Intelligent decision support system for transport infrastructure investment with emphasis on joint logistic concept

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ABSTRACT

The aim of this thesis is to provide to the governmental decision-maker/user, an instrument that can assist him/her in improving the infrastructure investment decision in the economical, environmental and sustainable aspects. This means that, the Return on Investment (ROI) of the concerned transport infrastructure, satisfying environmental and sustainable constraints must be positive, and corresponding to an optimal investment cost.

The decision support system can be applied in two dimensions. One dimension is where the real negotiation process is occurring between private and public stakeholders, called “real time negotiation process”. The second dimension is where the negotiation process is impelled by the user (public part) without private stakeholders interaction (but with interaction through simulation), called “virtual negotiation process”.

The simulation and local optimization techniques, in phase with agent technology, used in the “virtual negotiation process” enable us to achieve a certain amount of alternative decisions to the primary/suggested decision to be evaluated.

The CommonKADS methodology with mathematical modeling, and agent technology have been the support respectively for extracting and implementing the knowledge in the domain, monitoring, automating and updating the decision process.

The principle of “Joint logistic” [1] in my effort concerns by the means of sharing financial and information resources; This leads to the empowerment of the supply chain feedbacks (roles), involved in the earlier stages of public transport decision making-process.

It appears that within the decision-making process, the government is often dealing with the conflicting objectives, while interacting with the business stakeholders. For instance, the estimated investment cost of a specific transport infrastructure can exceed the income generated by this infrastructure, thus the ROI of the concerned transport infrastructure (TI) will be negative.

From this perspective the government faces three choices:

a) increase the rate of the taxes applied on that transport infrastructure or any other taxes, in order to make ROI positive, this can be matter of discussion/disagreement for the business community

b) reduce the investment cost which means suggest a different TI with a lower quality standard compared to the previous; this can also be a matter of disagreement between the two concerned stakeholders.

c) delay of the investment in the specific transport infrastructure.

In fact in the most situations the government uses the first approach, which effects might be consequently unpredictable and disastrous in the economical and environmental sense for the government.

From this point of view my attempt is to propose an intelligent decision support system for governments or project groups (e.g. East West project group), involving conceptually as components web portal, database, simulator and knowledge base, that bases on an approach, that enables this negotiation/information exchange at the earlier steps of decision-making situation. This is concretized by gathering in real time accurate and relevant information from the private sector; furthermore the knowledgebase of the designed system is conceived via the experience and historical knowledge of the concerned experts in the domain.

Keywords: public transport policy-making, infrastructure investments, supply chain management, key performance indicators, joint logistics, intelligent decision support system
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1. INTRODUCTION

The motivation of this study has been stimulated by the increase of the transportation issues, such as traffic congestion, accidents, few spatial resources available with the implication of the environmental issues (air pollution, noise).

The transport infrastructure investment decision is the platform on which the issues cited above are tackled by only the government (public stakeholder), and it is also a platform where the private stakeholder (supply chain) is a core element that influences the achievement of the governmental objectives (economical, environmental, social/sustainable) assigned to the transport system development; therefore the concern of this thesis is to study the transport investment decision-making process.

Referring to Gwo-Hshsuing Tzeng and Junn-Yuan Teng describing the transport infrastructure investment decision as “fuzzy decision problem” with the steps enounced below:

- Need of transport infrastructure
- Evaluation of potential private users using “selective method”
- Financial appraisal through cost-benefit and risk analyses
- Transportation impacts assessment
- Choice of the satisfying alternative action in phase with the parliament commitment
- Implementation stage

In order to handle the fuzziness of the infrastructure investment decision process, the author suggests strengthening the cost-benefit analysis methodology, used in the financial assessment, with risk analysis based on “Monte Carlo” simulation, applied in the transportation impacts/external effects assessment [22]. Basically this approach is typical technical and only based on the assessment techniques (not always accurate) without truly gathering the accurate information from the majority of the potential users.

