A Satellite Image Based Eco-Routing Solution: Requirements Analysis from Industry Interviews

Riccardo L. Notarangelo(✉), Petri Helo, and Heidi Kuusniemi

University of Vaasa, Wolffintie 32, 65200 Vaasa, Finland
riccardo.notarangelo@uwasa.fi

Abstract. This paper presents the initial requirements of eco-routing using Earth Observation in two industrial contexts. Earth Observation (EO) is the practice of taking images of earth from space using satellites. Recent progress in EO imagery means that these images are near real time. This creates additional opportunities to leverage image data. Currently, logistics companies have used location-based data for many cases. Exploring the use of EO imagery is promising, especially in the execution of logistics operations. Eco-routing is optimising routes by some parameter improving the routes' sustainability. Eco-routing has provided value to firms by reducing the operational fuel costs and also provides value by contributing to a cleaner future. This study will focus on the investigation of the requirements of EO images to contribute to eco-friendly routes between two nodes.

Keywords: Satellite image · remote sensing · eco-routing

1 Introduction

The primary research question this paper seeks to answer is "Should logistics companies implement remote sensing enabled eco-routing?". The secondary research questions are "What is eco-routing?", "What should be optimised?" and "How do we implement this using earth observation/remote sensing data?". The structure of this paper is as follows: We first explore satellite remote sensing and eco-routing in a short literature review. Next, we introduce the methods and materials for our interviews. Then, we present the results from the interviews. We split the results into their respective areas. Lastly, we discuss and conclude this paper with the implications for further research.

2 Literature Review

The purpose of this short literature review is to define what technologies and problems we are matching in our proposed solution to logistics related industry. To understand the technologies at hand, we first need to review satellite-based remote sensing. Eco-routing itself is a complex concept, with changing definitions. Hence, we need to define for this paper how we view eco-routing. ***Satellite-based Remote Sensing:*** In this paper, we consider satellite-based remote sensing in the specific application of earth observation

C. McNally et al. (Eds.): TRAconference 2024, LNMOB, pp. 501–508, 2025.
https://doi.org/10.1007/978-3-031-95284-5_71

(EO). EO is the technological advancements enabling us to observe earth through satellite imagery [1]. With advancements in this technology we now have a plethora of different sensing techniques [2]. The main sensing technique that we expect to use is the one where high-quality images are taken of the earth's surface. These pictures and other relevant imagery can provide data relating both to traffic [3], as well as road characteristics [4]. However, there are other techniques that may be useful for road characteristics. For example, commercially available radar technologies are able to detect the earth's surface through foliage and clouds. These advanced radar technologies are highly precise, being able to measure differences of up to 50 cm [5]. Therefore, since the goal of this paper is to outline the requirements for improved eco-routing, we should not exclude any way to get there. Existing research also supports the use of satellite remote sensing to capture moisture levels in soil [6]; topographical applications [7]; traffic levels [3]; size of load estimates [5]; patterns - due to the ability to record data over time [8]. ***Eco-Routing:*** Eco-routing is a specific practice in logistics of optimizing routes based on an objective function that includes ecological or environmentally motivated elements [9]. The criteria that are typically looked at include: fastest route (e.g. fastest average speed), least kilometres, context specific criteria [9]. Another angle of eco-routing is fleet management and ensuring that the fleet is as environmentally friendly as possible [10].

3 Methods and Materials

The method for this paper to explore whether logistics companies should implement remote sensing enabled eco-routing is the use of semi-structured interviews for relevant logistics actors. The interviews were scheduled for 60 min. The interviews were "semi-structured" in format. This structured enabled three things. First, the structure enabled an introduction and conclusion, which are important for stakeholder relations. Second, the structure ensured that about half of the interview was dedicated to listening and understanding to the industry expert and that the second half was dedicated to mapping and brainstorming key requirements for opportunities using satellite imagery. Third, the lack of a strict structured enabled discussion to flow so that we could uncover finer details. We invited people who would be familiar enough with the high-level strategic direction of the company, but are not so far removed from the logistics process that they would not be able to tell us about it at the operational level. As a result, we ended up trying to select people who were managers close to the logistics side. This method aligns with best practices outlined by user research publications [11] and [12].

