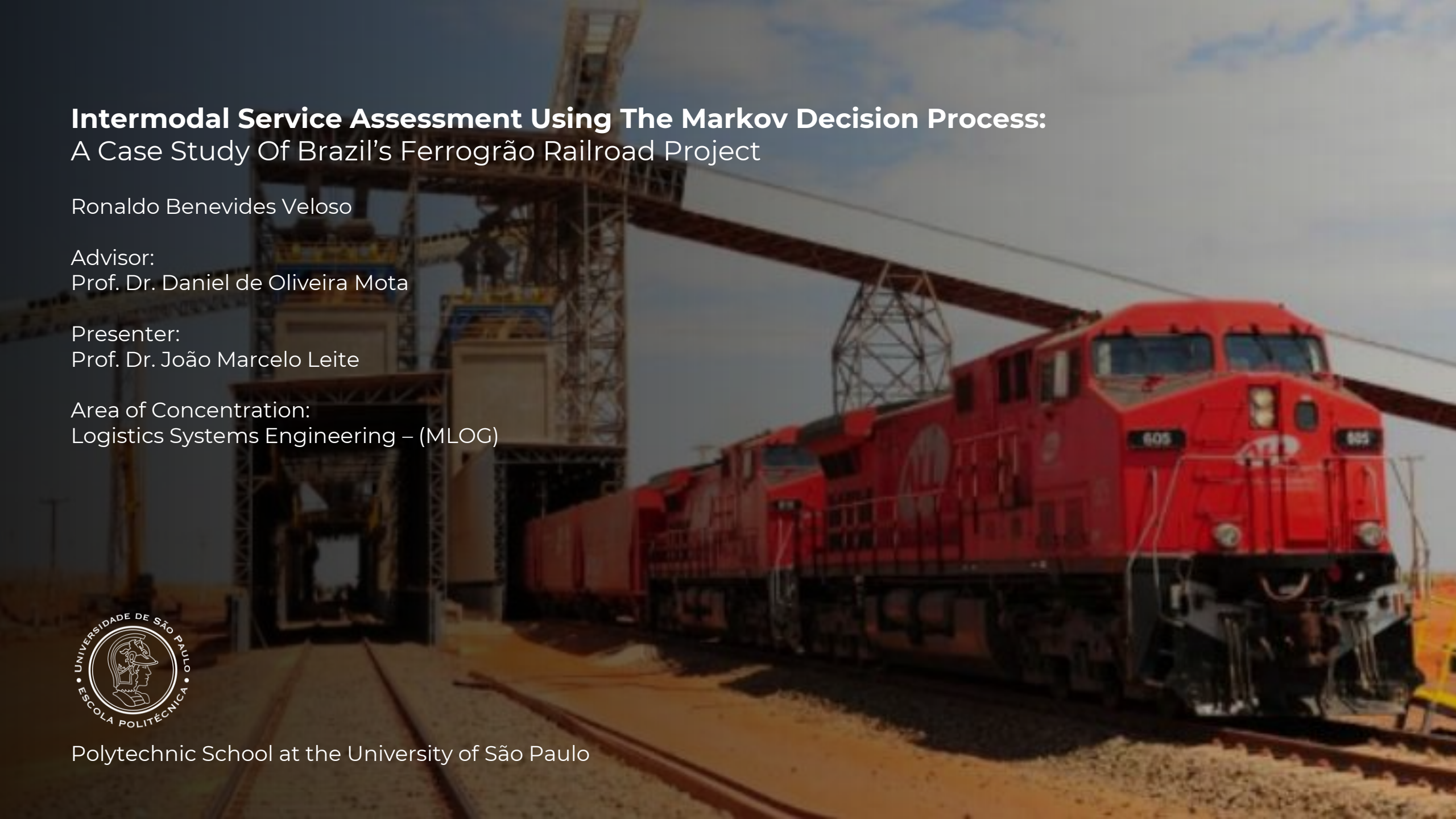

Intermodal Service Assessment Using The Markov Decision Process: A Case Study Of Brazil's Ferrogrão Railroad Project

Ronaldo Benevides Veloso

Advisor:
Prof. Dr. Daniel de Oliveira Mota

Presenter:
Prof. Dr. João Marcelo Leite

Area of Concentration:
Logistics Systems Engineering – (MLOG)

Polytechnic School at the University of São Paulo

AGENDA

- Motivation
- Problem Description
- Literature Review
  - Decision Support in Intermodal Transport
  - Mato Grosso’s soybean exports logistics
  - Markov Decision Process
- Methodology (ISA-MDP)
- Preliminary Results and Discussion
- Preliminary Conclusion

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Motivation

1. **Decisions on Transportation Infrastructure in Latin America:** competitiveness issue, economic development, inequality (Tiller; Till, 2017);

2. Brazil's rail infrastructure privatization process: higher volume, same extension (Sampaio et al., 2017);

   Brazilian cargo movement matrix (1993 – 2013): Road: 60%; **Rail: 20%;** Others: 20% (Casaca et al., 2017);

3. National Logistics Plan 2035. Priorities: **Agriculture** and Mining sectors (MINFRA, 2021);

   Agriculture: **EF-170**, FICO, FIOL.

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Problem Description

1. Brazil & China: strongest soybean trade route: 60M tons/year (38%);

2. China: population growth, urban migration and rising per capita income (He et al., 2021);

   Changes in eating habits;

   Soybean: primary source for converting plant-based protein into animal protein;

   Main import country: 91.6M tons (58%)

3. Brazil: largest soybean producer (130.5M tons/year - 38%) and export country (79M tons/year - 51%)

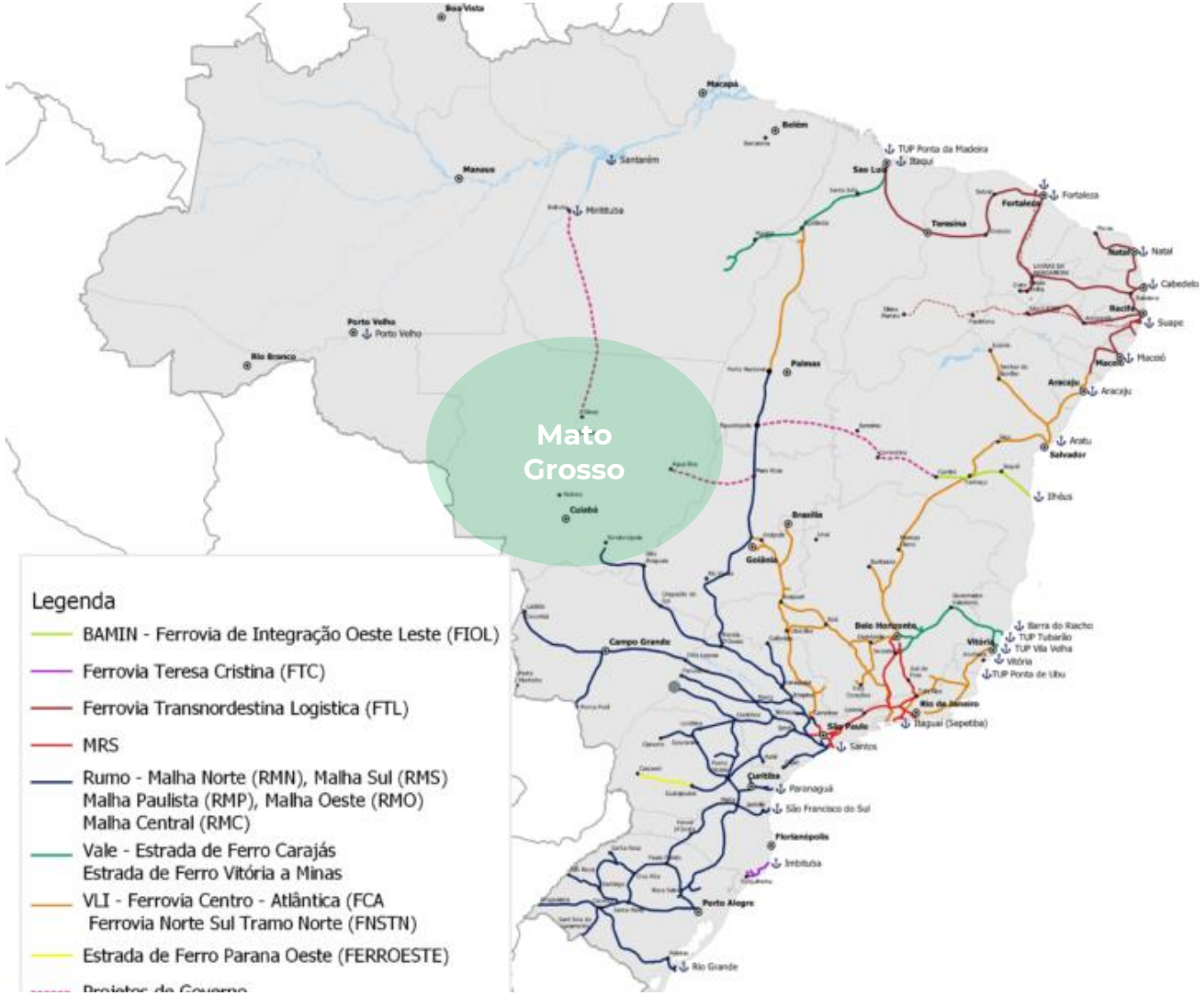
   Mato Grosso is the main production state: 35M tons produced. **~25% of Brazilian production**;

   Mato Grosso exports: 24M tons. **~70% of MT production**;

   MT logistics: Transportation costs correspond to **~15% of FOB port prices** (SALIN, 2023);

Sources: (USDA, 2023; IBGE, 2023, MDIC, 2023; SALIN, 2023)

Brazil’s Railway Network



Mato Grosso' Soybean Exports Logistics

MT-322: Connection to São Luís corridor

BR-163: Connection to Santarém (Belém corridor)

Problem Description

1. **EF-170** (Ferrogrão): **new corridor to replace BR-163** roadway traffic to the Northern Ports;

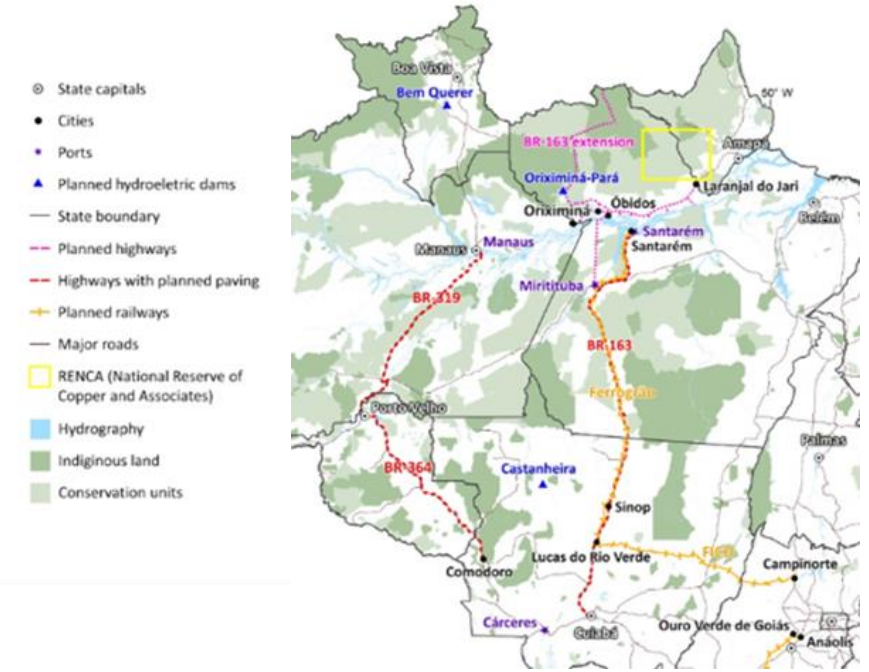
2. Decision process has been **questioned in Federal Supreme Court;**

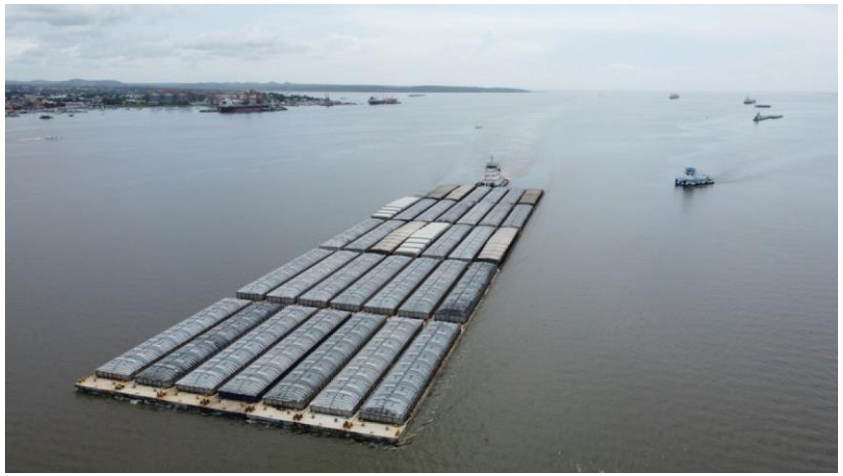
3. **Weaknesses** related to the Environmental Impact Assessment **(EIA)** and socio-economic evaluation;

   Determination of the **area under project influence**.

