UNDERSTANDING THE BARRIERS TO A SHIFT OF PROCESSED FOOD FROM ROAD TO RAIL THROUGH SYSTEM DYNAMICS

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ABSTRACT

One of the most important greenhouse gas (GHG) mitigation opportunities identified for the freight transport sector is a mode shift from road to rail. A system dynamics model was constructed to evaluate the drivers and barriers to such a mode shift and the impact on the wider economy. This paper focuses on the decision-making process that determines the movement of corridor freight, using processed food on the Cape Town-Gauteng corridor as a case study. In order that the model was an accurate representation which would facilitate discussion amongst decision makers, stakeholders were consulted as to the most important considerations in transporting processed food, their current perception of rail and the barriers to shifting to rail. Stakeholders included not only the decision makers, which included manufacturers of processed food and major retailers, but also Transnet, logistics companies, bodies lobbying government for a switch from road to rail and other experts. The paper presents the insights gained from stakeholder engagement and describes how it informed the construction of the decision-making routines in the system dynamics model. The relative importance of different decision making criteria and the tipping points in the system have begun to be identified, together with the implications of this for achieving a road to rail shift.

1 INTRODUCTION

South Africa's latest Greenhouse Gas Inventory indicates that in 2010 the transport sector contributed a total of 47.4 Mt CO_2e in direct greenhouse gas (GHG) emissions, or 8.4% of South Africa's emissions (DEA, 2013). Freight transport is thought to account for about half of the emissions from the combustion of transport fuels (CSIR, 2010).

The National Climate Change Response Policy identifies transport as a significant GHG emitting sector (Republic of South Africa, 2011). The Department of Environmental Affairs' DEROs (desired emission reduction outcomes) process currently underway aims to define DEROs for the transport sector (and possibly companies and subsectors within this) for which detailed GHG mitigation plans will be required. It is widely recognised that the most significant opportunity to reduce emissions in the freight transport sector is the shift from road to rail. Most mitigation modelling efforts tend to assume a linear (or other simple) transition to a desired future modal split, without much consideration of how this can be achieved. For example, the Mitigation Potential Analysis assumes a 70:30 rail to road split for freight transported along corridors is possible by 2050, based on work done in development of the Western Cape Infrastructure Plan (Palmer & Graham, 2013; DEA, 2014).

In this work, a system dynamics model is developed to facilitate a better understanding of the complexities of the freight transport system amongst decision makers, with a particular focus on the drivers and barriers to mode shift decisions. This paper describes the decision-making process used by freight owners in selecting one mode of transport over another. To capture the process of decision-making in the model, a wide range of stakeholders were consulted throughout the modelling process. This paper presents the insights gained from stakeholder consultations and describes how it informed the construction of the decision-making routines in the system dynamics model. The model itself is described in detail in a companion paper (van der Merwe et al., 2015).

The transport of processed food along the Cape Town-Gauteng corridor is used as a case study. The rationale behind this selection is that the nature of processed food and the distance of the selected corridor make it suitable for intermodal transport solutions even though currently most of this freight is transported by road (Transnet, 2012; Havenga et al., 2012). Further, processed foods make up a large portion of the total freight transported on this specific corridor (van Eeden & Havenga, 2010). For this case study, the relative importance of different decision making criteria and the tipping points in the system are in the process of being identified, together with the implications thereof for achieving a road to rail shift. An example is provided here in terms of the tipping points associated with the weighting applied to cost by a decision maker.

2 UNDERSTANDING THE SYSTEM

To construct a system dynamics model that provides a defensible representation of the freight transport system, it is important to understand the key system components and their behaviour. An important focus area that is relatively poorly understood is the decision-making process for selecting the mode of transport. To this end, initial phases of the work involved extensive stakeholder engagement in the form of workshops as well as one-on-one meetings with not only the decision makers, which included manufacturers of processed food and major retailers, but also Transnet, logistics companies, bodies lobbying government for a switch from road to rail and other experts and freight modellers.

Examples of the questions posed to stakeholders are presented in Figure 1.

