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MODAL COMPETITION AND COMPLEMENTARITY: COST OPTIMIZATION AT END-USER LEVEL

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Rezumat

Scopul lucrarii constă în identificarea metodelor pentru echilibrarea repartizării fluxurilor de transport între subsistemele modale în vederea utilizării eficiente a infrastructurilor de transport și reducerii efectelor negative ale dezechilibrelor existente. În prima parte a articolului, sunt analizate aspecte ale concurenței intermodale prin prisma conceptelor economice cu privire la substituibilitatea serviciilor specifice, gradul de conformare cu modelul concurenței perfecte, precum și natura elasticității reciproce a cererii.

Este realizată o analiză top-down a întregului sistem de infrastructuri. Se constată că, în condițiile de validitate a setului de ipoteze de lucru adoptat, mulțimea rețelelor pentru fluxuri materiale poate fi deconectată în vederea analizei ulterioare, de la celelate mulțimi ale rețelelor pentru fluxuri energetice, informaționale sau de valori.

În a doua parte a lucrării, pentru rețeaua astfel deconectată, se dezvoltă un model de optimizare a costului generalizat în transportul multimodal, în care sunt incluse și evaluări ale confortului și siguranței. Prin acest model, se pot îmbunătăți rezultatele algoritmilor aplicați în prezent care țin seama doar de distanțe, durate și consumuri de energie. Suplimentar, lucrarea propune în premieră, trei tipuri de analize independente, care permit utilizatorilor finali sau companiilor organizatoare de transport să optimizeze alegerea între modurile de transport sau organizarea proceselor de transport în ansamblu.

Cuvinte cheie: infrastructuri de transport, transfer modal, competiție, cost generalizat, externalități

Abstract

The paper aims to identify possible methods for balancing the allocation of transport flow on modal subsystems in order to efficiently use the infrastructures and reduce the negative effects of today's unbalance. The aspects of intermodal competition are reviewed, considering the economic concepts regarding the substitutability of transportation services, conformation degree to the perfect competition model and the nature of cross elasticity demand.

A top-down analysis over the whole infrastructure assembly is performed. The results, under the presumption of valid work hypothesis, indicated that for further analysis the set of networks transferring material flows can be assumed as disconnected from the other networks sets transferring energy, informational and values flows.

The second part of the paper develops, for that disconnected networks, a generalized cost optimization model for multimodal transportation, where the comfort and safety are accounted. Thus, the performance of the existing algorithms based only on trip length, trip duration and energy consumption can be significantly improved. Additionally, the author proposes three new independent types of modal analysis that allow end-users and companies involved in transport organization to optimize their modal choice and the whole transport process organization.

Keywords: transport infrastructure, modal shift, competition, generalized cost, externalities

1. INTRODUCTION

The incensement requirements of transport beneficiaries often accompanied by insufficiently substantiated regulations (for charging access and use of infrastructures, for charging external effects with consequences on overall society) have led to imbalances in the use of modes of transport, inefficient use of existing transport capacities and consequently, loss of public funds [SteadieSeifi *et al.*, 2014; Bougna & Crozet, 2016; Tomes, 2017]. The paper reviews the aspects of modal competition, considering the economic concepts regarding the substitutability of transportation services, conformation degree to the perfect competition model and the nature of cross elasticity demand. The specific levels of competition between transport modes as well as modal complementarities are identified.

Starting from the functional operational and socio-economic operational structures, a top-down analysis over the whole infrastructures collection is performed. The results, under the presumption of valid work hypothesis, indicate that for further analysis the set of networks transferring material flows can be assumed as disconnected from the other networks sets transferring energy, informational and value flows. For the sake of maintaining the general aspect of the problem, both freight and passengers for all four transportation modes (rail, road, naval, air) are maintained over the development of the model.