Generally we distinguish two types of transport infrastructure unimodal (one mode transport system, like road/railway/seaway) and multimodal (at least two mode transport system linked together). The study choice here is the investment decision for multimodal transport infrastructure, because of the positive aspects of the type of infrastructure from the environmental and users satisfaction perspectives.

The intermodal transport infrastructure, seen as a transport system which involves more than two transport modes, is today the optimal solution for freight and passenger movements, in terms of sustainable, environmental, and economical performances. According to David Banister, the intermodal transport infrastructure provides to the users a better execution of supply chain operations in terms of quality and reliability and also the better environmental performances [8].

The transport investment decision is a very complex decision-making process, which involves different aspects of the different activity fields, such as social, economical, environmental and region/country development, combined with the regulatory policy.

Depending on the aspect that should be prioritized, the risk/impact analysis will have more or less importance in the assessment of the decision. In addition to that, the large numbers of potential and real stakeholders with their individual specific goals, in the decision-making situation related to the dynamic of the interactions among different parties, make the impact/risk analysis unpredictable and, consequently the infrastructure decision process as well. The majority of the non-deterministic decision-making processes are highly risk-driven with minimum visibility along the process.

There are today certain numbers of approaches to tackle this issue, but the outcomes are largely deviated from the expected results; this leads to rise up the question of efficiency and effectiveness of those methods. In my thesis in addition to the technical solution proposed by Gwo-Hshsuing Tzeng and Junn-Yuan Teng we have included the knowledge extraction process (Fig.2) as complementary contribution toward better transport infrastructure investment decision.

The knowledge is illustrated by the set of Key Performance Indicators (KPI) (Tab1&2), which enable us to better capture the needs of each stakeholder in order to reach a consensus between public and private actors,
1.1 Background

The state-of-art today in the transport infrastructure investment is very complex, time consuming and asking a multiple-step and one-side decision-making process, described below:

First of all the needs of the infrastructure is examined (from the small modifications of the infrastructure to the design of a new transport system/infrastructure).

Secondly, the level of the investment in terms of finance, small investment can be handling at the regional level, much large investment at the level of the country.

In the third place the identification of the co-partners in the private sectors in terms of financial contribution, at this stage the “selective method” (governmental policy of selecting among the companies, often the largest ones and establishing a basis for cooperation via mails and meetings, and sharing the investment financial expenses) often takes place.

In fourth this decision investment should be strengthened by the parliament commitment, and at the end the implementation stage [13].

Many researchers, studying the issue enounced above, have identified the influences/impacts of the governmental policies on the supply chains in one part or vice versa in the other part [8&9]. In fact the transport investment decision process lacks an integrated view and common decision of both stakeholders; therefore the conclusion, which could be drawn from the review of these scientific documents, is that often the traditional infrastructure decision process involving private and public stakeholders can not be reliable in terms of the effective achievement of the designed goals for both stakeholders in a long term, is almost not suitable for evaluating the environmental performances of the concerned infrastructure, consequently the effects of the transport decision are unpredictable in a long term perspective(Fig.1). The illustration of the impacts of the non-integration between public and private actors into a “global supply chain management” has been exemplified in the framework of SRA as below:

According to the annual report of the Swedish road administration (SRA) the road freight movement has been increased by 4.3% in 2005[12]. In phase with the same annual report, a lot of investment (more than 8 100 million SEK) has been done in the Swedish road network and the customer satisfaction has been measured through web based survey, and it revealed, that the individuals are more satisfied than the business community by the road transport system.

From this perspective the SRA finds the need to improve this important cooperation and establish a more closer and real time interaction with the business part [12].

The non-satisfaction of the business community combined with the issue cited above reinforces the complexity of the interactions between the public and private sectors, by making difficult for the governmental decision-maker to understand the real impact of the taken decision. At the same moment, for the supply chains it is hard to measure the influence of their strategies on the environment, lack of visibility for both partners, redundancies one adjusting his policy in relation with the action of the other one repetitively, no accurate information exchanges between public and private sectors.