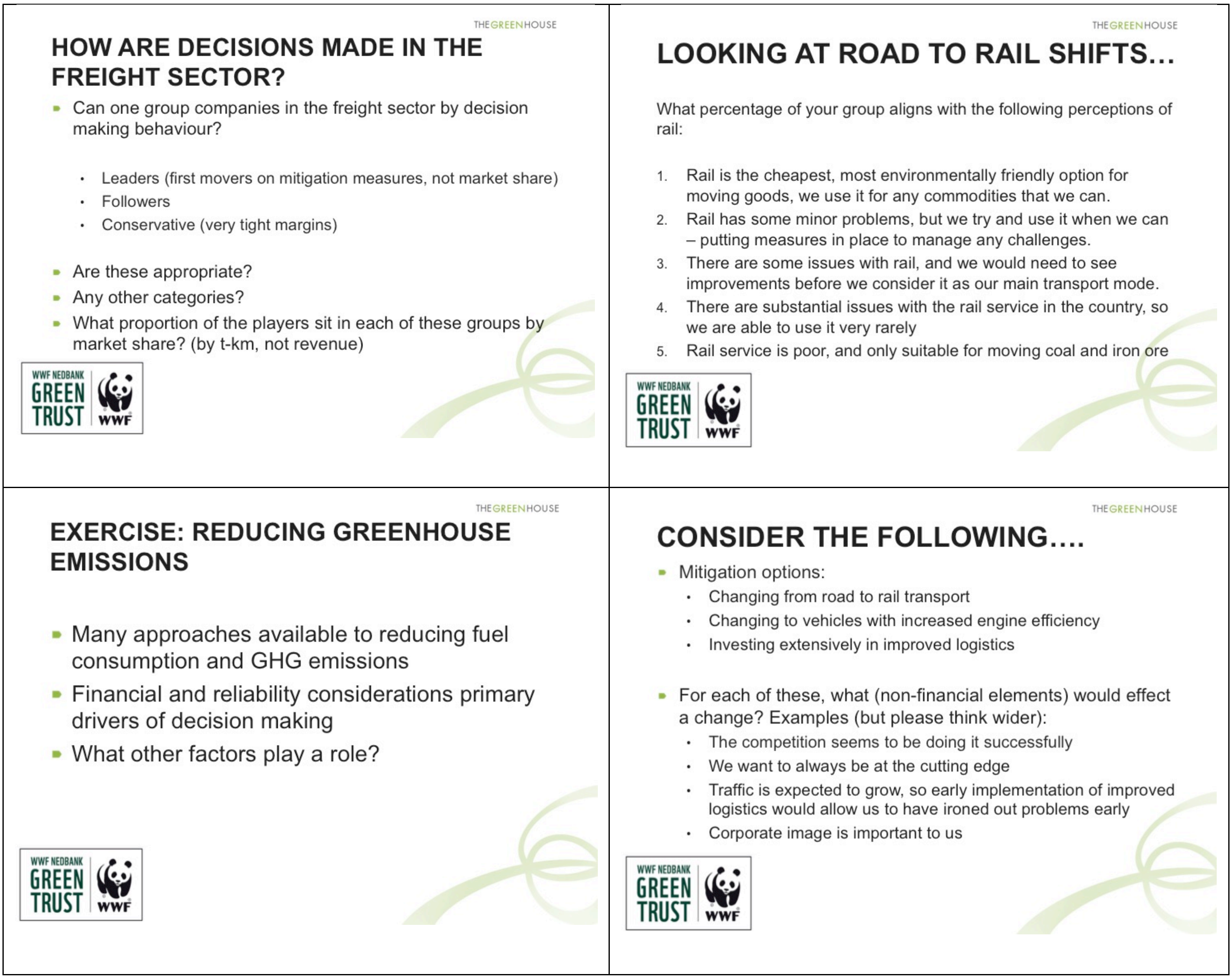

Figure 1: Examples of questions posed at various stakeholder workshops and forums.

Workshop activities also included the participants constructing causal loop diagrams to better understand the interactions in the system, an example of which is presented in Figure 2.

