteristics of this network and describes its current use, operational size and the variety of goods transported. Understanding this is important to reflect the potential of pipeline transport in freight logistics.

The current use of pipelines in the Netherlands is mainly aimed at transporting large volumes of often low-value goods such as crude oil, natural gas and chemical products. Pipelines provide a continuous flow of these goods, ensuring a continuous supply to industries and consumers. This mode of transport is especially advantageous for hazardous materials, as it minimises the risks associated with road or rail transport. The operational reach of pipelines extends across the country, with significant infrastructure concentrated around major industrial hubs and ports such as Rotterdam, which acts as a hub in the pipeline network.

The existing pipeline infrastructure in the Netherlands is both extensive and advanced. It comprises thousands of kilometres of pipelines connecting major industrial areas, refineries, storage facilities and distribution centres. The network is designed to handle a variety of substances, each with specific requirements for pressure, temperature and safety. This infrastructure supports not only domestic transport, but also international transport and connects the Netherlands with neighbouring countries via cross-border pipelines. The integration of pipeline transport with other modes such as sea transport, inland navigation and rail further improves efficiency and reach.

The figure below shows the main network structure with corridors of pipelines. In these corridors, there are often several pipelines next to each other, which limits the space required. The corridors have several branches that are not shown in the figure. The figure further shows that there are several border crossings connecting the pipeline corridors of the Netherlands with those of Germany and Belgium.

One of the strengths of transport by pipeline is the ability to transport large volumes of goods with minimal environmental impact. Pipelines are energy-efficient and have lower CO_2 emissions compared to other modes of transport. They operate silently and are less disruptive to the landscape, making them an environmentally friendly option for long-distance transport. Moreover, pipelines reduce congestion on roads and railways, contributing to a more balanced and sustainable transport system.

Despite its advantages, pipeline transport also faces a few challenges. High initial investment costs and long lead times for construction are a significant barrier to expansion. The specific nature of pipelines, which are usually designed for specific types of goods, limits their flexibility to adapt to changing market demands.

Furthermore, a pipeline network requires constant investment in monitoring and maintenance to prevent leaks and other incidents.

Strengths include safety, efficiency and environmental benefits, while weaknesses include high costs and limited flexibility. Opportunities arise from the current energy transition, which could increase demand for pipelines to transport hydrogen, CO_2 and other alternative fuels. Threats include regulatory changes, economic fluctuations and competition from other transport modes.

Figure 2: Main structure of pipe network in the Netherlands.

The types of goods transported by pipelines in the Netherlands are diverse and include a wide range of liquids and gases. Crude oil and natural gas are the main goods, but pipelines also carry refined products, chemicals and other industrial liquids. Examples include ammonia, butane, ethene and propylene. The ability of pipelines to transport these goods safely and efficiently is important for the functioning of many industries, from energy and petrochemicals to manufacturing and agriculture.

The role of pipelines within freight transport is multifaceted. They are not only a reliable means of transport, but also serve as critical infrastructure for the energy and chemical sectors. The integration of pipeline transport with other infrastructure, such as ports and railways, provides an efficient logistics network. This is especially important for handling large import and export volumes and confirms the Netherlands' position as a major logistics hub in Europe. By improving the connectivity and efficiency of the network, pipelines contribute to the competitiveness of the Dutch economy.

Pipeline transport is an indispensable part of logistics. By integrating pipeline transport into freight transport models such as BasGoed, policymakers can gain a better understanding of the dynamics of freight transport. This allows them to design measures to support and ensure sustainable and efficient freight transport.

Having stated the importance and value of pipeline transport it is also important to note that pipeline transport has major differences compared to the other modes of transport. The main difference is that the pipeline transport sector is mostly private (or a state monopoly), connecting private facilities. This lessens the ability for public authorities to influence decisions around investment and use of pipelines for transport.

The energy transition and ongoing discussions around the transport of dangerous goods has increased the attention for the use of pipelines and its potential to take over goods that are now transported “above the ground”. Hence also the attention for dealing with pipelines within the strategic freight models.

4. DESIGN AND IMPLEMENTATION OF THE PIPELINE MODULE

4.1 What is BasGoed?

BasGoed is the national strategic freight transport model of the Netherlands based on a growth factor approach. The model allows the forecasting of freight volumes for a chosen future year. The model includes national, import, export and transit freight flows in the Netherlands of maritime, rail, road and barge transport modes. The top-level structure of BasGoed is as follows. First, freight flow matrices are generated and Level-of-Service for various transport modes are calculated. Secondly, the economic growth in the forecast year is determined. Once an economic growth is established, the model distinguished multiple separate paths where maritime, non-container and container flows are modelled. Some of these flows, like barge and road freight flows, are further discretised into trips. The entire model is comprised of 18 submodules and aids policy makers in quantitative analysis of policy measures. The figure below presents a general overview of BasGoed. Also, the new pipeline module is shown in this figure.