According to the synchronic analysis over the relevant transportation markets, the equilibrium is reached in a suboptimal area. That fact has been verified by the results of last year's researches reporting important perturbation of the competition environment of the EU member states due to the national policies in transportation, causing chronic maintaining of externalities [Korzhenevych *et al.*, 2014] and implicitly a *sine die* postponing of "*user pays*" and "*polluter pays*" principles.

Two directions of action are identified in order to shift the market equilibrium point as close as possible to the optimal. The first one, covered by this paper, aims to develop the model on the generalized cost foundation, allowing to end-users and companies involved in transport organization, to optimize their modal choice and logistic chains design processes. The second direction, to be approached in a future work, is a concept development, allowing policy makers to deal with improving fairness within intermodal competition environment, eradicating the loss of public funds, internalization of external costs which today are not transferred to the end-user.

2. MODAL COMPETITION VS. MODAL COMPLEMENTARITY

Transportation market makes no exception from the economic theory, the different transport modes disputing the same demand which is in most cases under the level of their offered capacities. According to the same theory, two or more service suppliers are in competition when their services are substitutable, meaning that they could replace each other in consumption. By examining the relationship of the demand schedules for these services, one can classify them as substitutable if the increase in demand for the first service results in an increase for the others as well. A substitute service displays a positive cross elasticity of demand, while reversely, a complementary service displays a negative cross elasticity of demand meaning that their demands are not correlated [Heyne *et al.* 2014].

The transport modes could be considered as competing when for a specific global demand, their services are deemed as quasi-identical. Under this hypothesis, the transportation services are competing over the same market and the increase in demand for one of them induces an increase for the others, as for a positive cross elasticity of demand. As a matter of fact, that would be a rough simplification of reality, where actually the services of different transport modes are differentiated through their technical competence scopes, geographical area, vehicle capacity, load gauge, speed or overall capacity [Raicu, 2007].

In regard to assessing the extent of conformity with the ideal competitor status, it could be easily demonstrated that transport services delivered by different modes are not perfect substitutes for each other, their substitutability being actually a matter of degree. Otherwise, they would be in the situation of having the same utility function [Perloff, 2012] when for a price difference between mode’s services, there would be no demand at all for the more expensive services of the other modes, which is obviously not true.

As for placing the modal specific services in one of the substitute categories, a detailed analysis should be performed for every specific set of services. For some market scenarios, the services could fall in the within-category substitutes, having the same traits and belonging to the same taxonomic category. For some other incidences, the services could fall in cross-category substitutes, being part of different taxonomic categories but still resolving the same functional problem [Pindyck & Rubinfeld, 2005].

Within its technical competency scope, every mode owns an economic area of influence, defined mainly by its level of intervention costs. On the one hand, an exclusivity zone is in most cases present, when from technical and economic reasons no other mode can get involved (e.g. local collection and distribution tasks done by small vans). For these segments, there is actually no competition present. On the other hand, there is always an overlapping of mode's economic areas of influence where inter-modal competition takes place. Most authors classify it as a marginal competition detectable only at the borders of economic areas of influence. [Raicu & Popa 1997].

Within overlapping areas, the services are considered substitutable and modal competition could act. On a free and non-biased market, these are naturally narrow bandwidths, and this fact is worth mentioning, it is not economically effective to use the vehicle over them, as for the same level of minimal unit cost a higher speed could be used simply by shifting to a vehicle of next mode.

A quantitative way to assess the competition is eliciting the marginal rate of substitution to find the level where the users accept to substitute one service for another service, belonging to the same or different mode, given the same output of utility function is delivered. When the consumption equilibrium is reached, the marginal rates of substitution are the same. The later statement is true only when no externalities are present, which in the real world is not the case as will be further discussed.

Concluding, the analysis demonstrates that over certain market segments the intensity of the modal competition is high, but there are also areas where the transport modes occupy a natural exclusivity. That is, the modal complementarity could be used as an opportunity. Under these circumstances, a clearer separation between the action's scopes of the involved actors should be defined [Costescu, 2018a].