We prepared both interviews through due diligence to ensure that we had some prerequisite knowledge. This was important to focus the interviews around the research topic, rather than industrial knowledge.

The first firm interviewed was a large forestry company in Finland – Company A. Company A was represented by someone with the title of "development manager". This person had experience both in the forestry sector as well as the logistics sector. This is why we thought that their profile would be suitable for this research.

The second firm interviewed was a large organic materials recycling firm – Company B. Company B was represented by their "logistics manager". This title immediately signals that this representative has an adequate profile for this research.

4 Results

4.1 Timber Transport

The first interview exposed several facts to elucidate the current logistics set up (presented in Fig. 1) and shed light on what the forestry industry currently needs from satellite imagery. The transport set up in the forestry sector in Finland is not as centralized as we thought. Company A, despite being one of the largest operators in the Finnish forestry sector, does not own any trucks. Our interviewee explained that this set up is the cheapest way to do land transport, as it enables company A to set up calls for certain transportation areas/jobs/projects. The contracts remunerate companies based on cubic metres of timber as well as kilometres driven. Both of these are predetermined and known by company A, thus leaving the sub-contractors competing on price. This also shows that an eco-routing algorithm, should it be efficient at producing cost savings, would directly be reflected in the entrepreneurs' costs, and therefore allow entrepreneurs to compete in the market better. In terms of the existing software, both the logistics and the actual harvesting of timber is managed by a third party produced software, with appropriate packages for logistics and harvesting. Company A's representative broadly explained that this software catered mostly to the actual tracking of timber product, and that only the logistics package could be doing anything to optimise routing. Additionally, it was mentioned that company A struggles to see how any of the forestry logistics chain could be optimised as most timber products already have a pre-set destination before even being planted. However, we believe that he meant this in terms of optimising the actual transportation of the product from one node to another without taking into consideration how it is transported from one place to another. Table 1 describes the key requirements for a routing algorithm in the forestry sector, based on our discussion with company A. From this table we can begin to deduce that the primary Earth Observation techniques would be related to road characteristics and profile. Both these features are fairly static,

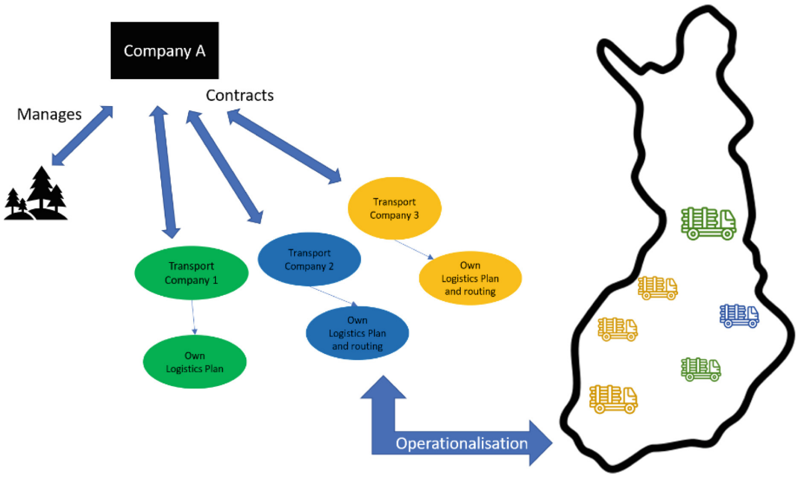

Fig. 1. Company A transportation set up

requiring maybe a single update every day to ensure that data for more sensitive items is updated.

Overall, it is intuitive that the entrepreneurs will compete on cost, and therefore the eco-routing algorithm should find a route that minimizes fuel consumption.