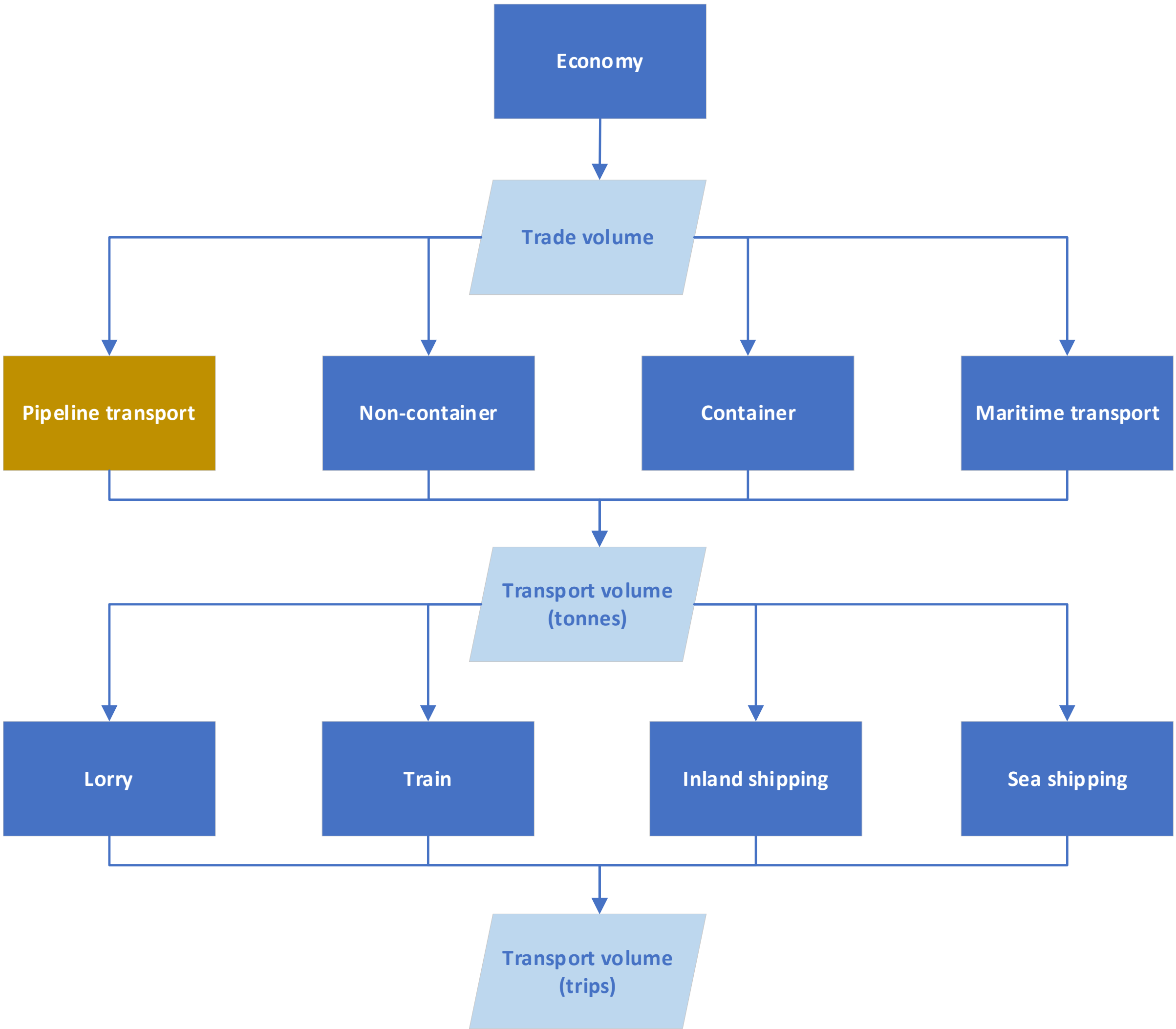

Figure 3: General overview of BasGoed

4.2 Pipeline module design

The Pipeline Module (BL) is prototyped as an add-on to BasGoed and generates a forecast for goods transport via pipelines for a future year. This forecast is based on data national freight pipeline transport statistics.