Optimization of interaction between different modal transport systems, sound techniques of modal assignment, frame improvement of major and interface processes, and last, but not least, changing of mentality from modal competition to modal complementarity approach could be the prerequisite for enhanced transport services and improved performance at both macroeconomic and microeconomic levels.

3. INFRASTRUCTURE NETWORKS AND TERRITORIAL DEVELOPMENT

Many examples have proved that regional or national development is in a close interdependency to infrastructure networks [Venables et al. 2014; Melo et al. 2013; Bhatta & Drennan, 2003]. More recently, the project of the European Union development as a supra-state, built on a common political platform, on the European economic area and upon related harmonized infrastructures as well. Transportation, telecommunication, energy, fuel or information technology infrastructures are the main pillars when it comes about generating cohesion, synergies and coordination within the European space [Costescu, 2016b].

The most well-known approaches for intervention in networks conceiving, development and management are rather sectorial than systemic, dealing with highly specialized technical concepts and often missing – the entire system overview. A broader, integrated assessment should be employed, considering the common territories, economic and social targets addressed. The new engaged models should be able to overcome the limitations of excessive technicality, tightly sectorial and even the narrative, plain geographical characterization applied in many studies [Costescu, 2018b].

An improved overall funds allocation mechanism is expected, able to generate savings that could be of further use for macro-economic tuning or simply optimized re-allocations. [Costescu, 2017, 2018a]. Besides of this macro-economic adjusting mechanism which could be instated only by national authorities and will generate massive modal reallocation, a micro-economic modal shift based on individual decision is also possible, if the companies are provided with an appropriate methodology to a realistic assessment of the resulted gain. Developing the later represents actually the goal of present work.

4. INFRASTRUCTURE NETWORKS FORMALIZATION

Aiming to formalize the complex cross-functions beyond the sectorial view and describe the multi-relational character of the networks serving the same economic and social system, the modelling is initiated in a top-down manner. The functional operatorial structure at the societal level can be defined as [Raicu, 2007, Bell & Iida 1997, Ackoff & Sasieni 1975]:

$$\mathcal{T} = \left[\langle \mathrm{N} \rangle \,|\, \langle \mathrm{F} \rangle\right] \quad (1)$$

where: $\langle N \rangle$ = collection of sets of territorial networks;

$\langle F \rangle$ = collection of operators for network $\mathcal{T}$ (sets of transfer flows over network $\mathcal{T}$).

By refining, that gives:

$$N = \{\{N_m\},\ \{N_e\},\ \{N_i\},\ \{N_v\}\} \quad (2)$$

and

$$F = \{\{F_m\},\ \{F_e\},\ \{F_i\},\ \{F_v\}\} \quad (3)$$

where: $\{N_m\}$ = sets of transport networks for material flow;

$\{N_e\}$ = sets of transport networks for energy flow;

$\{N_m\}$ = sets of networks transporting information flow;

$\{N_v\}$ = sets of networks transporting value flow;

$\{F_m\}$ = sets of material flow;

$\{F_e\}$ = sets of energy flow;

$\{F_i\}$ = sets of information flow;

$\{F_v\}$ = sets of value flow.

The socio-economic operatorial structure helps to define how the transfer flow is induced into the system $\mathcal{Z}$ from the territorial subsystems:

$$\mathcal{Z} = [\langle S \rangle \mid \langle A \rangle] \quad (4)$$

where: $\langle S \rangle$ = collection of sets of territorial (socio-economic) subsystems;

$\langle A \rangle$ = collection of sets of specific social and economic activities of the system.

The transformation mechanism of any territorial system $\langle S \rangle$ is its set of activities $\langle A \rangle$ that generates both the endogenous and exogenous transfer needs, referred as *ex-ante demand* or *prospective demand*. The percent in which this can be converted to the *ex-post demand* or *resolved demand* is up to the set of territorial networks $\langle N \rangle$ under the specific constrains at the time being [Raicu, 2007].