   Externalities mapping and quantification;

   Strategies to tackle the project liabilities.





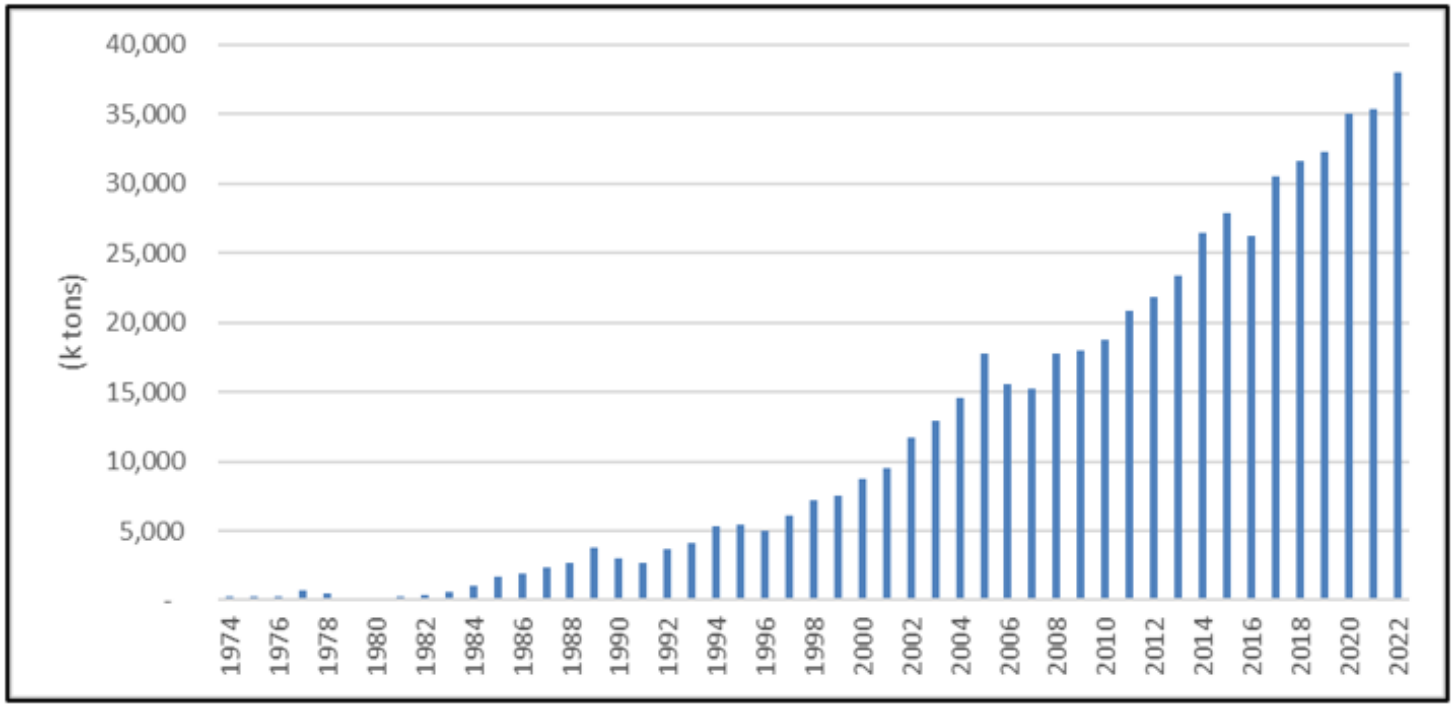
Barge Transport

Source: (GADELHA, 2023)

Mato Grosso' Soybean Exports Logistics

CONTEXT OF SOYBEAN PRODUCTION

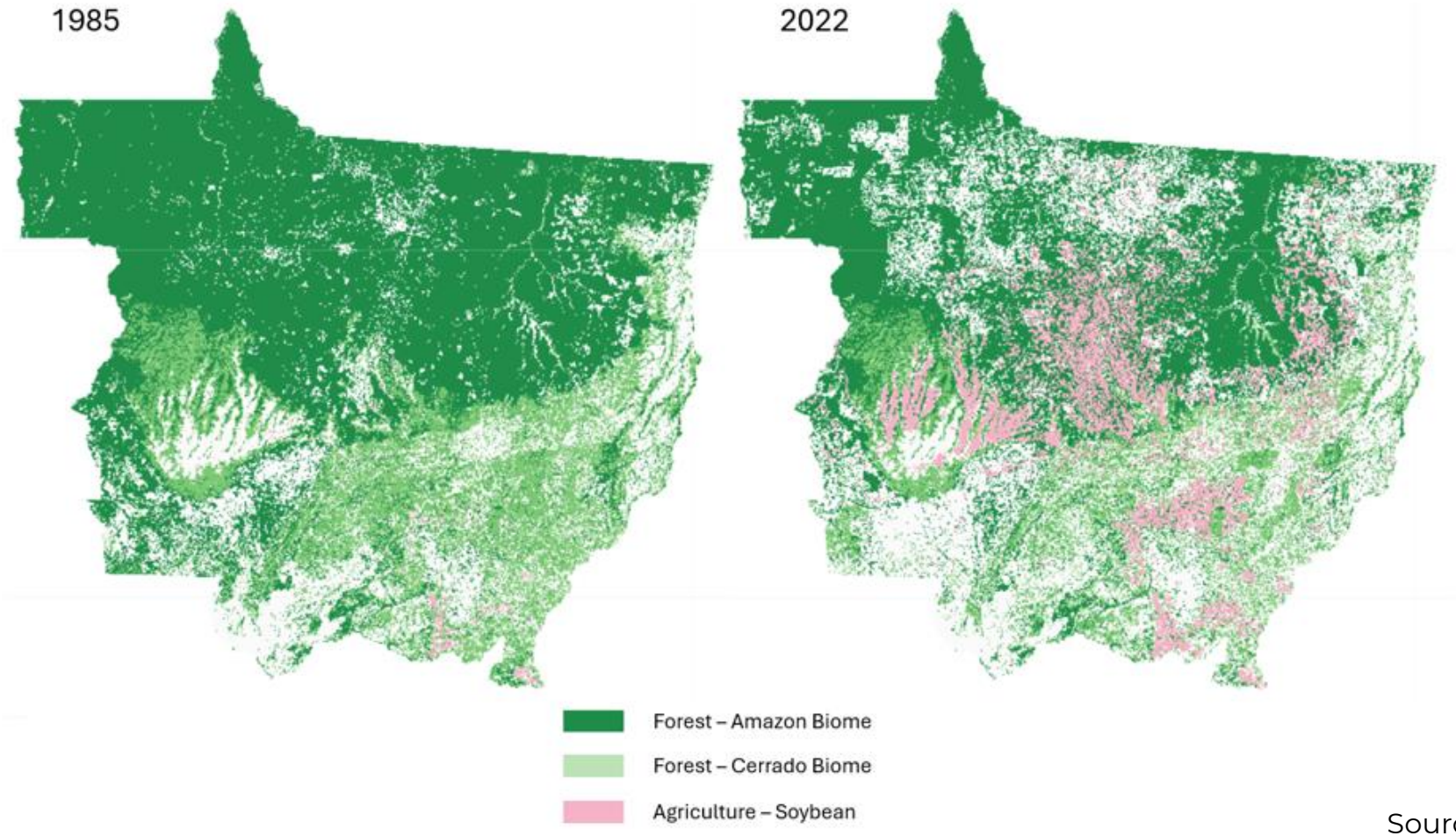
In 1985, 87% of Mato Grosso's area was classified as forest, with only 0.5% designated as soybean croplands, cultivated solely across 420 thousand hectares in the southeast portion of the state. Thirty-seven years later, the proportion of forest declined to 72%, while soybean croplands drastically increased to 15%, covering 10 million hectares.



Source: (IBGE, 2023)

Mato Grosso' Soybean Exports Logistics

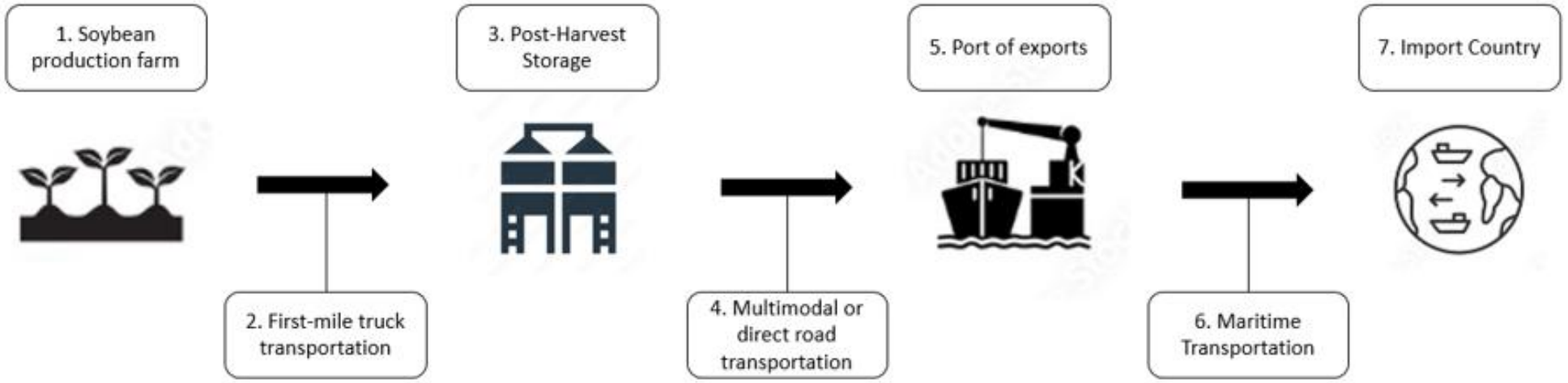
CONTEXT OF SOYBEAN PRODUCTION



Source: (MAPBIOMAS, 2024)

Mato Grosso' Soybean Exports Logistics

CONTEXT OF SOYBEAN PRODUCTION: DECISION MAKERS



The agricultural census in MT demonstrated a **significant level of land concentration.** In 2020, **only six companies** — Bunge, Cargill, ADM, Dreyfus, COFCO, and Amaggi:

1. **represented almost 15% of the total storage infrastructure capacity**, with more than 10 million tons of static capacity;
2. were **responsible for 63% of the total export volume from Mato Grosso**, totaling almost 14 million tons;
3. were **responsible for 78% of the soybean acquired** (directly and indirectly).

Source: (CONAB, 2022; IBGE, 2023; TRASE, 2024)

Mato Grosso' Soybean Exports Logistics

MT'S EXPORTS CORRIDORS

Export Corridor	Axis	Port of Export	Mode of Access	Transshipment Station	Volume (mmt) 2021/22	Estimated Mode Share (% of port total)	Port Share (% of MT exports)	Main Destination
Southeast	Santos	Santos	Railway (RMN)	Alto Araguaia; Itiquira; Rondonópolis	8,386	75%	46%	China (83%)
			Roadway	-	2,764	25%		
North	Tapajós	Belém Barcarena	Waterway (Tapajós)	Itaituba	4,390	67%	27%	China (36%), Europe (32%)
			Roadway	-	2,130	33%		
North	Madeira	Manaus Itacoatiara	Waterway (Madeira)	Porto Velho	1,660	~95%	7%	Europe, Africa, Mexico
		Santarém			1,045		6%	
Northeast	São Luís	São Luís	Railway (FNS)	Porto Nacional; Palmeirante	1,846	~100%	8%	China (75%)
Others							6%	

Source: (ANTT, 2023; ANTAQ, 2023; MDIC, 2023)

Problem Description

PRIMARY OBJECTIVE: to establish a methodology to support both private and public decision-makers in evaluating long-term intermodal infrastructure projects and services.

SPECIFIC OBJECTIVE: to contribute to the Ferrograo debate by addressing two fundamental questions:

i. How will the new terminal in Sinop change the soybean export traffic flow and reshape the hinterlands of the export ports?

ii. Based on the determined economic zone of influence of the Sinop terminal, what is the magnitude of the economic, social, and environmental impacts of EF-170 project?

