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GREEN CARGO MOVEMENT, LOCALITY: MEKONG REGION ACROSS LOCALITIES

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ABSTRACT: There is an issue in the identification of commonality across several localities associated with the problem of cargo movement via modes of transport other than the road. The approach in this paper considers movement from the locality of the multi-jurisdiction of the Mekong Region, an agglomeration of Myanmar, Thailand, Laos, Vietnam, Cambodia, and southern China. A mathematical approach was developed to analyze the impact of cargo movement away from the road transport sector to greener alternative rail mode. The analytical appreciation is considered from the review of large-scale cargo movement across the region. Results from the data analysis are indicative of an environmentally friendly or a green freight alternative. The mathematical model described in this paper is used to consider freight modal shifts under various infrastructure development scenarios. The outcome from the analysis results is the input into ongoing research to identify common mathematical functions across other jurisdictions. The conclusion is that there is a likelihood that common mathematical procedures are applicable in several localities.

Keywords: Mekong, GDP, Cargo, Mode

1. INTRODUCTION

The Mekong region in this context is defined to include seven localities namely the nation states of Myanmar, Thailand, Lao People's Democratic Republic (PDR), Cambodia, Vietnam and the two southern provinces of Guangxi and Yunnan within the People's Republic of China (PRC). The extent of the major infrastructure network is presented in Fig 1. The focus of this paper is the modal analysis of cargo or freight movement throughout the Mekong.

Within any region, the transport mode of cargo transport by road is an essential factor in economic activity and has historically played a strong role in the development of many areas across the globe. In many regions and countries with a single jurisdiction, there is a growing trend to develop strategies that move away from the dominance of cargo transport by road toward alternative environmental friendlier modes.

In a broader world context, almost all cargo movements are dependent on road transport. In for example, even in the European Union as reported in an earlier report [1], cargo movement in 2009 was dominated by the road sector. The road modal share for any of the major country members did not fall below sixty percent. This was true even in the case of Germany where twelve percent of cargo moves via the mode of inland water.

In France, the road cargo modal share is eighty percent increasing to eighty-five percent in the United Kingdom. Whilst the modal share by road in Italy is just over ninety percent. Thus, even in the context of the developed European Union cargo movement, road transport is the most significant mode. This dominance of the road sector makes it difficult to realize the objective of the European Union to reduce the dependence on road transport.

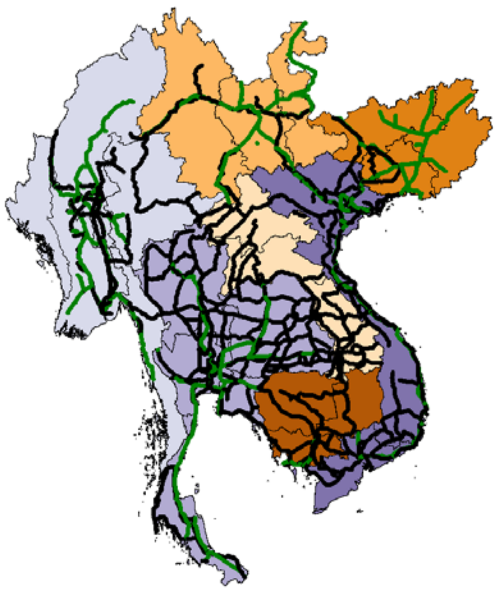

Fig. 1 The Mekong Region.

The Agenda 2020 of the European Union calls for member countries to reduce greenhouse gas emissions. There is implicit in this agenda within the Union the desirability of taxing fuels on road-based transport, [2] thus encouraging by financial incentives a modal shift away from the dominant road sector.

The Union is providing incentives towards a greener movement of freight with consequently fewer greenhouse emissions which in essence is to reduce the road component of cargo movement following the Paris Agreement on Climate Change [3,4]. This, of course, leads to the need for improving the alternatives to cargo movements by road.

2. THE REGIONAL SITUATION

There are two parts in the understanding of regional cargo movement namely the movement infrastructure, the transport supply and the actual amount and nature of cargo movement on the network, the demand side.

Within the framework of the regional transport network for the Mekong assembled as part of this research in the development of an analytical transport modeling tool, the primary regional road network identified as depicted in the earlier Fig. 1 is some 37,000 kilometers in length. The identified rail network is of some 17,000 kilometers in length. The length of the rail network is thus some 34% of the major transport corridor by comparison in length. There is a significant regional rail network although there are some missing connections between the earlier defined seven localities within the Mekong.