As the synchronic analysis is obviously not able to deal with the dynamic character of the processes, the diachronic analysis would be employed aiming to examine how the mutation in the set of social and economic activities $\langle A \rangle$ leads to qualitative and quantitative transformation and then, with direct consequences over the networks set $\langle N \rangle$, causes flow transfers between the elements of set $\langle F \rangle$ on two levels:

- On the upper *inter-sectorial level*, flow transfers occur *within the collections* $[\langle N\rangle | \langle F\rangle]$, among $\{F_m\}$, $\{F_e\}$, $\{F_i\}$, $\{F_v\}$ over $\{N_m\}$, $\{N_e\}$, $\{N_i\}$, $\{N_v\}$. Through migration, the type of flow changes, taking a different value from the set {"*material*", "*energy*", "*information*" or "*value*"}. E.g., the flow letters on paper, as material support, transferred mostly over land or air transportation modes, were replaced by e-mails transferred over internet, as informational flow).
- On the lower *intra-sectorial level*, flow transfers *within one* of the sets $\{F_m\}$, $\{F_e\}$, $\{F_i\}$, $\{F_v\}$ between its different networks. E.g., *(1)* migration of electronic messaging from E-mail networks to other communication networks with a greater interactivity, like *Messenger* or *WhatsApp* or *(2)* the *modal transfer* within $\{N_m\}$, between the networks transferring material flows, namely between road and rail network or inner navigation networks.

A synchronic analysis performed for the most European countries, as a snapshot of the moment [Korzhenevych *et al.*, 2014], reveals deviations under different degrees from the optimal system as defined in Frois [1994]. The free willing decisions of the service providers and of their customers still play an active role in reaching an equilibrium but that takes place in a *suboptimal area.*

The identified sub-optimality has its roots in the past governmental policies which ignored for years or delayed the implementation of the principles "*user pays*" and "*polluter pays*", avoiding the cost internalization according to the method proposed in the already available cost allocation studies [Link *et al.*, 2008]. That resulted in an asymmetric financing between transport modes, an unlevel playfield for them and in discriminating exactly the sustainable modes that should have been usually incentivized [Costescu, 2015].

However, that is another confirmation of the economic theory stating that, under the influence of external factors, the market mechanisms work imperfectly [L'Huilliet, 1965]. Under the pressure of macroeconomic effects of sectorial sub-optimality, the policy makers increased the research effort to identify the most appropriate tools and strategies able to allow the free movement of $\langle N\rangle$ and $\langle F\rangle$ to the optimal point):

$$Opt(\ T) = Opt\ (\langle N\rangle | \langle F\rangle) \quad (5)$$

To solve this optimum problem, the differences in migration speeds on inter-sectorial and respectively intra-sectorial levels should taken into account. The flow transfer within the *inter-sectorial sets* occurs as result of global technology advancement and has two major traits. It usually does not leave any choice to the policy makers, the alternative of not adhering to change being to remain behind and secondly, the change takes longer, sometimes tens of years.

On the contrary, the flow transfer *within the intra-sectorial sets* is concluded faster, usually in just a few years, but depends of the celerity the authority deals with financial, social and politic barriers. That means, on this level, authority has a choice, including the choice to do nothing.

Breaking down the optimum equation:

$$Opt(T) = Opt\left(\{\{N_m\}, \{N_e\}, \{N_i\}, \{N_v\}\} \mid \{\{F_m\}, \{F_e\}, \{F_i\}, \{F_v\}\}\right). \quad (6)$$

As the inter-sectorial flow transfer takes much longer than the intra-sectorial one, the former process could be considered as quasi-stationary (transfer speed *among* $\{N_m\}$, $\{N_e\}$, $\{N_i\}$, $\{N_v\}$ is small enough when compared with any transfer speed *within* these sets and could be assigned to zero). Then, for the purpose and stage of this research, the optimality of $(\{N_m\} \mid \{F_m\})$ can be considered as disconnected from $Opt(T)$ and assessed separately.