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Decision Support in Intermodal Transport

1. Intermodal transportation refers to the movement of passengers or **freight** from an origin to a destination **using multiple modes of transportation** (SLACK; RODRIGUE, 2020);

2. **Terminals**: central and intermediate locations that serve as points of cargo transfer between modes of transport. They are **essential links** that **demand substantial infrastructure and capital investments** (SLACK; RODRIGUE, 2020);

3. Railroad infrastructure and intermodal services necessitates thorough planning across **strategic**, **tactical**, and **operational** decision-making levels in transport operations (CRAINIC; LAPORTE, 1997);

   - **Strategic level:** network design and location models;
   - **Tactical level:** service network design problems;
   - **Operational level:** operational capabilities which determine system performance.

Decision Support in Intermodal Transport

DECISION MODELS IN LITERATURE

Reference	Geography of scope	Contribution
Crainic et al. (1990) – STAN model	Brazil, Sweden, UK, Finland, Spain, US	Soybean network benchmark; Concept of baseline vs modified scenario.
Jourquin et al. (1999)	Belgium - Italy	Set of performance indicators for service evaluation.
Southworth et al. (2000)	US	Logic of edges and nodes for intermodal representation; Connection with Geographic Information Systems (GIS).
Macharis et al. (2009) – LAMBIT model	Belgium	Terminal zone of influence concept beyond construction area; Connection of intermodal evaluation and shortest path problem.
Macharis et al. (2009) – LAMBIT model	Belgium	Application of internalization of external costs concept.
Tsamboulas et al. (2007)	Europe	Connection between externalities and the strategies and action plans to tackle with them.

Decision Support in Intermodal Transport

DECISION MODELS IN LITERATURE

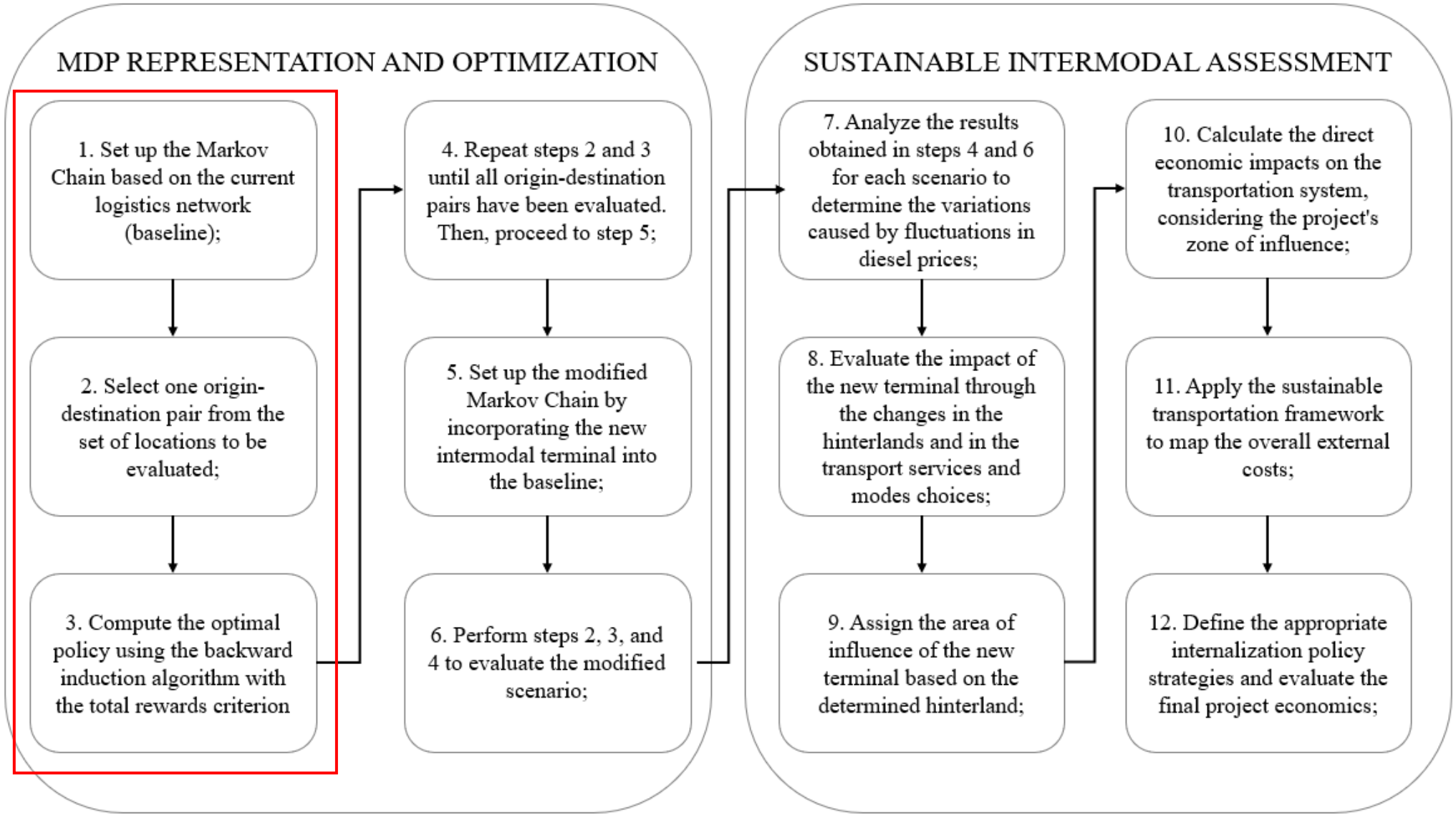
Reference	Contribution
Rahimi et al. (2008)	Strategic importance of considering the external costs; Competition effect between infrastructure projects.
Arnold et al. (2004)	Connection between individual shortest route computation and the transportation system total cost optimization;
Niérat (1997)	Micro-economic concept of market area as an important element to be evaluated.
Vidovic et al. (2010)	Importance of determining the terminal's zone of influence when resolving terminal location problem.
Iannone (2012)	Use of hinterlands to evaluate the impact on the transportation system.

Mato Grosso' Soybean Exports Logistics

EF-170 RAILROAD PROJECT (FERROGRÃO)

Reference	Contribution
Rocha and Caixeta-Filho (2018)	- Confirmation of Sinop as the optimal location for the intermodal terminal; - Estimated an average reduction of $8 per ton in transportation costs and a shift in volume from the Port of Santos to the Northern Arc Ports.
Branco et al. (2021)	- Positive results from transportation cost reductions and decreased CO2 emissions perspective; - Ferrogrão would become one of the most important intermodal routes by 2050.
Branco et al. (2022)	- Market shares for the Ferrogrão railway and barge transportation would increase; - Reduction in freight costs and CO2 emissions by 15% each.
Costa et al. (2022)	- Reduction in transportation costs by approximately 30%; - Only 5% of the cargo from Ferrogrão would migrate to FICO and FIOL,
Costa et al. (2020)	- Estimated area affected by the project is significantly larger than indicated by the legislative methodology; - 57% of the municipalities are classified as high soybean productivity areas.
Costa et al. (2021)	- Discussion on Matupá terminal is that it would intensify traffic on the MT-322 roadway, which crosses the Xingu Indigenous Territory; - It is estimated that 230 thousand ha could be deforested by 2035.
Assuncao et al. (2020)	- Deforestation by 2,043 square kilometers in the state of Mato Grosso.
Loch et al. (2020)	- Project's average commercial speed might have been overestimated.

Intermodal Service Assessment MDP (ISA-MDP)



Markov Chain Representation

1. A finite-horizon MDP has been developed to model the Brazilian soybean export chain. In this model, the **trading company is the agent** making route decisions. At the tactical level, this entity operates the unimodal or intermodal service network, utilizing the **transport infrastructure established by public authorities**, who are responsible for strategic decisions concerning transportation network design and terminal locations;

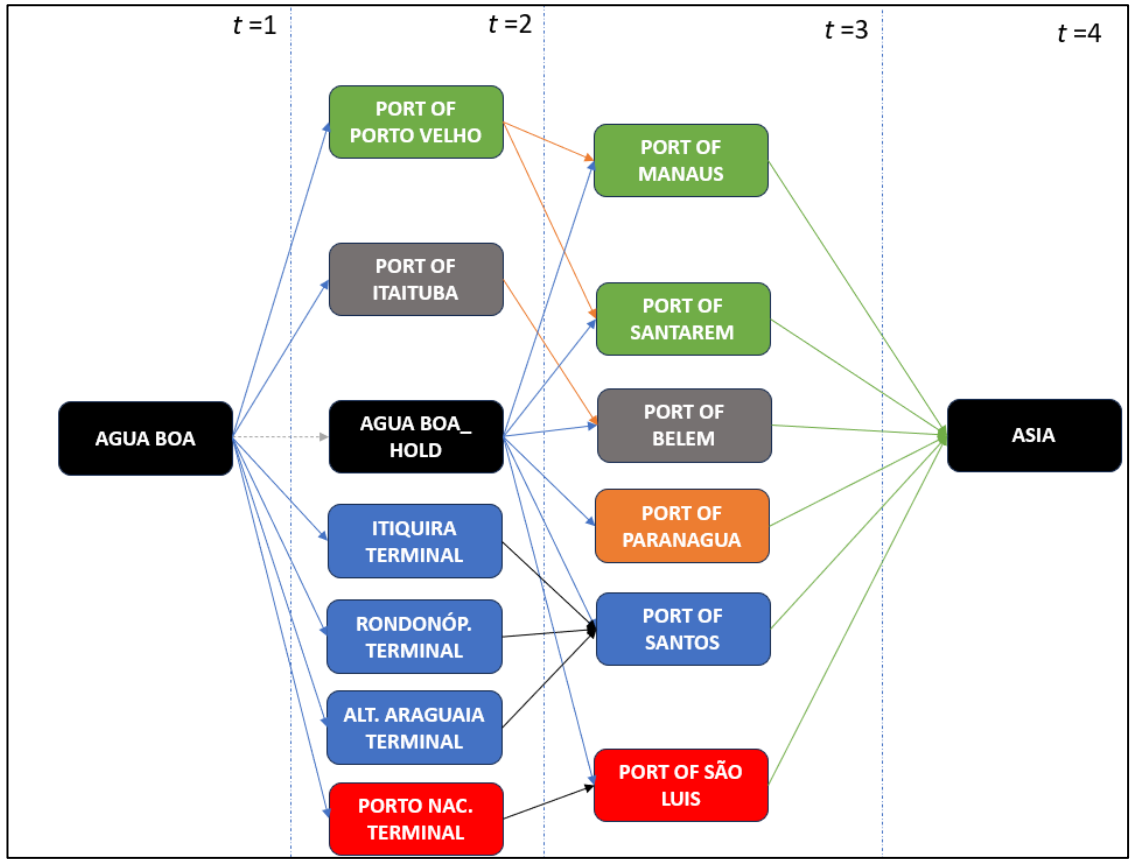
2. The basic unit moved through the system is a 60-kilogram soybean bag;