In addition to the land transport network, there are a further 10,000 kilometers each of Inland Waterway Transport (IWT) and Coastal Shipping or Sea Mode included in the transport network. For the movement of people an extensive air transport network is incorporated into the overall network framework.

The cargo road mode of transport is often driven by the lack of high-quality alternatives. In the understanding of the cargo transport demand today and that of the future, the key inputs are the macro economic indicators. These indicators reflect the overall development of each of the seven localities and the propensity for cargo movement.

2.1 Historical Activity Levels

Between 1998 and 2014, the Gross Domestic Product (GDP), as measured in constant US dollars in the base year of 2010 at market prices has grown at an overall of 8.6% per annum. The regional population has grown at 0.8% per annum. As depicted in Table 1, there is differential growth by locality with Myanmar registering the highest growth in GDP closely following by the two Chinese provinces. Thailand which is starting at a higher level of GDP also registers significant economic growth over this period.

Population growth is seen as the higher in the two larger population localities of Cambodia and Vietnam. The Lao PDR has the highest historical population growth albeit from a lower base.

The noted differential growth rates in the future are likely to lead to changes in the distribution of GDP Use at most three levels of headings that correspond to chapters, sections, and subsections.

Table 1 Locality growth per annum 1998 - 2014

Locality	GDP	Population
Cambodia	10.1%	1.4%
Guangxi, PRC	12.4%	0.1%
Yunnan, PRC	11.3%	0.9%
Lao PDR	9.7%	2.1%
Myanmar	13.4%	0.8%
Thailand	6.3%	0.7%
Viet Nam	8.6%	1.1%

2.1.1 Associated environmental concerns

The continued movement of cargo via the road mode especially over long distances will also lead to a continued increase in emission gases. This is not in alignment with the overall Paris environmental agreement. Whilst to some degree, such emissions from within cities for personal mobility have been contained. This is not the case for the movement of cargo, especially over long distances. Within the context of another large jurisdiction namely Egypt [5], the use of the road-based transport mode has increased exponentially in the last few years.

Whilst this phenomenon has fulfilled a variety of economic goals and expectations, unfettered growth is increasingly contributing to various negative environmental impacts. This high level of usage in Egypt is a historical consequence of pricing policies (such as the fuel subsidy), and “road focused” capital works programs. There is a beginning of an understanding of the notion that a more balanced approach to providing cargo mobility is desirable especially in respect to the transportation of cargo within the borders of Egypt.

For example, in another large country jurisdiction such as Australia, over the period 1990 to 2006, overall transport emissions grew by 27.4 percent, however, emissions from the movement of freight grew by 40 percent. Freight transport emissions now contribute around four percent of the national emissions total throughout the country and are forecast to more than treble to thirteen percent by 2020 as reported in a recent freight transport review paper [6].

3. METHODOLOGY

The most commonly used tool for understanding the movement of people or cargo throughout a defined geographical space is in the form of a transport model [7,8]. A classic four-step transport model is developed as the analytical tool for the examination of cargo movement through the region.

The structure for understanding movement within the Mekong is built initially from the understanding the existing regional movement.

Of course, cargo movement does not happen in isolation. The four-step procedure is followed both for the movement of cargo and people as depicted in Fig. 2. In the final step, the network assignment combines all movement across all transport network infrastructure. In fact, the performance of the road network is defined by both the movement of people and cargo.

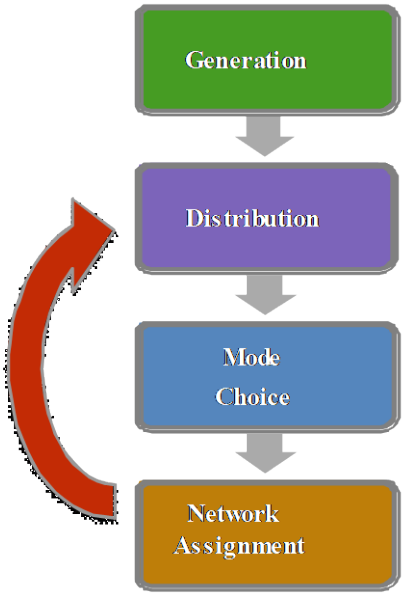

Fig. 2 The regional model structure.