5. PROBLEM DEFINITON

5.1. Bottom-up analysis from end-user to infrastructure owner

The proposed goal is to minimize the overall social cost (or global cost) for the system of the $\{N_m\}$ set transferring material flows $\{F_m\}$, whose functioning is influenced by the customer's spontaneous decisions and buying behavioural patterns behind them. Therefore, it is appropriate to start in this stage a bottom-up analysis of the system, namely from the end-users of the transport system and from the companies in charge of transportation organization.

The decision is assumed in spite of the existing suboptimal equilibrium, acknowledged as being generated exactly by the end-user choices, provided that the *external causes of sub-optimality* will be identified, treated and added to this model in a later work, as the bottom-up analysis progresses to the upper levels, through the infrastructure administrators to the policy makers. The final aim is to define a clear and comprehensive methodology for this category of companies, allowing them to deal for now with the *internal causes of sub-optimality* and then select, asses and integrate the most appropriate transport components into the finally, cost optimized transportation process.

5.2. Minimization of the generalized cost

Transportation demand is allocated in a transport system function on generalized cost as a function of monetary cost of transportation and service's quality (traditionally broken-down in duration, comfort and safety) [Quinet 1998, Raicu 2007]:

$$C = \mathrm{m} + c_T \cdot T + c_R \cdot R + c_S \cdot S \quad (7)$$

where: C = generalized cost of transportation;
m = monetary cost of transportation;
T = trip time;
R = comfort measure;
S = safety measure;
c_T, c_R, c_S = unit monetary values of time, comfort and safety.

For the sake of simplicity, it is stated that the commercial margin δ of transportation actors has been accounted in the first term of equation (7):

$$\mathrm{m} = \mathrm{m}_0 + \delta = \mathrm{m}_0 + \sum_i^n \delta_i \quad (8)$$

where: m_0 = cost of transport operators;
δ_i = margin of member i of the transportation process;
n = number of members of transportation process.

Any new user accessing to transport system claims a fraction of its total capacity, influencing the operational parameters (speed, time, regularity etc.). Consequently, each category of costs (c_T, c_R, c_S) is defined as function of flow. E.g., the function speed – flow is non-linear, experiencing a weaker variation for low values of flow and a stronger variation in capacity saturation domain.

The term of comfort in equation (7) is understood in a larger sense including also the willingness to pay for door-to-door transportation or e.g., willingness to accept an extra-charge for the comfort to keep working with a traditional transportation supplier. This way, the generality of formula is maintained in order to deal, by case, with both freight and passengers transportation.

While the monetary cost and duration are the most prevalent terms in decision mechanisms of the end users, followed closely by comfort, the fourth term of equation, regarding safety was for a long time ignored. The situation is about to change, due of the proliferation of the Safety Management Systems in transportation and the increasing awareness regarding transportation risks, among the end-users.

Considering that all the terms in equation (7) depend on flow, for a given transport system demand, the problem consist in allocation and consolidation of flow on different modal transport subsystems so that the overall, generalized cost is minimal.

5.3. Modal analysis

From the point of view of a user interested in transportation services over $\{N_m\}$ and ignoring for now the external influences in market, the problem $Opt(\{N_m\} | \{F_m\})$ is similar to:

$$\min(C_i)\ \forall\{N_i | F_i\} \in \{\{N_m\} | \{F_m\}\},\ i \in \{rail, road, naval, air\}, \quad (9)$$

that will make possible the development of the following types of analysis to be used resolving specific transportation tasks.

5.3.1. Simple Modal Analysis (SIMA)

This type of analysis starts from the assumption that between the origin and destination of the requested transport more modes are available, but due to the existing constraints no intermediary modal transfer is possible or desired (e.g. no available inter-modal terminals or transfer points, freight sensitive to transfer or multiple connections not accepted by passengers).

SIMA consists in calculating the generalised cost, according to equation (7), for every transport mode available on the envisaged transport relation and chooses according to equation (9) the most appropriate transport mode (rail, road, naval or air) based on the smallest cost.