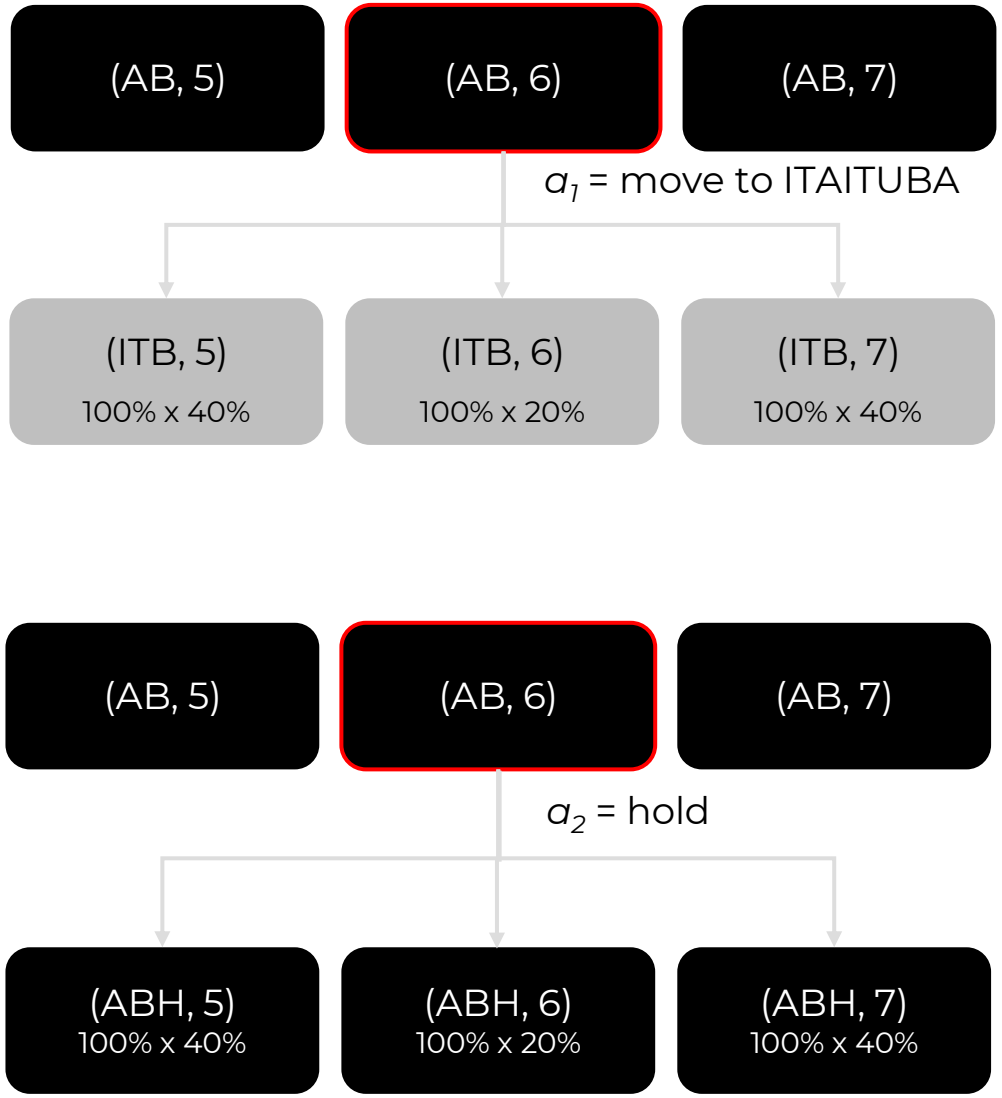
3. Calculations are represented in R$/bag;

4. The ISA-MDP methodology focuses on **routing competition** rather than capacity evaluation, so the problem statement is **based on the movement of the system unit** through the available routes **without capacity constraints** to determine the most efficient path.

Markov Chain Representation

The formulation of an MDP model includes five components: **decision epochs, states, actions, transition probabilities, and rewards** (PUTERMAN, 2005).





Markov Chain Representation

1. The reward function is calculated at each decision epoch based on the costs of handling and storage (NC) and the transportation costs (TC) related to the state's transitions based on the selected actions.

$$NC_t = SPP_t + HC_t + SC_t\ ,\ t \in \mathrm{T}$$

2. The Soybean Purchase Price at decision epoch t (SSP) assumes the value p_r when t = 1 and, $SPP_t = 0$ otherwise.

3. Transportation Costs (TC) at decision epoch t (Mode Cost - MC): $TC_t = MC(m_{a_t})_t\ ,\ t \in \mathrm{T}$ and $a \in \mathrm{A}$

$$MC(\mathrm{Road})_t = [1 + diesel_{perc} * (\frac{s_t(\mathrm{diesel})}{diesel_{ref}} - 1)] * (0.1218 * x_{a_t}{}^{-0.323})$$

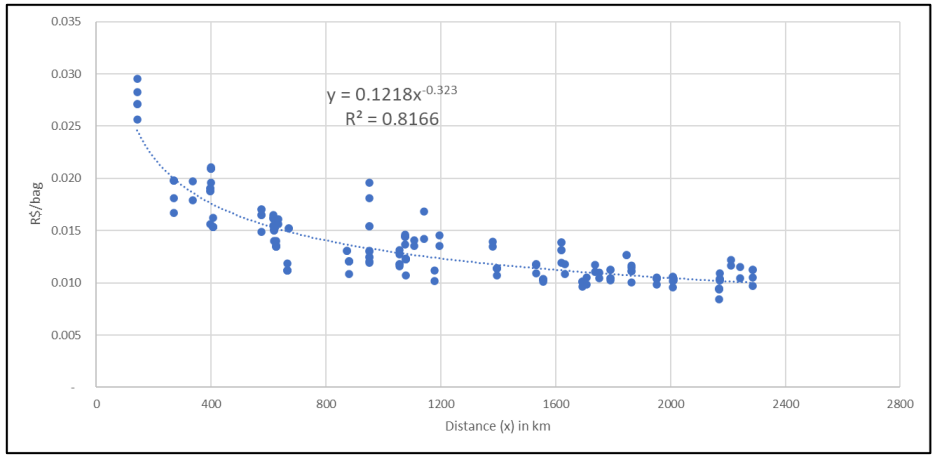
$$t \in \mathrm{T} \text{ and } a \in \mathrm{A}$$

$diesel_{ref}$ = R$ 6.00

$diesel_{perc}$ = 35%

$$MC(River)_t = 0.001488 * x_{a_t} + 0.298212,\ t \in \mathrm{T} \text{ and } a \in \mathrm{A}$$

$$MC(Rail)_t = 0.003708 * x_{a_t} + 0.517788,\ t \in \mathrm{T} \text{ and } a \in \mathrm{A}$$



4. Total Reward r_t of the transition is calculated by (Soybean Selling Price - SPR):

$$r_t(s_t, a) = \mathrm{SPR} - (NC_t + TC_t)\ ,\ t \in \mathrm{T}$$

Markov Decision Process (MDP)

- The optimal solution for the finite-horizon police evaluation algorithm is obtained solving at each iteration of the algorithm the Bellman Equation 5 and the Bellman boundary condition in Equation 6 (BELLMAN, 1954).

$$u_t(s_t) = \max_{a \in A_{s_t}} \left\{ r_t(s_t, a) + \sum_{s'_{t+1} \in S} p_t(s'_{t+1} | s_t, a) * u_{t+1}(s_t, a, s'_{t+1}) \right\} \qquad (5)$$

$$u_N(s_N) = r_N(s_N) \qquad (6)$$

- Backward Induction Algorithm.

Step 1

Set t = N;

$u_N^*(s_N) = r_N(s_N)$, for all $s_N \in$ S ;

Step 2:

Substitute $t-1$ for t and compute $u_t^*(s_t)$ for each $s_t \in$ S by Equation 7

$$u_t^*(s_t) = \max_{a \in A_{s_t}} \left\{ r_t(s_t, a) + \sum_{s'_{t+1} \in S} p_t(s'_{t+1} | s_t, a) * u_{t+1}^*(s'_{t+1}) \right\}$$

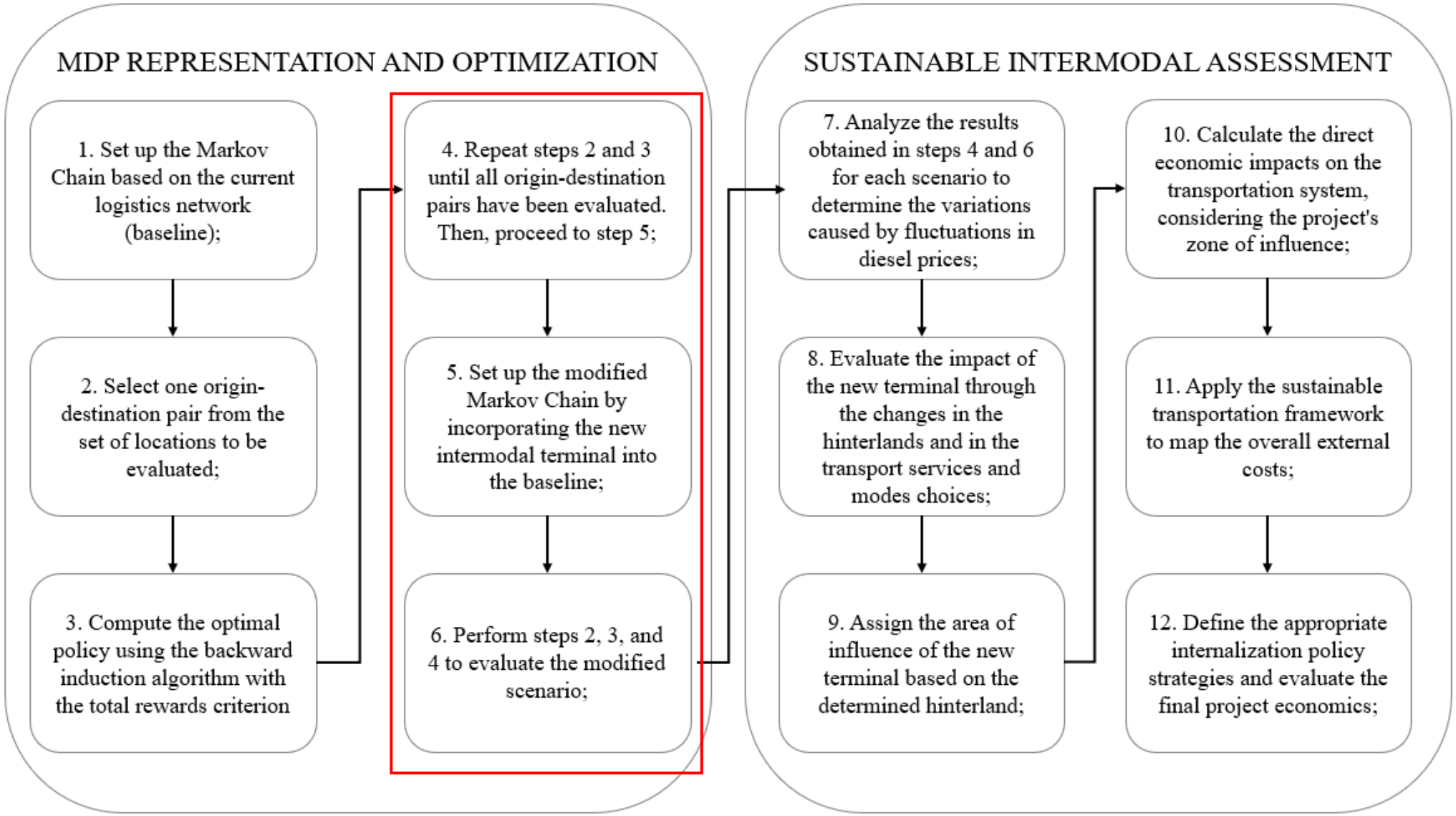
Set

$$d_t^*(s_t) = \operatorname{argmax}_{a \in A_{s_t}} \left\{ r_t(s_t, a) + \sum_{s'_{t+1} \in S_t} p_t(s'_{t+1} | s_t, a) * u_{t+1}^*(s'_{t+1}) \right\}$$

Step 3:

If t = 1, stop. Otherwise, return to step 2.

Methodology (ISA-MDP)



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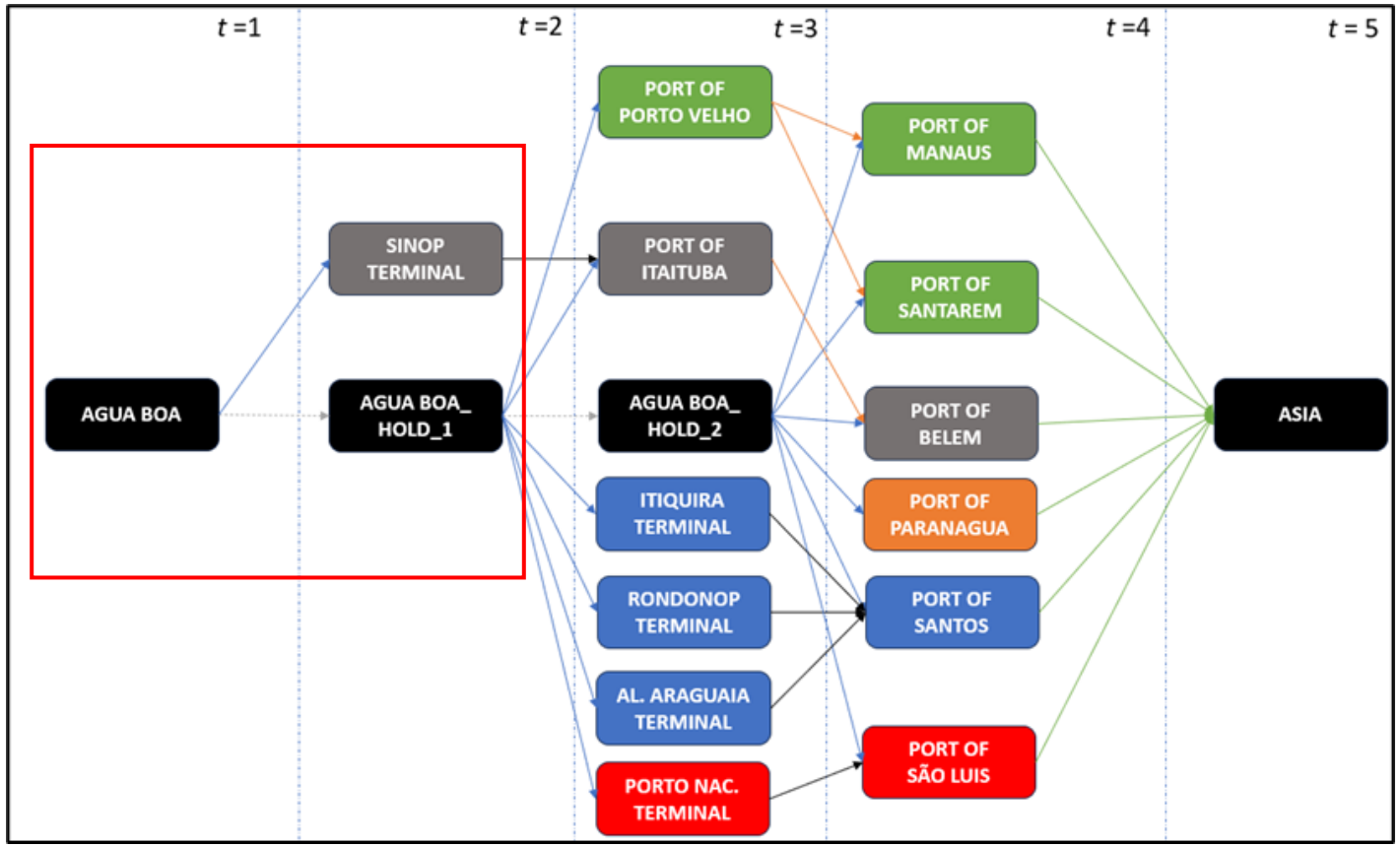