Table 1. Requirements from the forestry sector

Requirement	Problem Solved	Logistics Chain Link	Satellite Imagery Application
Different time windows for different plans	This is potentially addressed by company A's existing software	timber transport	Predictive monitoring
Home base routing plan ("MePa")	Most trucks operate around a home base	timber transport/routing	–
Road characteristics identification: load of tracks	Ad hoc solution exists: surveying and self-reporting	harvesting and collection to roadside storage	Predictive analysis of truck load bearing capacity of roads/tracks
Road characteristics identification: Depth of Tracks	Ad hoc solution exists	harvesting and collection to roadside storage	Potentially solvable using simple imagery from different angles
Accuracy and frequency of satellite data	predictive and informative solutions	–	Frequency of passovers needs to be checked
Precision of satellite data	This addresses the specific case in which data may autocorrelate because of limited definition	–	Different satellites have different definitions
Profile of roads	Potentially addressed by subcontractors	timber transport/routing	Topographic surveying by satellites
Strategic loading	Loading the trucks in a way that it is at its lightest when the roads are most difficult	routing	Topographic surveying by satellites

4.2 Organic Materials Transport

The organic materials recycling process of company B relies on an internally developed logistics operating system. The most interesting process for this research is the carcass collection process, as this is the one that has most room for optimization according to our interviewee. Company B has two main lines of input – the first is by product from

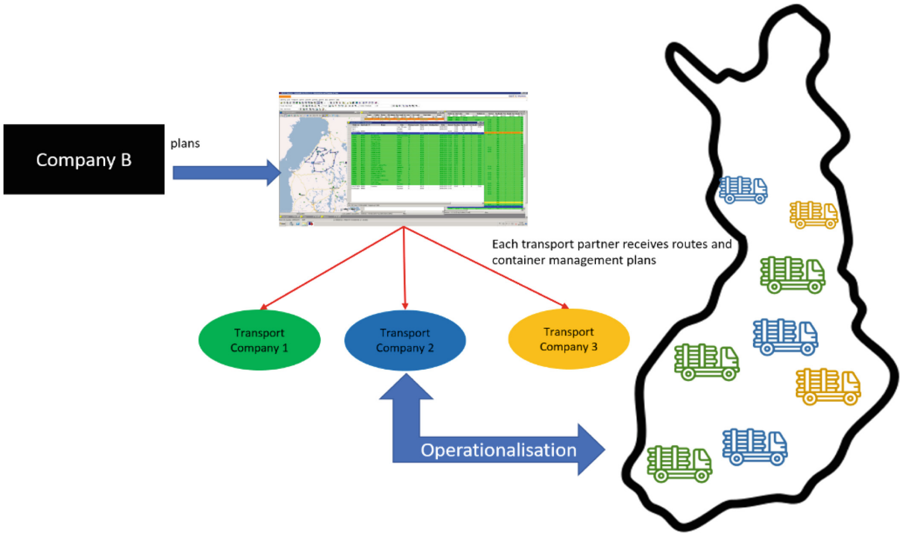

Fig. 2. Company B transportation set up

meat processing plants. The second is carcasses which are collected from around the country side. Figure 2 describes the transportation process for the carcass collection.

In terms of structure, company B does have its own logistics department, but they do not own a fleet of trucks. All of the transportation is done by subcontractors. Company B's business model revolves around containers – which they own - and are spread out over different locations. The freshness of the raw material is a critical factor in this industry. Company B's internal logistics operating system is already extremely advanced, and from the initial discussion it is already clear that they have some sort of routing algorithm for carcass collection. Company B's representative explained that the two key factors were based on the "cost" (distance) and the "retrieval time". This is because there are EU regulations dictating the time until when a carcass can be recycled. If this deadline is missed, the carcass is still collected, but is destroyed rather than recycled – therefore causing a net loss for company B. This highlights why these two were highly ranked as routing criteria. Additionally, the routing system also relies on a "home base" system, as in the timber trucking world as well. These ideas are also reflected in Table 2 which outlines some of the gleaned requirements from the discussion with company B.