5.3.2. Intra-Modal Analysis (IMA)

There are many cases when the user should select not between two or more transport modes (rail, road, naval, air), but look for the optimum *within one specific mode*. For this purpose, IMA can be used for the assessment of alternative solutions of the same mode: e.g. comparing the generalized costs for two different routes, *both on road*, for two kinds of vehicles (truck vs. van) or any other combination which does not imply mode changing. The IMA outputs can be used to extend the capability of existing routers able to deliver solution based in most cases only on time or distance. The use of equation (7) can improve the weighting of network’s graph by the components of comfort and safety bringing the advantage of a more precise assessment of different transport options and an improved, cost saving, transport optimization.

5.3.3. Complex Inter-Modal Analysis (CIMA)

It was conceived to resolve a diversity of scenarios, when between origin and destination, different transport modes should be used, different inter-modal terminal or changing nodes are present, a choice of vehicles with various features (speed, volume, fuel-consumption, safety and comfort) are available, and different infrastructures with specific traits (flow capacity, speed regime, weight constraints, taxes, safety class) can be selected.

Basically, looking for the optimum of a transport request over the network $\{N_m\}$, CIMA employs firstly equation (7) to calculate the generalized cost for every elementary section of the network over which, the requested flow could eventually be transported between origin and destination.

Elementary section is understood here as a section where the variables used by equation (7) remain homogeneous between its ends. When at least one of these variables changes, a new section shall be defined.

Finally, applying equation (9), the sections compounding the optimum path (minimum cost) are selected and assembled.

5.3.4 Generalized cost concretization for an elementary section

For further development of the model in order to be used by every above proposed analysis, let's define the modal vectors V_i as per equation (7):

$$V_i = [M_i, T_i, R_i, S_i],\ i \in \{rail,\ road,\ naval,\ air\} \tag{10}$$

and the *weight vectors* ω_i:

$$\omega_i = [1, c_{Ti}, c_{Ri}, c_{Si}]. \tag{11}$$

The set of generalized costs for $\{N_m\} | \{F_m\}$ is defined by the dot products:

$$C_i = \omega_i^T \cdot V_i, \tag{12}$$

resulting,

$$C_i = M_i + c_{Ti} \cdot T_i + c_{Ri} \cdot R_i + c_{Si} \cdot S_i. \tag{13}$$

Then, the solution for the stated problem is obtained from:

$$\min(C_i),\ i \in \{rail,\ road,\ naval,\ air\}. \tag{14}$$

At this point, besides *SIMA, IMA and CIMA,* the outcome of equation (13) can also be used to improve the performance of any already existing flows allocation algorithm based on mathematic theory of virtual graphs [Jourquin et.

Limbourg, 2006]. The updated algorithm is presumably accessing its own database for costs of intermodal transfer in relevant nodes (vertices).

6. COST MINIMIZATION ON NETWORK AT END-USER LEVEL

With the aim of further concretization of *SIMA, IMA, CIMA,* the results obtained at the elementary section's level (virtual graph's edge) are extended over the network or more precisely, to the subset $\{N_{rel}\}$ of the set $\{N_m\}$. The set $\{N_{rel}\}$ is defined as the union of all elementary section of the network over which the requested flow could eventually be transported between origin and destination. The following consideration will refer to this subset.

Let us consider the *n* sections of the $\{N_{rel}\}$:

$$n = \sum_i n_i \text{ , i} \in \{rail, road, naval, air\}. \tag{15}$$

and the total amount of transported units

$$U = \sum_i^4 \sum_j^{n_i} u_{ij} \cdot l_{ij} \tag{16}$$

where u_{ij} = transported units on section *j* of the modal network$\{N_i\}$;

l_{ij} = length of the section *j* of the modal network $\{N_i\}$.