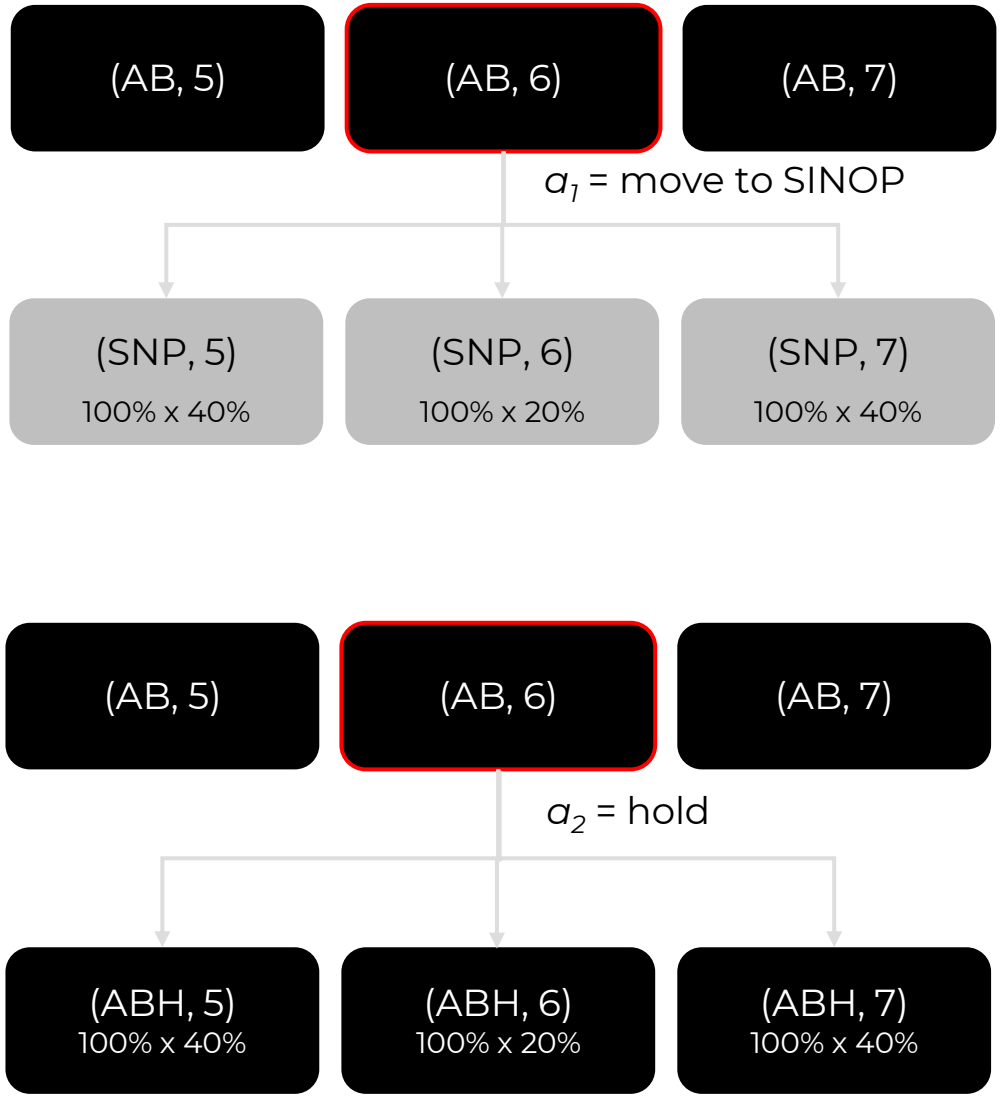

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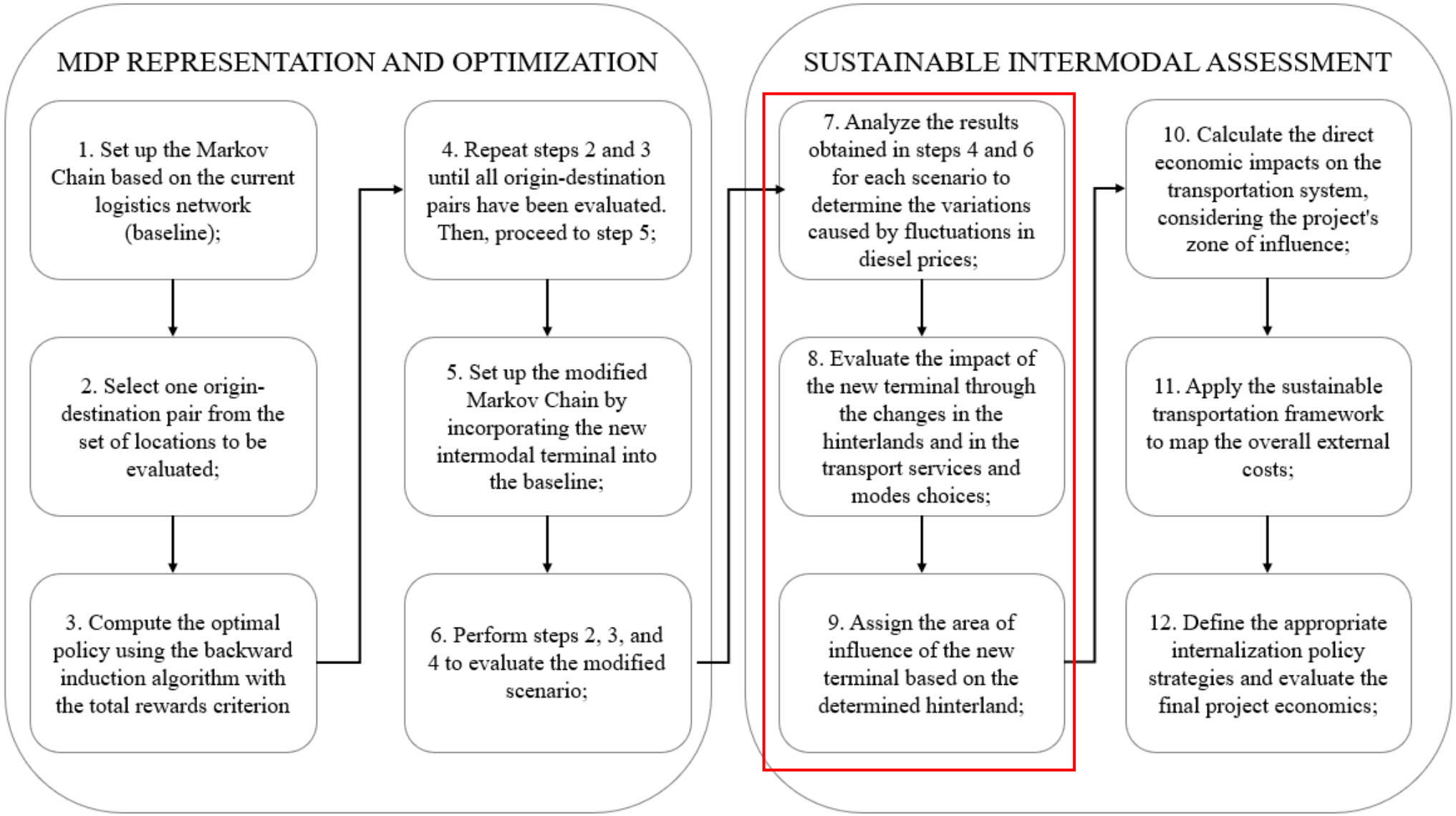
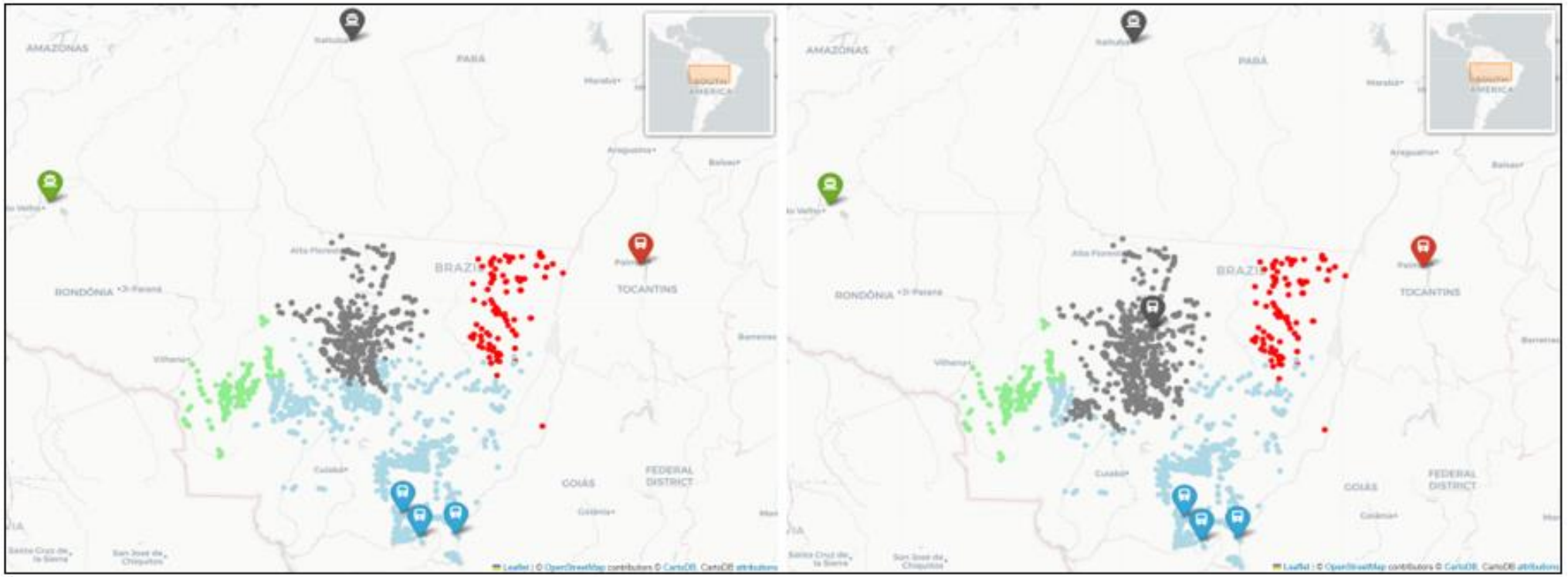


Preliminary Results and Discussion

RESULTS OF ISA-MDP (DESTINATION: ASIA)