3.1 Data Preparation

The base input data are a collation of databases available by locality held by the various responsible agencies throughout the region. The master transport network includes all known transport projects at present, both existing and proposed, that are incorporated into a master network with the potential opening year of any new project provided as a network parameter. At the same time, the economic and population datasets are prepared for the base time horizon of 2015 and a future time horizon of 2050.

The data is prepared in detail at the level of traffic analytical zone that corresponds to administrative boundaries with the amalgamation of smaller administrative areas into a single traffic zone.

The zone system adopted for the model is the same as that for the earlier 2006 GMS Transport Sector Strategy Study [9]. Within the two provinces of China, there are 30 zones. In Myanmar, there are 40 zones whilst Thailand has a total of 56 zones. There are 17 zones and 24 zones in Lao PDR and Cambodia respectively. Finally, Viet Nam has 49 zones. Thus, the model has a total of 216 internal zones. The total number of zones is 254 including 38 external zones of which 30 of the externals represent seaports.

3.2 The Key Inputs – Drivers of Future Demand

The two planning inputs, drivers of future cargo movements are the regional GDP and the population. The future economic and population projections are based on trend data except for Thailand [10], Myanmar [11] and Vietnam [12]. In these three localities, the economic and population projections were derived from the national transport databases.

3.2.1 Regional GDP distribution

The Mekong wide GDP is projected to increase at 6.2% per annum until the year 2025 and estimated to grow at 5% per annum thereafter until 2050. These overall projected growth rates are in line with earlier detailed historical growth rates [13] as well as those available from national transport databases. The key important change in the future is the forecast distribution balance of GDP. As earlier noted, the differential locality growth rates predict a change in regional economic distribution.

In 2015, as depicted in Fig 3., Thailand has nearly 40% of regional GDP. This is projected to decrease to under 20% by 2050. This share of GDP is transferred to the two Chinese provinces and Myanmar by 2050. By 2050, the two Chinese provinces are projected to increase their share of overall GDP by 15% from an initial 39% to 54% whereas Myanmar will increase its share of regional GDP from 7% to 10%. The remaining localities of Lao People's Democratic Republic (PDR), Cambodia, Vietnam are expected to maintain approximately their existing share of GDP.

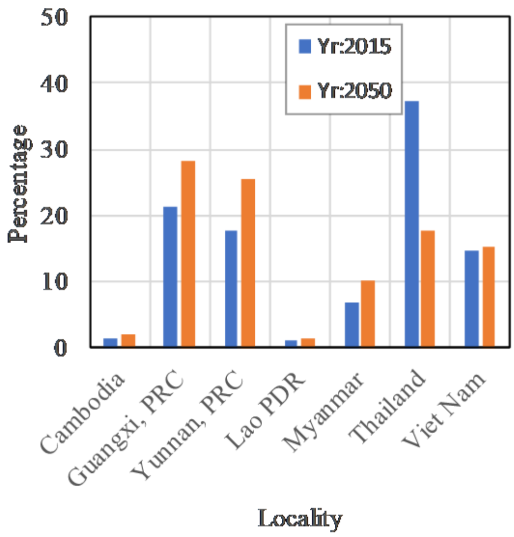

Fig. 3 Distribution of GDP by locality.

3.2.2 Regional Population Distribution

The regional population is projected to increase at 0.8% over the overall time horizon between 2015and 2050. Between 2015 and 2050, the regional population is anticipated to grow from 340 million to some 453 million people thus forming a potentially significant trading block. The regional population distribution is depicted in Fig 4.

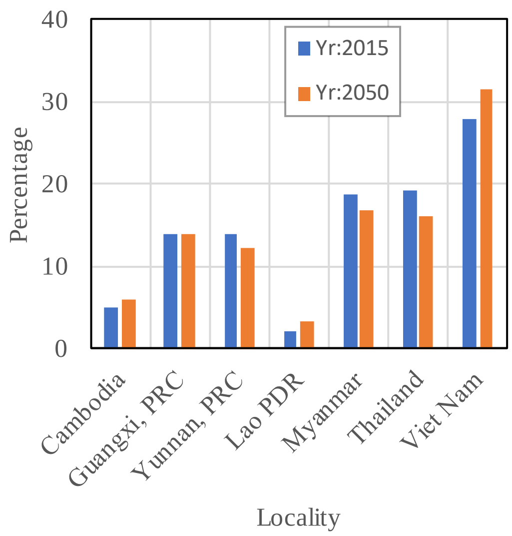

Fig. 4 Distribution of Population by locality.