Starting from eq. (13) and estimating the unit costs, c_{uij}, for each transport mode *i* and section *j*, and the unit costs of any possible intermodal transfer c_{uij}^{imt} from section *j*, the total cost could be expressed as:

$$C = \sum_i^4 \sum_j^{n_i} (c_{uij} + c_{uij}^{imt}) \cdot u_{ij} \cdot l_{ij} \tag{17}$$

Consequently, the optimal solution on the transport network at end-user level results for:

$$\min\left(\sum_i^4 \sum_j^{n_i} (c_{uij} + c_{uij}^{imt}) \cdot u_{ij} \cdot l_{ij} \right), \text{ i} \in \{rail, road, naval, air\}, j \in \{N_i\}, \tag{18}$$

which allows practically to organize transport processes and build an optimised path between origin and destination with the lowest generalized cost, by choosing for every section the transport mode offering the best combination between the generalized transport cost over current section and the intermodal transfer cost to the next section.

They could be easily implemented as optimization tools in any existing software for transport organization. That is, the four concurrent edges of virtual graph corresponding to rail, road, naval and air are weighted with the costs *C*, allowing further independent analysis and decisions where the newly proposed generalized cost method is valuable.

When *SIMA, IMA and CIMA* are separately coded to be used as independent optimising applications, a routing algorithm should be also integrated in that package. That should be able to generate the initial path and the related possible alternate paths as a selection set from where the optimising process should start.

The proposed model remains valid when the macroeconomics eventually changes (e.g. an improved budgetary allocation mechanism between modes will be developed, any kind of cost internalization takes place or a specific set of guiding policies designed to reduce market sub-optimality are approved). However, despite the fact that the model is not affected, the optimisation results and conclusions should be then revisited, as the macroeconomic measures will also change the microeconomic premises used as inputs to the model.

7. CONCLUSIONS

The demand for transportation services on the intermodal and modal markets generally displays a positive cross elasticity of demand as it operates with *imperfect substitutable services,* meaning that their substitutability is rather a matter of degree.

From the classification point of view, transportation services fall either in the *within-category substitutes,* having the same traits and belonging to the same taxonomic category or in *cross-category substitutes*, belonging to different taxonomic categories but still resolving the same functional problem.

For some market segments, there is an *intense modal competition* detected, but *modal complementarity* is present as well, which reveals a high potential still to be explored. Based on this observation, a clearer separation between the action’s scopes of the involved actors could be achieved.

The companies from the pyramid’s bottom, in charge for logistic chain’s building or coordination, shall innovate and optimize as much as possible their services which is important for the *microeconomics*, but they have rather limited if any resources to generate a real game changing.

The policy makers instead, should be mainly responsible for *macroeconomic* adjustment, securing a level play field and for this specific case, by taking advantage of the opportunities that an increasing modal complementarity could offer.

The results of the synchronic and diachronic analyses, allowed for the scope of present work, under some simplification hypothesis, a disconnected analysis of the networks transferring materials flows (rail, road, naval, air), from the other sets of national operatorial structure (energy, information, values).

With future works, when the analysis shifts to macroeconomics, the present simplification hypothesis should be revisited and adjusted, accordingly.

The newly developed model, based on the generalized cost, allows the companies in charge with transport organization and management to optimize the transportation processes for freight or passengers, by case. The model is comprehensive, addressing all modes, but a reduction of the general aspect of the problem, to address specific cases, can be anytime, easily operated.

The following types of analysis, as a personal contribution of the author, have been proposed and defined. They could be easily implemented as optimization tools in any existing software for transport organization or can be separately coded and used as an independent application:

a) *Simple Modal Analysis (SIMA):*one simple trip, single transport mode choice;
b) *Intra-Modal Analysis (IMA):* multiple alternative within one transport mode;
c) *Complex Inter-Modal Analysis (CIMA):* complex chains, multiple modes.

Further research is necessary. As stated, the analysis revealed the presence of both *modal competition* and *modal complementarity*, the former is to be contemplated in future works as an *opportunity*.

An *improved overall allocation mechanism* is to be developed, able to generate public funds savings that could be of further use for macro-economic tuning or simply optimized budgetary re-allocations within transportation sector.

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