The module consists of four submodules:

1. Growth Module (BL.1)
2. New Flows Module (BL.2)
3. Modal Shift Module (BL.3)
4. Output Module (BL.4)

In the Growth Module (BL.1), a growth factor method is applied to pipeline goods flows in the base year. There are two options for the user to apply growth in the Pipeline Module. The growth is calculated from the Economic Module of BasGoed (option 1), or the user provides growth figures themselves an input (option 2). By default, the module operates by option 1. It ensures that the calculation of growth factors for specific freight segments and/or origin/destination zone is consistent with the BasGoed methodology.

According to experts, pipelines could play an important transport role in the energy transition in the coming decades. Fossil fuels – substances often transported via pipeline – will be phased out in favour of alternative energy carriers. Some conceivable scenarios assume that the current pipeline network will transport hydrogen or CO_2 in the future. The New Flows Module (BL.2) offers the option to add goods flows per pipeline to the forecast, that are not present in the base year[1]. The use of the New Flows Module is optional.

The Modal Shift Module models the potential towards a modal shift of freight transport, via inland waterways, rail, or road to pipelines in the future. This scenario is conceivable when (1) there is sufficient spare capacity in the pipeline network, (2) the goods are suitable for pipeline transport, and (3) the volume of the forecasted goods flow between the origin and destination zones is large enough to make pipeline transport profitable. Data on freight flows via inland waterway vessels, rail, and road transport is obtained from the Modal Split (MS) module of BasGoed.

The core design concept of the Modal Shift Module is its flexibility on information definition by its user. The module is set up so that the user is allowed to mix and match spatial detail and substance classification of freight flows, to however the information is provided. The only requirement is that the spatial detail and substance classification are also available in BasGoed.

[1] And therefore, no forecast volume can be generated through the growth-factor approach of the Growth Module

Lastly, the Output Module compiles and saves the results in the form of an Excel file and individual graphs. While still being a prototype, the Pipeline Module can be fully integrated within the BasGoed framework. This means that similar coding language is used and that modal shifts are transferred to BasGoed results as well.

4.3 Proof of concept: the Delta Rhine corridor

To put the new prototype to the test a scenario was designed. The Delta Rhine Corridor is a proposed development of a “pipeline artery”, with several branches and connections being explored. These include both minor branches and potential connections to large industrial clusters, such as Antwerp (Belgium) or southern Germany (around Ludwigshafen). This main artery could consist of five pipelines for the transport of LPG, Propylene, and future pipeline freight flows such as CO2, Hydrogen, and Ammonia.

The route runs from the Rotterdam port area, via Moerdijk to Venlo. At Venlo, the Delta Rhine Corridor branches off to the south of the Netherlands (towards Geleen) and has two branches into Germany: one towards Gelsenkirchen and the other towards Wesseling. This route applies to all pipelines in the Delta Rhine Corridor.

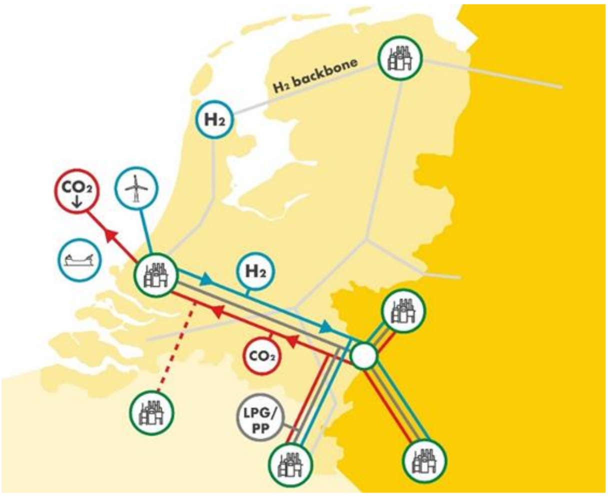

Figure 4: Situational plot of the Delta Rhine corridor

For the use case we included an energy transition scenario. It is expected that the transport of fossil fuels will decrease, while chemicals will increase, due to its use in new fuel technologies. Results of the Pipeline Module prototype show a sharp decrease in (crude) oil and natural gas in this scenario, whilst chemicals such as ammonia show large growths in our forecast year 2040. These results are show in table 1 and figure 5.