You can observe in CAMEROON, where one airport (NSIMALEN airport) had been built in order to reduce the congestion in the town of Douala (Douala airport), but today not in used only because there were no commitment among the different stakeholders, another case, the example of “Ryan Air”, whose the success today (low total running costs) is based on the use of the regional airports (ref. http://en.wikipedia.org/wiki/Ryanair), for instance Paris-Beauvais airport. Those airports were in standby position for a long period of time, which causes to the government waste of financial resources (http://en.wikipedia.org/wiki/Paris-Beauvais-Till%C3%A9_Airport)

The analyses of the literature, scientific and non-scientific documents (such as annual reports of different governmental transport organizations in Sweden, ref to [9], [12] and [15]) enable us to foresee the needs to establish a strong, transparent and large cooperation, involving more participants in the private sector(avoid the selective method), in the joint manner, between the public and the private sectors at the earlier stages of transport system investment decision(for instance at the first step described above), which should be followed by the legal commitment among these stakeholders (see Fig.4).
Joint logistic is a deliberative concept, mainly applied in the army forces, of sharing the service logistic and information resources in order to improve synergy and reduce both redundancies and costs, and decrease congestion [1].

Our concern is to apply this concept, in the perspective of sharing information and financial resources between the supply chains and government(s) in the global supply chain management (GSCM), precisely at the level of governmental investment decision to establish an intermodal infrastructure in the conformity with the balanced objectives for both actors.

The traditional relationship supply chains-Public sector, involving suppliers-distributors-customers, which goals were defined within the supply chain (SC)[3], and supply chains were the simple users (not participating actively in infrastructure decision-making process) of intermodal infrastructure. Meanwhile the government was a stand-alone decision maker for realization of intermodal infrastructure. Here, we must understand that the government here includes the governments at customer location or/and supplier location, respectively and also by considering international forwarding activities, we should include the government of transit countries.

Nowadays the changes in the supply chains strategies (for instance, Just-In-Time concept, Vendor-managed-Inventory approach) and greater demand of products and services have an important consequence for governmental transport management [10], those facts lead to the increase of goods transportation/freight movements. Consequently, the government faces the rising demand, for instance in road space, the needs of transport infrastructure and updated regulation, and in addition to that the necessity to decrease the negative impacts of the transportation activities on the environment via regulatory policy.

The fundamental changes with this approach is to involve actively at the strategic level both actors (government(s) and supply chains) in the intermodal infrastructure decision process (joint logistic principles), in the collaborative way (not optimizing the respective goal separately) by balancing the multiple, sometimes conflicting objectives.

The application of information and agent technologies, meaning that the modeling of actors via computer agents(controllers) and the use of computer system in information exchanges and in the decision-making process is essential and relevant in this issue for the following reasons:

♦ Involve the maximum of potential users, so that it will be more accurate to predict the behavior of these stakeholders by getting exact information.

♦ Enable a learning process, which eliminates the redundancies within the decision process. For instance, in the case where we have known approximately the potential number of users of the suggested infrastructure, we can easily evaluate the environmental performances of the transport infrastructure without going through all the steps of the related decision-making process.

♦ Reduce the risk of investment and the processing time

♦ Enable better visibility and clarity of the decision process and the impacts of these decisions on the society

Moreover optimize the balanced multi objectives in the framework of GSCM.
Fig. 1 Government – Supply Chains interaction diagram in the traditional infrastructure decision
1.2 Research Questions

The continuously growing demand in freight transportation[5] predicts some future issues, such as congestion at the terminals (airport, port), traffic congestion, environmental problems, the over utilization of natural resources (land, energy), visibility of activities by the users along the global chain, redundancies along the global chain, reduce administrative business processing time, implicitly delivery time.