Preliminary Results and Discussion

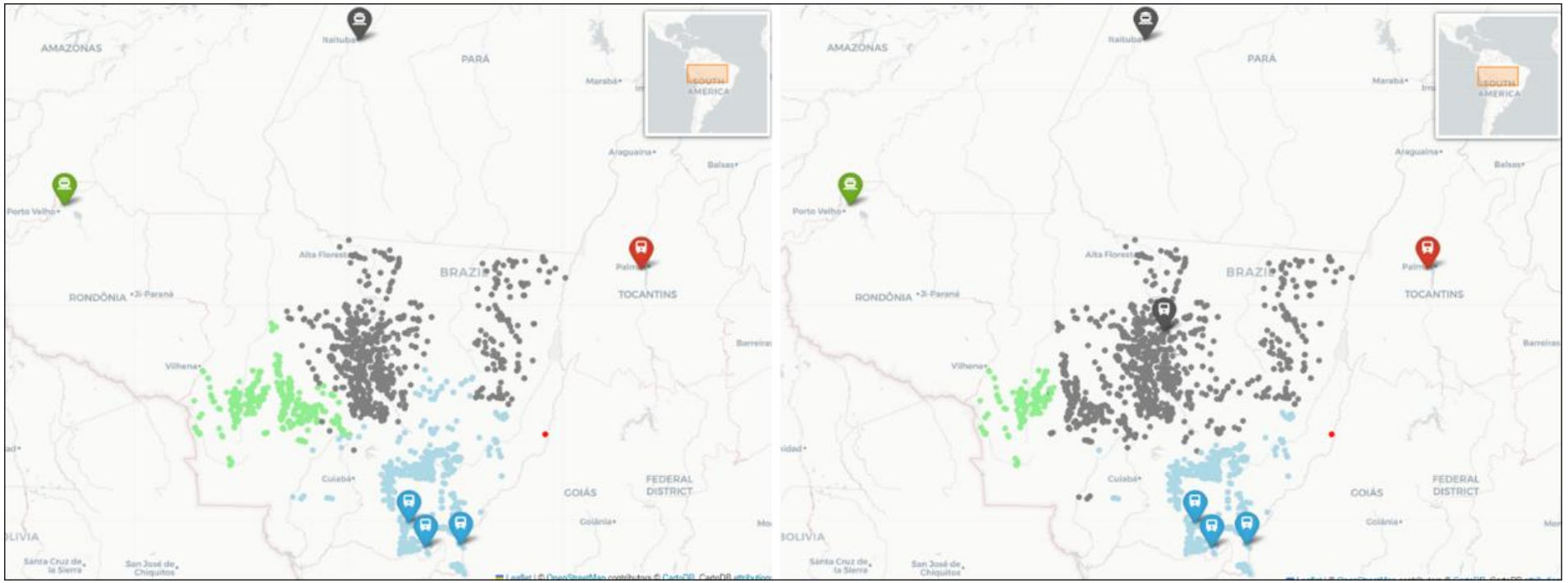
RESULTS OF ISA-MDP (DESTINATION: ASIA)

BASELINE SCENARIO - DESTINATION: ASIA				Captive Hinterland		Contestable Hinterland	
Export Corridor	Axis	Port of Export	Color	Number of Cities	Exports Potential (mmt)	Number of Cities	Exports Potential (mmt)
Southeast	Santos	Santos	Blue	44	11.3	2	1.4
North	Tapajós	Belém / Barcarena	Gray	20	4.2	8	3.4
North	Madeira	Manaus / Itacoatiara / Santarém	Green	8	2.5	6	2
Northeast	São Luis	São Luis	Red	11	2.6	0	0

EF - 170 SCENARIO - DESTINATION: ASIA				Captive Hinterland		Contestable Hinterland	
Export Corridor	Axis	Port of Export	Color	Number of Cities	Exports Potential (mmt)	Number of Cities	Exports Potential (mmt)
Southeast	Santos	Santos	Blue	37	8.3	2	0.1
North	Tapajós	Belém / Barcarena	Gray	33	10.6	3	0.7
North	Madeira	Manaus / Itacoatiara / Santarém	Green	7	2.7	1	0.6
Northeast	São Luis	São Luis	Red	11	2.6	0	0

Preliminary Results and Discussion

RESULTS OF ISA-MDP (DESTINATION: EUROPE)



Preliminary Results and Discussion

RESULTS OF ISA-MDP (DESTINATION: EUROPE)

BASELINE SCENARIO - DESTINATION: EUROPE				Captive Hinterland		Contestable Hinterland	
Export Corridor	Axis	Port of Export	Color	Number of Cities	Exports Potential (mmt)	Number of Cities	Exports Potential (mmt)
Southeast	Santos	Santos	Blue	30	5.8	3	0.1
North	Tapajós	Belém / Barcarena	Gray	43	13	1	0.1
North	Madeira	Manaus / Itacoatiara / Santarém	Green	12	4.2	0	0
Northeast	São Luis	São Luis	Red	1	0.1	0	0

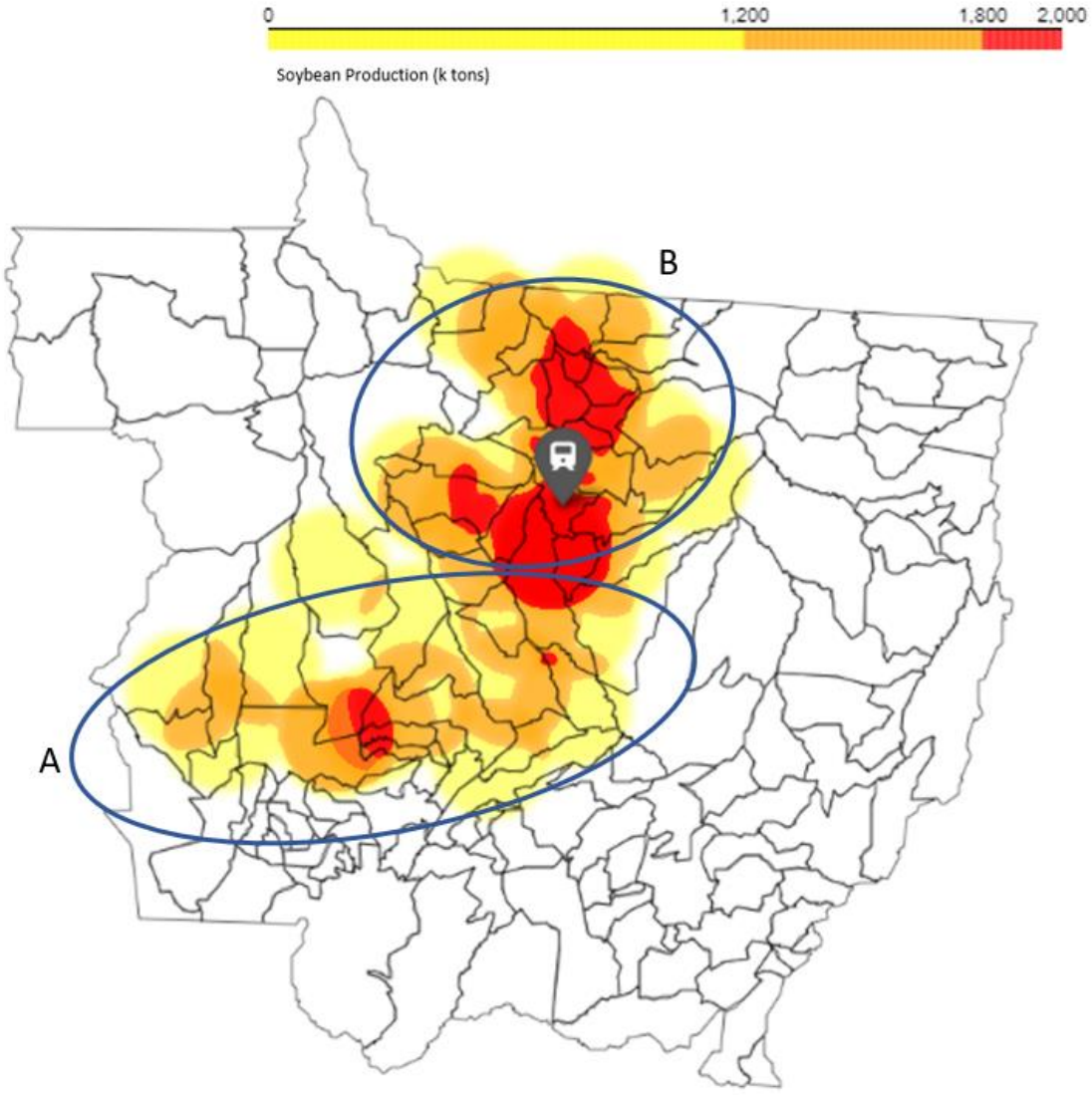
BASELINE SCENARIO - DESTINATION: EUROPE				Captive Hinterland		Contestable Hinterland	
Export Corridor	Axis	Port of Export	Color	Number of Cities	Exports Potential (mmt)	Number of Cities	Exports Potential (mmt)
Southeast	Santos	Santos	Blue	25	4.7	0	0
North	Tapajós	Belém / Barcarena	Gray	58	17.5	0	0
North	Madeira	Manaus / Itacoatiara / Santarém	Green	7	1.9	0	0
Northeast	São Luis	São Luis	Red	1	0.1	0	0

Preliminary Results and Discussion

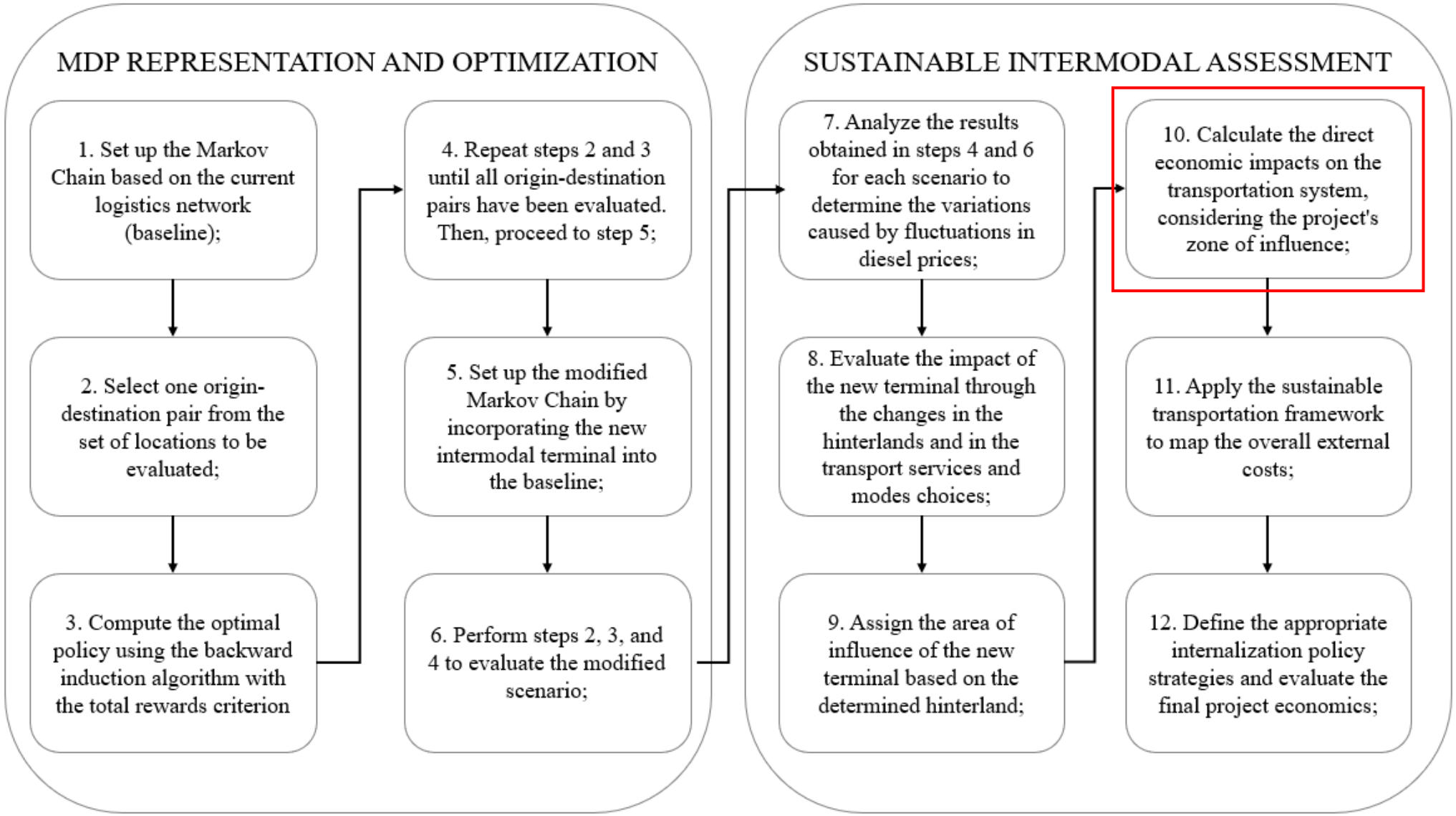
SINOP TERMINAL: ZONE OF INFLUENCE

The results from the optimal policy indicate that the EF-170 project has:

- significant potential to **redirect existing roadway traffic (B) to Itaituba and the Port of Belem** when servicing Asia and Europe**;**
- ~25% of the cargo currently routed to **Asia through the Port of Santos will likely be shifted to the new project (A);**
- ~50% of the cargo currently routed to **Europe through the Madeira Corridor will likely be shifted to the new project (A)**.