Figure 2: Causal loop diagram developed in a workshop unpacking the factors influencing mode choice and freight emissions.

2.1 The decision makers

The main decision makers identified through stakeholder engagements were:

- Freight owners;
- Vehicle fleet owners; and
- Railway owners and operators (i.e. Transnet).

Freight owners are responsible for deciding how their goods are transported (i.e. mode choice). Vehicle fleet owners transport goods by road and will make decisions regarding the efficiency of their fleet. Transnet owns and operates the railways and thus is responsible for decisions that affect the performance of this mode of transport.

It is recognised that the delineation between freight owners and vehicle fleet owners is artificial as some freight owners own and operate their own vehicle fleets, while others may only outsource a fraction of their transport needs. Nevertheless this simplification was deemed acceptable for the modelling purposes. Due to a lack of market information, it was not possible to further characterise the processed food freight market.

2.2 How mode shift decisions are made

The overwhelming response from freight owners was that the mode of freight transport needs to make business sense, and therefore cost is the most important criterion considered in decision-making. Although rail transport cost is lower than that of road transport on a Rand per tonne km basis, decision makers consider the total logistics cost, which include (CSIR, 2014):

- **Transport cost**: For road, this cost comprises fuel costs, driver wages, maintenance and repair of vehicles, depreciation, cost of capital, insurance, tyres, toll fees and licence fees (CSIR, 2014). For rail, the tariff is normally determined independently from the actual running cost of the rail service, and is influenced by markets, customers, pricing regulations, etc. The rail system is also more complex than road given that Transnet owns the infrastructure and operates the rolling stock, which means that investments in infrastructure upgrades and utilisation of infrastructure will also impact on the tariff (PPIAF, 2014).
- **Storage and handling cost**: This is the cost relating to warehousing and handling freight during transfers. The storage time is dependant on the reliability of freight shipments, while the handling time depends on the efficiency of distribution centres (DCs) and intermodal points.
- **Inventory carrying cost:** Inventory carrying cost includes the opportunity cost of capital and the cost for insurance and damages to freight. According to de Jager (2009), inventory carrying cost for the economy can be split into the cost while freight is in transport (11%) and that while freight is in storage (89%).
- **Management and administration cost**: These are company specific costs that vary across the industry, but relate to the size of company as well as the tonnage of freight transported. Utilising a dedicated logistics company to manage freight can also increase this cost.

Although cost is the most important aspect in decision-making regarding the mode of transport, it is not the only criterion considered. Some responses from freight owners and other stakeholders regarding other factors that impact on decision-making are as follows:

- "**Cost** and **service level to the stores** are the most important factors. In fact, service level is probably more important than cost. This links to the cost of delay and lack of goods on the shelf, but is also a **reputational issue**."
- "**Cost** and **sustainability** of the transport company"
- "Inventory levels are also important, therefore the **reliability** of the service is very important."
- "Finance and procurement are quick to say they want to switch because of cost. But the ultimate decision doesn't just look at the cost benefit, **quality and on-shelf availability are equally important**."
- "Quality, cost and sustainability."
- "Conversations in the industry have started changing and people are not just asking about profit, but **environmental impact** of companies."
- **"Cost** seems to be the main driver. Decisions are made for business. All the other parameters affect the cost (e.g. delays as a result of **poor reliability**, holding cost as a result of **long transport times**, or a carbon tax)."
- "**Reliability** is a very important factor. For our business, reliability is most important."
- "Other benefits like **emissions** and **jobs** will only be considered if **cost is on par**."
- "Our business model is built on service (**reliability/punctuality**) and **efficiency** (travel time and holding time of goods, as well as fuel savings) -

cost savings comes as a result of that. We may be willing to sacrifice cost for service, but want to deliver that level of quality to do that. This is our niche."

2.3 Stakeholder perceptions of rail transport

From the stakeholder engagements it became apparent that some stakeholders have ingrained perceptions of rail transport. While these may or may not be valid concerns, they do represent a barrier to a mode shift for processed food. It is noted that costs can be reduced and technical performance improved, but perceptions require a different set of measures to result in behavioural change.