Unlike GDP, the population distribution is unlikely to change significantly. The regional population share of Viet Nam increases from 28% to 32%. The regional population share of Thailand decreases by approximately three percent. The change in distribution in all other localities is less than 2%.

3.2.3 Impact of Distribution Change

The change in distribution between localities is important because such change will impact the likely future pattern exchange of cargo movement between the localities.

3.3 The Structure of Cargo Movement

For the analysis of cargo movements, the key modes represented within the model are a road, rail, inland waterways transport, and coastal shipping. The model developed is known as the Mekong Regional Transport Model henceforth referred to simply as the MRTM.

Cargo movement is divided into 5 commodity classifications. The MRTM was developed to produce forecasts of passenger and 5 categories of cargo movement by mode for the time horizons of the base year of 2015 and two future horizons of 2025 and 2050.

The parameters in the equations vary by locality and commodity group. The five commodity groups were summarized based on the international Harmonized System codes also referred to as simply the HS codes. These codes are an internationally standardized system of names and numbers to identify an individual product. The code is an 8-digit number but broad classifications are developed using the first two digits of the code.

Broadly the five commodity categories in numerical order one through to five are agriculture, processed food, wood products, chemicals, and miscellaneous goods. The link of the five commodity categories to the Harmonized System of coding is presented in Table 2 which tabulates the first two-digits of the HS code against the commodity category.

Table 2 Cargo commodity category

Category	Description	HS Code	
		Start	End
1	Agricultural	1	15
2	Processed Food	16	24
3	Chemical/Mineral	25	40
4	Wood/Skins	41	49
3	Chemical/Mineral	50	63
4	Wood/Skins	64	67
5	Miscellaneous	68	97

4. THE ANALYSIS

The focus of this research as stated earlier is on the modal allocation and the key input parameters namely the population and GDP. However, prior to the modal allocation step, there are the two earlier steps associated with the trip generation and distribution of cargo movement. Cargo movement generations are estimated by traffic zone via a relationship linking population and GDP per capita in a series of linear regression equations derived for each locality separately.

Cargo trip distribution used the Fratar growth factor distribution method [14] that takes as a base an existing distribution patterns sourced from an earlier Mekong study [9]. The trip distribution is across all localities so that there are not separate trip distribution procedures via locality.

For the mode split step, the commodity movement cost and travel times are the key inputs into the freight mode split model. The mode split structure for freight is a hierarchical three-level mode split logit model as depicted in Fig 5. The total cargo trips were distributed across four modes. At the first level, coastal trips are separated while at the second level, inland water transport trips are separated, with the final level being the allocation of movement between road and rail. In many cases, the mode choices were limited to road and rail since there was no logical route via other modes.

The master transport network of MRTM includes all known transport projects at present, both existing and proposed, that are incorporated into a master network with the potential opening year of any new project provided as a network parameter. In this manner, there is inbuilt flexibility as it is actually possible to develop the network other than for the two future time horizons of 2025 and 2050.

The structure of the binary logit equations is shown in Eq. 1.

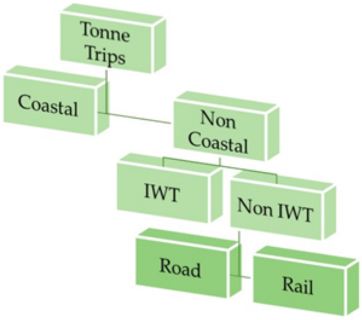

Fig. 5 Modal Allocation Structure

The cost of travel on alternative modes is referred to as the generalized cost of travel and is a function of time and cost.

$$P_1 = \frac{\exp^{V_1}}{\exp^{V_1} + \exp^{V_2}} \quad (1)$$

Equation (1) defines the probability of using mode 1 as opposed to mode 2 whereas V_1 and V_2 are the generalized travel costs associated with modes 1 and 2 respectively.

The variables in the determination of generalized travel cost are namely the travel time and the travel cost weighted by scale factors. These scale factors are presented in Table 4 by commodity category for each level of the modal analysis. The cost of travel by the various modes of travel was determined by locality.

The final step was the assignment or the allocation of the flow of people and freight to air, road, rail, inland waterway and coastal shipping networks. The final network travel times across the road network were estimated following a capacity restrained assignment.