Methodology (ISA-MDP)

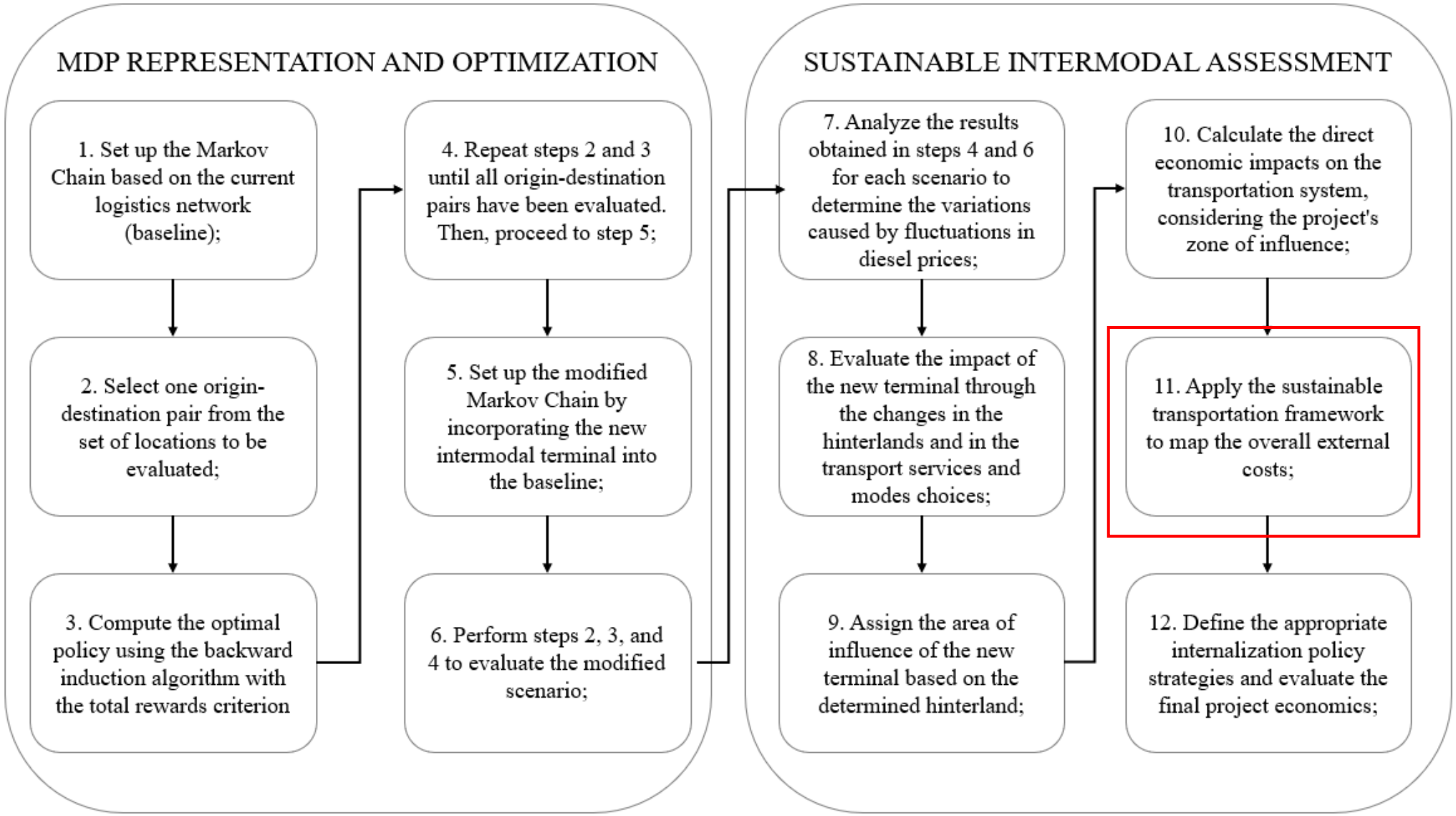


Preliminary Results and Discussion

TRANSPORTATION COSTS IMPACT

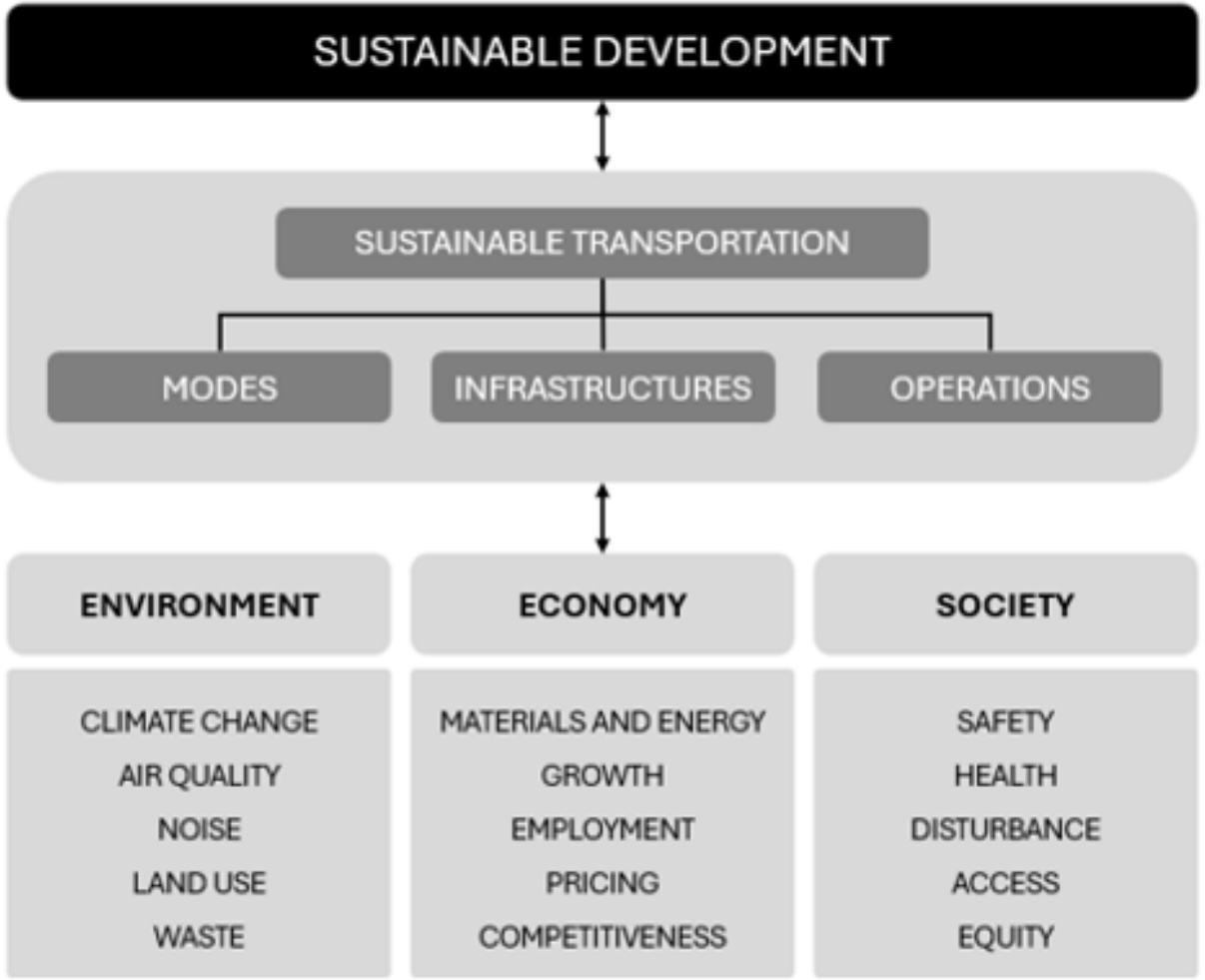
Origin	Destination	Income per bag (EF-170)	Income per bag (Baseline)	Δ Income per bag	Δ Income per bag (%)
Sinop	Asia	R$ 18.35	R$ 12.74	R$ 5.61	44%
Sorriso	Asia	R$ 16.85	R$ 11.75	R$ 5.10	43%
Vera	Asia	R$ 17.48	R$ 12.32	R$ 5.16	42%
Santa Carmem	Asia	R$ 17.56	R$ 12.42	R$ 5.14	41%
Lucas do Rio Verde	Asia	R$ 14.43	R$ 10.35	R$ 4.08	39%
Itanhanga	Asia	R$ 16.18	R$ 11.62	R$ 4.56	39%
Feliz Natal	Asia	R$ 16.35	R$ 11.79	R$ 4.56	39%
Tabapora	Asia	R$ 16.65	R$ 12.31	R$ 4.33	35%
Nova Ubirata	Asia	R$ 15.37	R$ 11.40	R$ 3.97	35%
Tapurah	Asia	R$ 15.15	R$ 11.36	R$ 3.80	33%
Ipiranga do Norte	Asia	R$ 15.68	R$ 11.76	R$ 3.92	33%
Claudia	Asia	R$ 17.30	R$ 13.27	R$ 4.03	30%
Juara	Asia	R$ 14.75	R$ 11.34	R$ 3.42	30%
Porto dos Gauchos	Asia	R$ 13.81	R$ 10.78	R$ 3.03	28%
Itauba	Asia	R$ 16.39	R$ 13.68	R$ 2.72	20%
Uniao do Sul	Asia	R$ 14.54	R$ 12.33	R$ 2.21	18%
Marcelandia	Asia	R$ 15.33	R$ 13.08	R$ 2.24	17%
Nova Mutum	Asia	R$ 13.59	R$ 11.63	R$ 1.95	17%
Nova Maringa	Asia	R$ 12.89	R$ 11.08	R$ 1.81	16%
Nova Santa Helena	Asia	R$ 16.01	R$ 13.88	R$ 2.13	15%
Colider	Asia	R$ 15.46	R$ 13.51	R$ 1.95	14%
Diamantino	Asia	R$ 11.30	R$ 10.37	R$ 0.94	9%
Terra Nova do Norte	Asia	R$ 15.45	R$ 14.19	R$ 1.26	9%
Nova Guarita	Asia	R$ 14.87	R$ 13.66	R$ 1.21	9%
Sao Jose do Rio Claro	Asia	R$ 12.25	R$ 11.35	R$ 0.91	8%
Nova Canaa do Norte	Asia	R$ 14.24	R$ 13.68	R$ 0.56	4%
Santa Rita do Trivelato	Asia	R$ 13.63	R$ 13.11	R$ 0.52	4%
Matupa	Asia	R$ 14.74	R$ 14.60	R$ 0.14	1%

Methodology (ISA-MDP)



Decision Support in Intermodal Transport

SUSTAINABILITY IN INTERMODAL



Source: (RODRIGUE, 2020)

Sustainable Intermodal Assessment

1. Tons of CO_2 equivalent emissions for each segment are calculated according to the respective transportation mode.

$$CO_2e = \alpha * y$$

Mode	α	Unit of measurement
Barge	2.0760E-07	tonCO2e/60kg-bag.kilometer
Rail	9.7692E-07	tonCO2e/60kg-bag.kilometer
Road	2.1762E-06	tonCO2e/60kg-bag.kilometer