The following concerns regarding rail transport were raised by stakeholders:

- "There is a perception of rail being dirty and unhygienic, with lots of dust and bad handling of goods."
- "Rail comes with quality control issues. Most processed foods are sensitive to humidity and temperature. Handling and storage of goods also impact on state in which the final product reaches the shelves. This makes rail less desirable."
- "Current rail infrastructure is an issue and not sufficient to handle more sensitive goods."
- "Other problems with rail are capacity and management and administration of the railway system, e.g. it takes ages to get a quote for rail transport, whereas trucks are almost immediate."
- "Rail might have additional cost of carrying as a result of the extra packaging materials required to minimise damage to product. Much work has been done on light weighting of packaging materials to reduce fuel consumption of trucks, which will no longer be appropriate on rail. This increased weight will result in associated increased energy consumption and more emissions due to manufacturing of packaging materials."
- "Railway costs are not transparent: Railway used to have "price list", but now negotiations are done individually with each company."

3 TRANSLATING THIS UNDERSTANDING INTO THE SYSTEM DYNAMICS MODEL

The understanding gained from stakeholder engagements was applied in the model by first characterising different types of freight owners and vehicle fleet operators, and secondly defining their decision-making behaviours based on their priorities and requirements.

3.1 Defining decision maker types

In the model, three freight owner decision maker types were distinguished:

- **Cost focused:** Cost is identified as the main driver for this type of decision maker. Typical companies have large volume products that serve the majority of consumers;
- **Reputation focused:** Reliability is the main driver for this decision maker. Environmental issues are also considered to enhance the brand value. Typical companies cater for a higher-end market with consumers willing to pay more for better quality and consistent availability of products; and,

- **Sustainability focused:** For the client WWF, this represents the client of their aspirations, one who makes decisions for the greater good. Priorities are to reduce emissions, increase employment and reduce externality costs. This may represent the focus of a government decision maker attempting to drive more of a development agenda.

In terms of the current landscape of processed food freight owners, it is assumed that the market consists of 90% cost focused decision makers with the remainder being reputation focused. Sustainability focused decision makers were judged to be substantially non-existent at present.

Within vehicle fleet companies, a distinction was made between two types of decision makers:

- **First adopters:** Typically larger freight logistics companies with more stringent maintenance and driver training programs. At the forefront of adopting new technologies to improve vehicle efficiency and have more capital, which therefore allow for longer payback periods.
- **Late adopters:** Smaller companies or one-man driver and truck operations. Sometimes these decision makers utilise second-hand trucks and drivers do not typically receive driver training. Capital is limited, therefore these types of fleet owners rarely consider adopting new technologies if not required by law.

Further assumptions were required to define the composition of the fleet that services each freight owner type. The default values are presented in Table 1.

Table 1: Assumed fleet composition for processed food freight owner types

	Reputation focused	Cost focused	Comments
First adopters	90%	30%	Reputation focused freight owners predominantly use first adopter fleets. Occasionally make use of late adopter trucks during times of high demand. Cost focused decision makers utilise a far greater percentage of late adopter fleets.
Late adopters	10%	70%	

3.2 Defining decision making behaviour

Freight owner decision-making is assumed in this work to follow a bounded rational decision-making process. Bounded rationality is a theory that purports to more realistically portray how decisions are made in organisations (Robbins et al., 2010). As opposed to rational decision-making, where it is assumed that all information is at the disposal of the decision maker, bounded rationality only considers decision-making criteria that are available and readily understood by the decision maker. To evaluate alternatives in the decision-making process, weightings specific to each decision maker are applied to the criteria considered.

The decision-making criteria included in the model are:

- **Total logistics cost:** the total cost paid by the decision maker to transport freight;
- **Reliability:** punctuality of the mode of transport;
- **Emissions:** emissions associated with the mode of transport;
- **Jobs:** job creation associated with the mode of transport; and
- **Externality cost:** wider cost to the economy as a result of utilising this mode of transport.