In the case of the road network, the movement of persons by car and bus were converted into equivalent passenger car units together with the cargo-carrying trucks on the network. The impact of person and cargo trips were combined in consideration of the impact on the shared road network.

It was necessary to convert cargo movements allocated to road network into vehicles via load factors. The remaining freight trips do not use the road network except for access to the non-road network (e.g. truck to rail).

In the case of truck trips, there was also an implied back loading factor to allow for trucks returning from their destination without any load. The non-road trips are then assigned to their respective networks such as rail. This results in a final network that represented travel across all modes.

Table 4 Scale factors by commodity category

Category	Equation Level	Time	Cost
1	1	-0.2244	-0.0001
2	1	-0.0004	-0.0004
3	1	-0.0858	-0.0004
4	1	-0.0355	-0.0004
5	1	-0.0355	-0.0004
1	2	-0.0194	-0.0001
2	2	-0.0387	-0.0004
3	2	-0.0732	-0.0006
4	2	-0.0169	-0.0004
5	2	-0.0173	-0.0001
1	3	-0.3892	-0.0008
2	3	-0.2078	-0.0003
3	3	-0.176	-0.0008
4	3	-0.5941	-0.0034
5	3	-0.5891	-0.0006

Passenger vehicles and trucks share the road networks. For the traffic movements assigned to the road network, there is a feedback loop to adjust the road traffic speed until there is equilibrium across the network (i.e. that assumed input speeds match the actual output speeds after the traffic assignment). The travel time on the road network impacts the mode split of both person and cargo movement. All the assigned trips across all networks are combined into a single output network following the equilibrium procedure.

One potential bottleneck for the movement of cargo between the different localities is both the formality and physical barriers at international border crossing points. This is currently being addressed by various cross-regional organizations such as The Greater Mekong Rail Association. In the distant future scenario, these are resolved to facilitate economic prosperity.

4.1 The Model Validation

The validation of the model was undertaken from data sources not currently used as input data in the model development. Two such comparisons are discussed here. The base output from combined road vehicle movement in 2015 was validated against screen line traffic counts in Thailand in the north-west and south-east where such traffic has the potential to be traveling to locality crossing points. The screenline comparison of vehicle traffic was within 10%.

A Big Data comparison was made between the model estimation of the overall trade between

Thailand and the two localities of Yunnan and Guangxi in China via a comparison of the two custom databases. The estimation of trade between the two Chinese localities and Thailand is 1,409 tonnes on average per day in 2015 compared to an observed volume of 1,400 tonnes per day. The comparison is good.

5. RESULTS AND CONCLUSIONS

In the current situation incorporating all infrastructure proposals, there is a small modal shift in terms of tonne-kilometers of travel. However, this implies that significantly more effort is required to ensure a modal shift away from the road sector.

5.1 The Future Result

Cargo movement as measured in terms of tonne-kilometers of travel is estimated to grow at 4.9 % per annum between 2015 and 2025. However, as a result of the changing interaction between the economic parameters, the differential distribution of cargo across localities changes as depicted in Fig 6.

In 2015, Thailand has nearly 50% of regional cargo movements. This is projected to decrease to under 40% by 2050. This share of cargo is transferred across all localities by 2050. By 2050, the two Chinese provinces are projected to increase their share of overall cargo movements by 40% from an initial 14% to 20% whereas Myanmar will decrease its share of regional movement from 12% to 9%. The localities of Lao People's Democratic Republic (PDR) and Vietnam are expected to increase approximately their share of cargo movement.

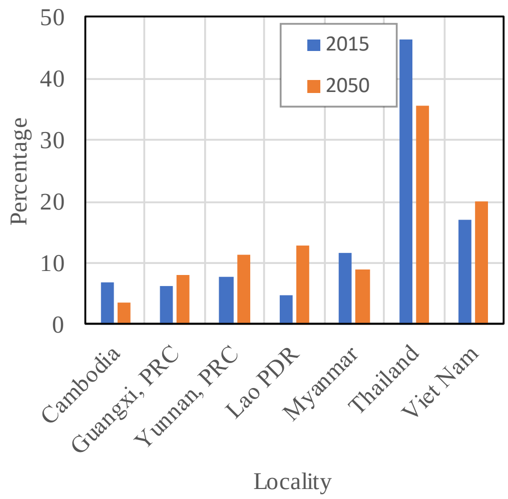

Fig. 6 Distribution of cargo travel by locality

In the current proposal incorporating all new rail infrastructure proposals of the seven localities, there is a small modal shift in the movement of cargo as reported in Table 5. The truck remains the dominant mode of transport across the region.