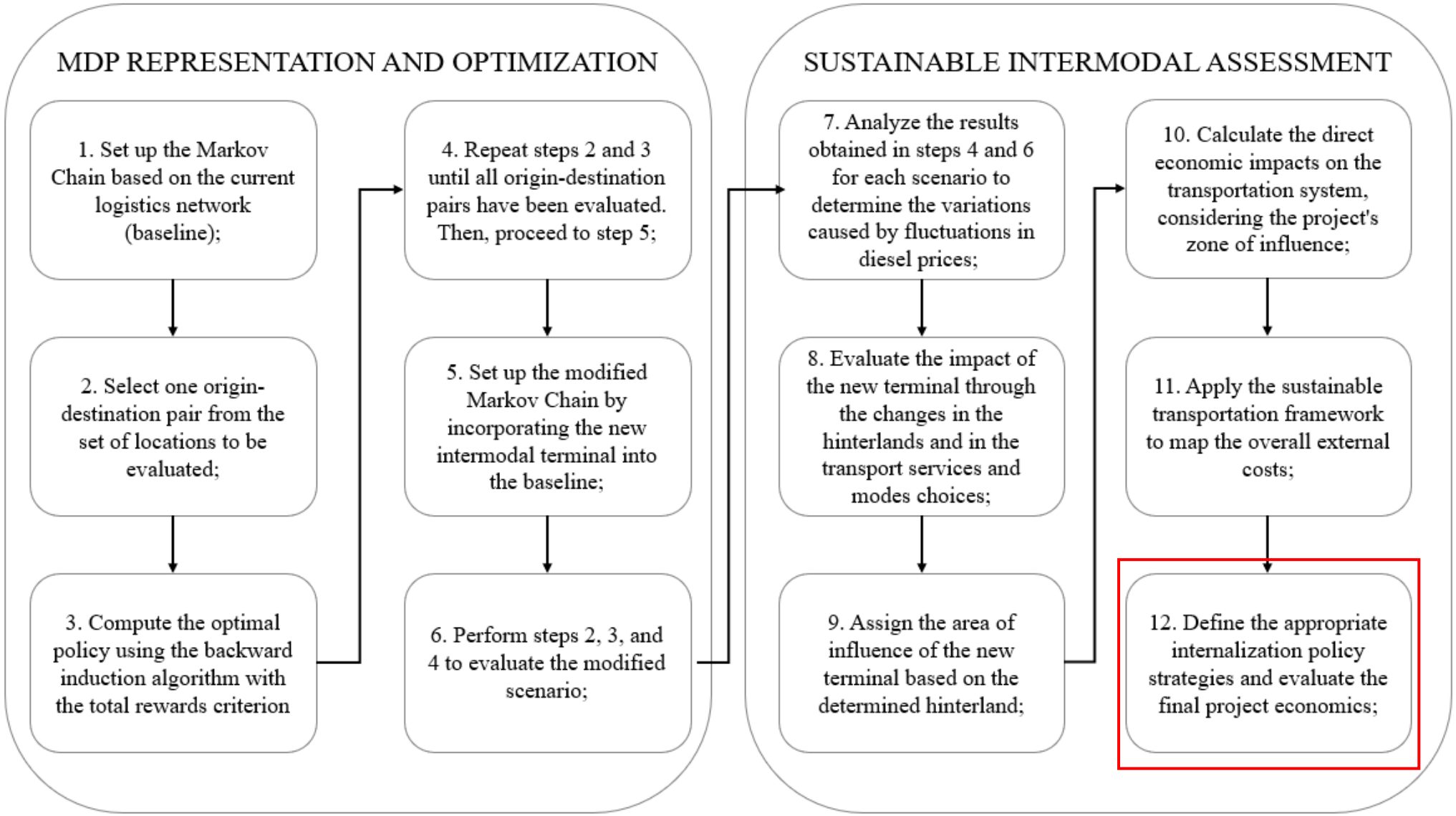
Source: (EPL, 2022)

Preliminary Results and Discussion

CO2 EMISSIONS DIRECT IMPACT DUE TO TRANSPORTATION MODES SHIFT

Origin	Destination	Roadway distance (EF-170)	Railway distance (EF-170)	Waterway distance (EF-170)	Roadway distance (Baseline)	Railway distance (Baseline)	Waterway distance (Baseline)	Total tCO2 emissions per bag (EF-170)	Total tCO2 emissions per bag (Baseline)	Δ	Δ (%)
Tapurah	Asia	24	976	1,132	1,154	-	1,132	0.00124	0.00275	- 0.0015	-55%
Juara	Asia	50	976	1,132	1,156	-	1,132	0.00130	0.00275	- 0.0015	-53%
Porto dos Gauchos	Asia	105	976	1,132	1,223	-	1,132	0.00142	0.00290	- 0.0015	-51%
Nova Mutum	Asia	58	976	1,132	492	1,648	-	0.00131	0.00268	- 0.0014	-51%
Uniao do Sul	Asia	46	976	1,132	1,041	-	1,132	0.00129	0.00250	- 0.0012	-48%
Nova Maringa	Asia	165	976	1,132	608	1,648	-	0.00155	0.00293	- 0.0014	-47%
Sao Jose do Rio Claro	Asia	158	976	1,132	582	1,648	-	0.00153	0.00288	- 0.0013	-47%
Sinop	Asia	54	976	1,132	1,016	-	1,132	0.00131	0.00245	- 0.0011	-47%
Tabapora	Asia	89	976	1,132	1,043	-	1,132	0.00138	0.00250	- 0.0011	-45%
Lucas do Rio Verde	Asia	154	976	1,132	1,146	-	1,132	0.00152	0.00273	- 0.0012	-44%
Itanhanga	Asia	152	976	1,132	1,123	-	1,132	0.00152	0.00268	- 0.0012	-43%
Diamantino	Asia	203	976	1,132	560	1,648	-	0.00163	0.00283	- 0.0012	-42%
Ipiranga do Norte	Asia	176	976	1,132	1,123	-	1,132	0.00157	0.00268	- 0.0011	-41%
Santa Rita do Trivelato	Asia	156	976	1,132	424	1,648	-	0.00153	0.00253	- 0.0010	-40%
Nova Ubirata	Asia	269	976	1,132	578	1,648	-	0.00177	0.00287	- 0.0011	-38%
Marcelandia	Asia	114	976	1,132	956	-	1,132	0.00144	0.00231	- 0.0009	-38%
Santa Carmem	Asia	162	976	1,132	1,031	-	1,132	0.00154	0.00248	- 0.0009	-38%
Nova Canaa do Norte	Asia	124	976	1,132	890	-	1,132	0.00146	0.00217	- 0.0007	-33%
Sorriso	Asia	235	976	1,132	1,046	-	1,132	0.00170	0.00251	- 0.0008	-32%
Terra Nova do Norte	Asia	102	976	1,132	835	-	1,132	0.00141	0.00205	- 0.0006	-31%
Feliz Natal	Asia	340	976	1,132	1,104	-	1,132	0.00193	0.00264	- 0.0007	-27%
Nova Guarita	Asia	203	976	1,132	892	-	1,132	0.00163	0.00218	- 0.0005	-25%
Colider	Asia	238	976	1,132	909	-	1,132	0.00171	0.00221	- 0.0005	-23%
Nova Santa Helena	Asia	217	976	1,132	869	-	1,132	0.00166	0.00213	- 0.0005	-22%
Claudia	Asia	283	976	1,132	935	-	1,132	0.00180	0.00227	- 0.0005	-21%
Vera	Asia	370	976	1,132	1,042	-	1,132	0.00199	0.00250	- 0.0005	-20%
Matupa	Asia	195	976	1,132	791	-	1,132	0.00161	0.00196	- 0.0003	-18%
Itauba	Asia	392	976	1,132	890	-	1,132	0.00204	0.00217	- 0.0001	-6%

Methodology (ISA-MDP)



Preliminary Results and Discussion

STRATEGY MAP TO TACKLE THE SOCIO-ENVIRONMENTAL IMPACTS

Impact Description	Reference	Impact Type	Strategies	Strategy Type
Deforastation - Area under influence	PPCDAm (MMA, 2023)	Environment - Cumulative	Development and implementation of a territorial governance plan and mitigation actions for the area influenced by the Logistics Corridor	Prevention
Deforastation - Area under influence	PPCDAm (MMA, 2023)	Environment - Cumulative	Regularization of area of federal public conservation units within the area influenced by the project	Prevention
Deforastation - Area under influence	PPCDAm (MMA, 2023)	Environment - Cumulative	Land regularization of traditional peoples and communities within the area influenced by the project	Prevention
Deforastation - Area under influence	PPCDAm (MMA, 2023)	Environment - Cumulative	Allocation of federal public forests that have not yet been designated within the area influenced by the project	Prevention
Deforastation - Area under influence	PPCDAm (MMA, 2023)	Environment - Cumulative	Creation of Conservation Units in priority areas for biodiversity conservation	Prevention
Communities displacement	EIA (Rosa, 2020)	Society - Direct	Execution of expropriation and eventual resettlement, as well as the associated costs	Damage compensation

AGENDA

- Motivation
- Problem Description
- Literature Review
  - Decision Support in Intermodal Transport
  - Mato Grosso's soybean exports logistics
  - Markov Decision Process
- Methodology (ISA-MDP)
- Preliminary Results and Discussion
- Preliminary Conclusion

Preliminary Conclusion

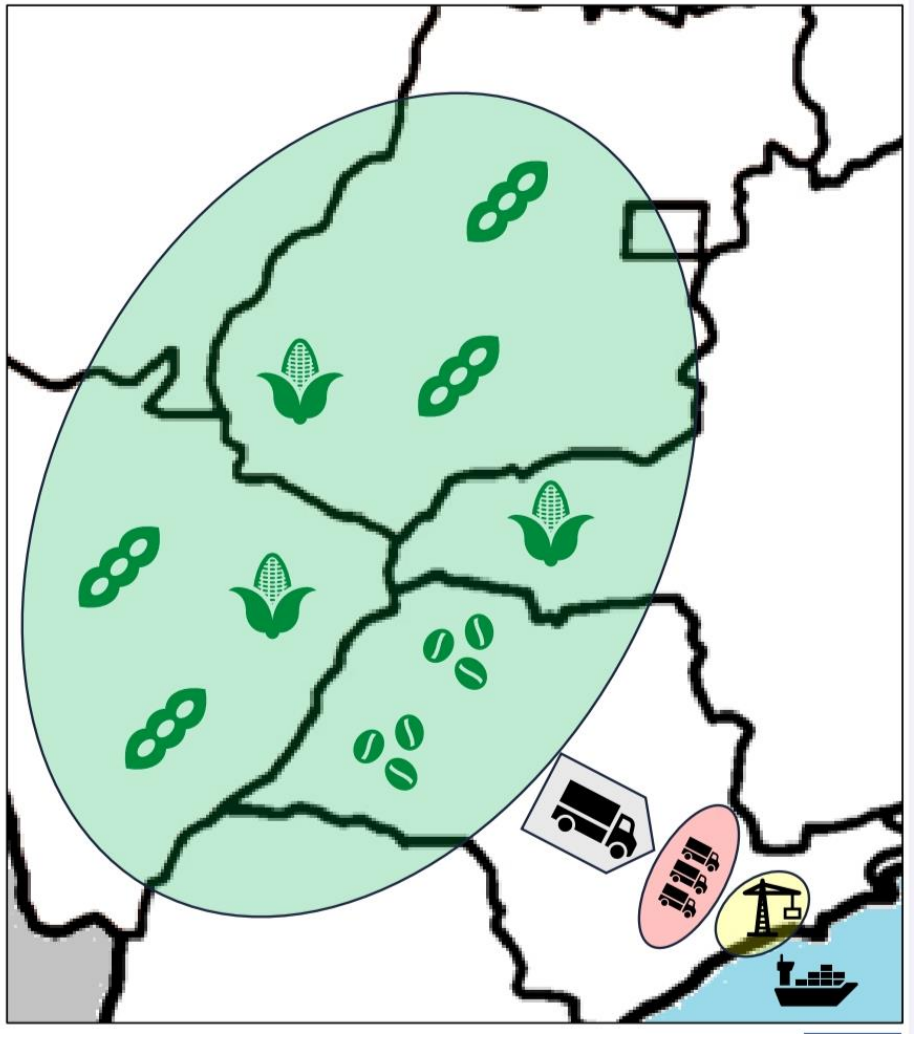
1. ISA-MDP can be used in further research:
    1. revising **demand estimates** by correlating hinterlands with production municipalities;
    2. assessing **changes in social aspects** such as per capita income, employment rates, and city development indices.
2. ISA-MDP can be refined and further developed:
    1. adapting it for **multi-commodity capacitated scenarios**, enabling a more comprehensive analysis that includes transportation synergies and capacity bottlenecks;
    2. assessing the combined impact of the **entire infrastructure portfolio outlined in the National Logistics Plan**, including the Central-West Integration Railway (FICO) and the West-East Integration Railway (FIOL I, II, III).

Conclusion

1. The discussion around Ferrogrão needs to be strengthened concerning the **definition of the area under project influence, the measurement of externalities, and the prevention or internalization of remaining external costs;**
2. The project current documentation is **insufficient to ensure that liabilities are not unfairly transferred to society** and that the **benefits of the project are equitably distributed** to the most impacted groups, including civil society and the environment.

Further Research

Truck Schedule for Grain Terminals in Port of Santos (Supported by Santos Port Authority)



Intermodal Service Assessment using The Markov Decision Process
A Case Study Of Brazil’s Ferrograo Railroad Project

João Marcelo Leite (joaomarceloleite@usp.br)