The cost focused freight owner puts the largest weighting on cost for decision-making, but also factors in the reliability of the mode of transport to an extent. Reputation focused freight owners consider reliability as the most important criterion, with cost second. This decision maker sometimes also considers emissions as this aligns with the company's values and enhances its reputation. The default assigned decision-making weightings are presented in Table 3.

Table 3: Decision-making weightings

Variable	Cost focused	Reputation focused
Cost	70%	40%
Reliability	30%	55%
Emissions	0%	5%
Jobs	0%	0%
Externality cost	0%	0%

In line with the bounded rationality approach, the more uncertain criteria (job creation and externality costs), which are largely unknown to the decision maker, are weighted zero. These criteria are included in the model structure for completeness and in order to be able to test their impact on model outcomes.

Based on stakeholder input, and to address the fact that decision makers often settle for a satisfying option rather than an optimal one, minimum requirements for cost and reliability variables are built into the model. These are user input buttons that act as hurdles that must be satisfied before the bounded rational decision-making process is considered:

- **Cost**: cost of rail must be equal to, or lower than, that of road;
- **Reliability**: punctuality of rail must be equal to, or better than, that of road.

If these above conditions are satisfied, the weighted decision making criteria (variables from the model with user assigned weightings per freight owner type) are evaluated for road vs. rail. Other bounds fixed in the model are[1]:

- If the values for road and rail are within 10% of each other for a specific variable, the criterion will not be considered in the decision making process; this difference is deemed insignificant; and
- A difference greater than 100% between road and rail are defaulted to 100% difference; larger differences cannot be processed by the decision maker and are therefore irrelevant to decision making.

[1] These bounds were informed by personal communication with Prof. T. Stewart from the University of Cape Town.

Once the selected decision-making criteria have been assessed, the decision outcome is evaluated indicating whether rail is a more desirable mode than road. If this is the case, the demand for rail will be activated. Mode shifts are not assumed to occur instantaneously in the model and are phased in over a number of years to account for lags in the system including contractual considerations, the need for implementing new systems etc.

4 USING THE MODEL TO IDENTIFY TIPPING POINTS, BARRIERS TO RAIL AND LEVERAGE POINTS IN THE SYSTEM TO DRIVE A ROAD TO RAIL SHIFT

Based on the default weightings as simulated for the different decision makers it is projected that 53% of the cost focused processed food freight will be on rail by 2050, while only 25% of the reputation focused freight moves to rail. It is noted that the model aligns with Transnet's classification of freight, which identifies a portion of freight that is more suitable for road transport and will likely remain on road (approximately 47% of total processed food freight (Transnet, 2014a)). More detailed model results can be found in van der Merwe, et al. (2015).

The real benefit of this system dynamics model lies in evaluating the sensitivity of model outputs to decision-making weightings and impacts of external measures. The latter include planning, economic, regulatory and technological mitigation measures (see van der Merwe, et al. (2015) for more detail on measures included in the model). In testing the sensitivity of these input parameters to the model, tipping points can be identified that will inform the type of mitigation measures and the extent to which these should be implemented, to achieve the desired outcomes: a road to rail shift.