Table 1 - Example of Pipeline module output per commodity type

Commodity	2018	2040
(Crude) Oil and Natural Gas	319,620,000	251,288,000
Chemicals	8,054,000	35,729,000
Total	327,674,000	287,017,000

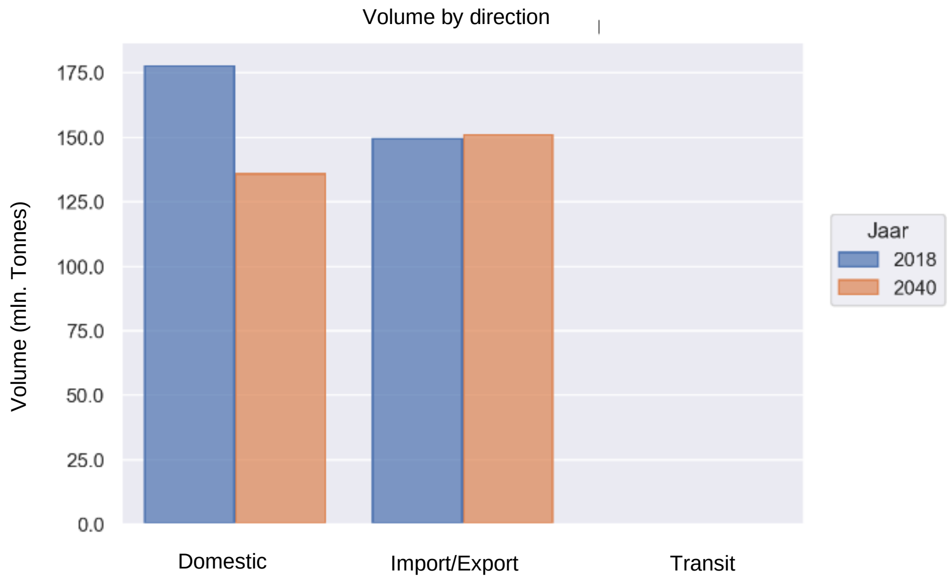

Figure 5 - Example of output by flow type from the pipeline module (in Dutch)

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The integration of pipeline transport into the BasGoed freight transport model represents a step forward in freight transport modelling. This paper shows the importance of pipelines as an important part of the transport system in the Netherlands, given their efficiency, safety and environmental benefits.

The SWOT analysis shows that while pipeline transport has numerous strengths, such as safety and efficiency, it also faces challenges such as high initial costs and limited flexibility. The opportunities presented by the current energy transition and the threats posed by regulatory changes and economic fluctuations highlight the dynamic nature of this mode of transport.

The functional and technical implementation of the pipeline module in BasGoed have been carefully done to address various challenges such as data availability, forecasting modal shifts and accommodating new transport demands. The modular architecture of the pipeline module, consisting of the growth module, new flows module, modal shift module and output module, ensures that the model is both robust and flexible. This architecture enables predictions of pipeline volumes even with limited baseline data.

Use case simulations demonstrate the ability of the pipeline module to adapt to different future conditions and provide valuable insights into the potential impact of economic growth, regulatory changes and new commodities for transportation. These simulations highlight the importance of integrating pipeline transport into national freight transport models to fully understand freight transport dynamics.

The integration of pipeline transport into BasGoed improves the model and provides a more holistic view of the Dutch freight transport system. This innovation supports better policy-making and decision-making and ultimately contributes to more efficient and sustainable freight transport.

5.2 Recommendations

Based on the findings of this study, several recommendations can be made to further improve the integration and use of pipeline transport within the Dutch freight transport system. Firstly, efforts should be made to improve the collection and availability of data related to pipeline transport. Greater data accuracy will enable better modelling and forecasting and support better decision-making. Working with industry stakeholders to share data and insights will help fill current data gaps and improve the overall reliability of the pipeline module.

Furthermore, continuous research and development are essential to keep the pipe module up to date with technological advances and changing market conditions. Regular updates of the module, based on the latest data and trends, ensure that the module remains relevant and accurate.

In conclusion, the integration of pipeline transport into BasGoed represents a significant advance in freight transport modelling. The recommendations provide a path for continuous improvement and innovation in pipeline transport to support the broader goals of a resilient and future-proof transport infrastructure.

5.3 Discussion

Pipeline transport differs fundamentally from the other transport modes. It is more dependent on company strategies and policy decisions than the other transport modes. And it has a different timeline, hight development costs, low transport costs, and is mostly suitable for large volumes. The question is whether it is useful to integrate this mode in the BasGoed model. We decided to include it as a separate, but interacting module, which can be used when information about pipelines is necessary, but which can be turned off when more detailed studies to other modes are performed. Advantage of this integration is that predicting all the transport modes within one model assures consistent predictions based on economic developments, and that modal shift can be computed. Disadvantage is that the results give no information about the timelines and company strategies.

The ‘new flows’ module allows the user to reduce this disadvantage by adding flows depending on policy decisions, company strategies and climate. In this way the module allows policymakers to get a more objective view of the possibilities of pipeline transport, showing among others how large the amounts of goods must be to successfully exploit a pipeline, or how small the modal shift possibilities are. This makes the pipeline model useful for developing the general transport policy in The Netherlands.

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