Table 2. Requirements in the organic materials recycling context

Requirement	Problem Solved	Logistics Chain Link	Satellite Imagery Application
Home base + intermediate warehouses	Truck fleet subcontracting + maximising by product transportation from all of Finland to company B's production lines	Carcass and by product collection	"Live" status of containers (live tracking of containers) for: 1) moving containers, 2) stored containers at production facilities; or 3) intermediate warehouse management
Daily route planning for carcass collection and container routes	once a day is enough to set the routes	operations	
Minimise cost	Current routing algorithm minimises costs based on kms	operations/routing	
Collection Time	Current routing algorithm optimises route based on collection times for different carcasses (Most urgent first)		

5 Discussion and Conclusions

From the introduction, the main research question was defined as "Should logistics companies implement Remote Sensing Enabled Eco-Routing?". The secondary research questions were "What is eco-routing?", "What should be optimised?" and "How do we implement this using earth observation/remote sensing data?".

The first question is answered by the interviews. It is clear that in both industries – logging and organic materials recycling – the logistics aspect has been curated to be highly economically efficient. Both company A and company B do have some policies and interest with regards to sustainability, however this is not their top concern when it comes to routing. Both firms operate with a no-ownership principle in terms of trucks. It appears that company A is much less concerned as to how the transportation plans are executed, as there is a high level of clarity around what timber products should go where. According to our interviewee there is little to no room for optimisation. In company B's case, they have already spent a significant amount of resources constructing their own internal logistics system in order to fulfil their needs. The carcass collection process has potential for further optimisation using eco-routing principles, however it would still have to fulfil the minimum requirements of having a home base system, minimising kilometre cost, and ensuring that collection times are respected. Both firms showed interest in using satellite imagery and remote sensing to solve problems. However, both problems proposed in either industry fall outside of the realm of eco-routing. In the Forestry context, a lot was discussed around the use of satellite imagery to look at moisture levels and load bearing capacity of logging tracks. Additionally, other use cases included ditch-road level comparisons, as well as rut depth in existing forestry tracks. In the context of company B they showed an interest in managing and having an overview of their containers – especially around slaughterhouses, to explore optimisation opportunities there.

In terms of the technology requirements for company A, we have precedent to believe that moisture analysis for roads, and surrounding areas is feasible through the use of Special Sensor Microwave Imager/Sounder (SSMIS) Technology and Special Sensor Microwave Imager/Sounder (SMAP) L-Band Radar Technology [13, 14].

Change detection, which is the use case for company B, can be achieved through Synthetic Aperture Radar (SAR) technology [15], and is already implemented to some extent by players in the private market [8]. Despite the existing use case, the application of change detection to land transport would be novel.

The second research question is answered by the literature review in that Eco-routing is a specific practice in logistics of optimizing routes based on some objective function that includes ecological or environmentally relevant elements [9]. What should be optimised – we argue that the movement of the trucks, rather than the goods, should be optimised. Based on our interviews this would allow for more economical and ecological logistics.

The third question is about implementation. From our interviews it was clear that neither firm had use cases that were ready to experiment with the implementation of Eco Routing and Remote Sensing. However, on a theoretical level, an existing eco-routing algorithm could modify with additional parameters. These additional parameters would be fed with additional data coming from remote sensing to optimise a route based on known eco-routing parameters – e.g. route profile and road characteristics.

The conclusions that we can draw from here are: 1) further investigation, closer to the operational level is needed to understand the forestry context more deeply to see if it is truly as closed as system as company A made it out to be. 2) Collect and present use cases more clearly for potential users of satellite imagery for eco-routing. 3) Explore other industries to see if eco-routing in industry is something that is useful. The next steps are to address at least point 2 in more depth, and continue collaborating with industry players to understand their needs and address how satellite imagery could address them. Additionally, we will continue to investigate on how to ensure that satellite imagery in eco-routing can be achieved, also towards near real-time utilization, and presented in a more concrete manner so as to show stakeholders how this could benefit them.

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