The modal share of the alternative non-road modes in combination increases nearly four times. The modal share increases in rail alone increase by nearly 150%. There is in this case also an estimated shift to IWT as a direct result of increased road congestion.

Table 5 Modal shift between 2015 and 2050

Mode	2015	2050
Truck	98.43%	96.29%
Rail	0.78%	1.30%
IWT	0.18%	0.24%
Sea	0.62%	2.17%

Another issue that arises from the continual maintenance of the high cargo modal split towards road movement is that by 2050, there is an estimated significant change in the distribution of road traffic across the region. As depicted in Fig. 7, by 2050, that there is a dramatic shift in the sharing of regional road space in terms of road movement as measured in terms of passenger car units.

Today, trucks account for 23% of all movements across the regional road network, the model developed in this research suggests that this will rise to 45% in a future scenario. This is a significant change and is likely to have an impact on traffic accidents.

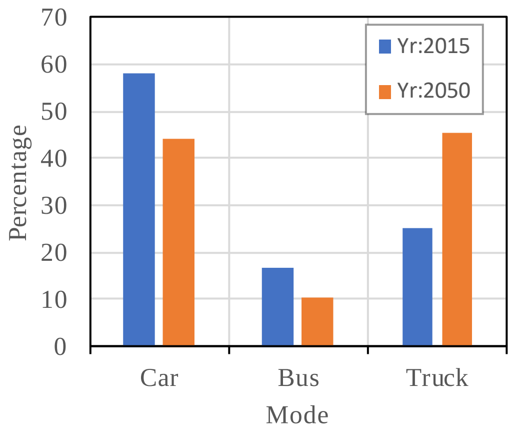

Fig. 7 Road Usage (pcu-km of travel)

5.2 The Future Result-Ultimate Scenario

In the case of an ultimate rail scenario such as the double tracking of the complete existing region rail together with improved border crossings, there is, in this case, an ultimate shift in cargo movement. The truck remains the dominant mode of transport across the region. The modal share of the alternative modes in combination increases nearly seven times.

The modal share increase in rail alone is of the order of five times higher as depicted in Table 6. The transport model prepared as part of this research is an analytical tool that is an initial starting point for researchers to understand the mobility of cargo throughout the Mekong.

Table 6 Modal comparison – increase infrastructure

Mode	2015	2050
Truck	98.43%	92.62%
Rail	0.78%	5.09%
IWT	0.18%	0.46%
Sea	0.62%	1.83%

If the localities of the Mekong are to consider a modal shift away from the road there will likely need to be a change in the pricing structure of the movement of cargo by road and rail. Such a change in cost is reported in a test case in Table 7.

Table 7 Modal comparison – cost differential

Mode	2015	2050
Truck	98.43%	89.48%
Rail	0.78%	7.90%
IWT	0.18%	0.45%
Sea	0.62%	2.15%

In this test case, the cost differential is changed with an increase in the cost of cargo movement by a truck whilst at the same decreasing the cost of cargo movement by rail. This suggests that there is a potential for the truck modal share of the movement of cargo across the Mekong to fall below the 90% level.

5.3 Feasibility of Green Cargo Shift

When considering the development of new infrastructure in the Mekong Region to assist in the transfer to Green freight movement, the desired modal split should be pursued in a realistic manner taking the growth trend in road cargo into account. Large increases in the sector capability of the non-road sector are implementable but difficult from a practical and economic point of view.

The long-term forecast for the region demographically in accordance with the various locality economic forecasts demonstrates via infrastructure development that it is possible to halt the fact that the road sector for cargo movements was continuing to approach the one hundred percent mark. Of course, such movement away from the road sector is not achievable overnight so that the mathematical model considers a thirty-five-year time frame for intermodal shift [15].

The dilemma is the establishment of Green Cargo Movement and the shifting of cargo movements from the dominant road mode to alternative modes. The development of the mathematical model for cargo movement has enabled the transport planner practitioner to advance the understanding of cargo movements and provide a numerical framework for understanding the impact of a green cargo modal

6. ACKNOWLEDGMENTS

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