4.1 Tipping points: decision maker weightings

For decision-making where only cost and reliability are considered as criteria (which is the case for the cost focussed decision maker), the model is more sensitive to an increased weighting on reliability than on cost. This is due to the difference in road and rail punctuality (a measure of reliability) being larger than the difference in cost. The tipping points for the cost focussed decision maker are graphically presented in Figure 3. The tipping points are identified at cost weighting percentages of 40% and 70%. For cost weightings larger than 70% all freight of this decision maker will shift to rail by the year 2019, whereas for weightings below 40% no freight will shift to rail over the simulation period. Decreasing the cost weighting from 70% to 40% results in freight shifting incrementally later to rail.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
0%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45%	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	24	25	25	25	25	25	25	25	25	25	25	25
50%	0	1	1	0	0	10	22	22	22	22	22	22	23	23	23	23	23	23	23	23	24	24	24	24	24	24	24	24	25	25	25	25	25	25	25	25	25	25	25
55%	0	1	1	0	10	22	22	22	22	22	22	22	23	23	23	23	23	23	23	23	24	24	24	24	24	24	24	24	25	25	25	25	25	39	54	54	54	54	54
60%	0	1	1	9	22	22	22	22	22	22	22	22	23	23	23	23	23	23	23	23	24	24	24	37	52	52	52	52	53	53	53	53	53	53	53	54	54	54	54
65%	0	1	1	9	22	22	22	22	22	22	22	22	23	35	49	49	50	50	50	50	51	51	51	51	51	52	52	52	52	52	53	53	53	53	53	53	53	53	53
70%	0	1	1	9	22	22	34	48	48	48	48	48	49	49	49	49	50	50	50	50	50	50	51	51	51	51	52	52	52	52	52	52	53	53	53	53	53	53	53
75%	0	1	1	9	22	22	34	48	48	48	48	48	49	49	49	49	50	50	50	50	50	50	51	51	51	51	52	52	52	52	52	52	53	53	53	53	53	53	53
80%	0	1	1	9	22	22	34	48	48	48	48	48	49	49	49	49	50	50	50	50	50	50	51	51	51	51	52	52	52	52	52	52	53	53	53	53	53	53	53
85%	0	1	1	9	22	22	34	48	48	48	48	48	49	49	49	49	50	50	50	50	50	50	51	51	51	51	52	52	52	52	52	52	53	53	53	53	53	53	53
90%	0	1	1	9	22	22	34	48	48	48	48	48	49	49	49	49	50	50	50	50	50	50	51	51	51	51	52	52	52	52	52	52	53	53	53	53	53	53	53
95%	0	1	1	9	22	22	34	48	48	48	48	48	49	49	49	49	50	50	50	50	50	50	51	51	51	51	52	52	52	52	52	52	53	53	53	53	53	53	53
100%	0	1	1	9	22	22	34	48	48	48	48	48	49	49	49	49	50	50	50	50	50	50	51	51	51	51	52	52	52	52	52	52	53	53	53	53	53	53	53

Figure 2: Cost Focussed Decision Maker Tipping Points: The percentage of freight on rail per year as cost weighting in decision making changes from 0% to 100%.

4.2 Identifying leverage points related to decision maker behaviour

Taking into consideration that the cost of delays is already captured as part of the total logistics cost of the model, the weighting of reliability in decision-making is to account for the decision-maker's perception of the mode of transport. Therefore, if Transnet were to put a focus on improving the reliability of rail services, as well as marketing these improvements to prospective clients, a change in perception may be realised (and less weighting assigned to reliability in decision-making). These rail improvements will also reduce rail logistics cost which should make rail transport even more desirable.

A weighting on emissions in the decision making process (as assigned for the reputation focussed decision maker) is one of the alternative criteria that can have positive impact on shifting freight to rail due to the lower emissions of rail transport compared to that of road. If the decision-making process can't be influenced, implementing certain mitigation measures is hypothesised to have similar results, for example taxing road emissions, or raising fuel levies or toll fees. The most effective mitigation measures and extent to which they should be implemented to positively impact the system are still being determined.

5 FURTHER WORK

At the time of writing further model analysis was underway to identify tipping points related to other model parameters and system changes including:

- Increasing traffic volumes
- Deteriorating road conditions
- The distance between intermodal links and origin and destination points
- The impact of high speed rail and/or dedicated rail without additional stoppages
- Improved rail reliability and performance
- A carbon tax
- Fuel levies and road tolls
- Driver wages and labour costs
- Subsidies for rail

Once this work has been completed it will be compiled into a technical report which details the model construction and operation, and a series of briefing papers which it is hoped will provide stakeholders with a deeper understanding of the factors that impact on greater uptake of the road to rail shift. As a final output, the model will be web-hosted[2] and available to the public. The web-based interface will allow users to adjust input parameters and see the resulting changes in model output thus increasing their understanding of the system and the impact of various measures on the freight system and the wider economy.

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