The relevance of this research is that this approach/concept overcomes the issues cited above, and it is a means of improving the infrastructure investment decision of the public stakeholder at the same time improving the factors/parameters enabling the better performances of the supply chain(s), which means better satisfaction for both stakeholders.

By elaborating this concept, the aim is to answer these following questions:

RQ1) which approach traditional or joint transport infrastructure decision process can better function as an intelligent decision support system for public infrastructure investments?

RQ2) how can we evaluate the impact of the decision on the individual actors of the supply chain?

RQ3) How to improve the investment decision process with the application of IT tools?

1.3 Contribution

The relevance of this thesis is the fundamental changes in government decision-making process, where Supply chain(s) and government bring their respective contribution in implementing the intermodal infrastructure, comparing to the approach where the government was taking a stand-alone infrastructure decision and the supply chain(s), as financial support, were readjusting their strategies in relation with the new decision. The challenge of the supply chain management is better intermodal freight execution, involving in the collaborative way all the stakeholders in order to establish a synergy in their actions (principles of joint logistic).

Looking at the weaknesses of the described infrastructure investment decision process and of the methods (section 1&1.1) applied to handle them enables us to build up targets, which are the backbone of the suggested solution, described below:

► develop a macro-level approach that defines respectively the public infrastructure investment decision and private stakeholders feedbacks (decision) as set of uniform Key Performance Indicators (see Tab.1 & Tab.2)

► Apply fair transport policy on the TI by categorizing the private stakeholders according to their impacts on the environment

► Shift the action of the supply chain from the latest stage of the decision process to the earlier and empower his role

► Application of the joint logistic concept in the financial and external appraisal at the middle of the decision process

► Application of information technology

The conceptual knowledge based system (IDSST2I) is my scientific contribution toward transport system development in order to reinforce and improve the interaction between the government(s) and supply
chains/business communities in the transport infrastructure investment in order to achieve the common balanced economical, social and environmental goals

1.4 Methodology

This thesis is a “proof of concept”[6] in the framework of case-study (“East-West intermodal corridor”), initiated by the literature review process on certified research papers, where the issue, enounced in part 2.1, was identified.

The suggested concept, emphasizing on involving the private sector at the earlier stages of governmental decision-making process, is built on quantitative methodology( mathematical modeling) with the use of trade-offs and responsibility sharing between the different stakeholders. The presence of the conflictive goals imperatively forces us to focus on the way(s) to reach a suitable consensus for both stakeholders, first avoid to optimize the individual objective value(in other words avoid the use of individual rational behavior in this concept), but balance the objective values in order to reach a consensus among the actors, second gather more accurate information for a transparent decision-making process and third assign and implement the common balanced goals reachable in a long term perspective.

As we have stated earlier, the conceptual decision support system can and will be used in the “virtual” and “real time” negotiation processes; in both directions the crucial question is how to generate a large amount of alternative decisions in order to increase the probability of achieving a consensus between stakeholders, if there are disagreements among the actors.

The first direction provides to the decision-maker a better simulation platform for impact or performance analysis of the concerned infrastructure decision without risk. In this case to handle the raised crucial question above, the techniques and methodology appropriate here are discrete-event simulation and optimization (see section 4.3.2), agent-based technology, which models the behaviors of the private and public actors, combined with the elements of rule-based reasoning and rationality of the decision-maker in order to generate alternative decisions (prescriptive decision theory).

The rational behavior of the stakeholders, in this case, suppose that none of them has the maximization (minimization) objective value, for instance the Supply Chain(SC) will not follow the goal of minimizing the cost related to the new Transport Infrastructure(TI) compared to the cost related to the current TI if the quality criteria of the new TI is greater than the current; in fact the government will not increase the taxes, fees and Infrastructure Utilization Cost(IUC) if the quality criteria of the new TI is less than the current used by the SC. This rationality enables the process to be objective, better prepares the both parties for the active negotiation on the legal agreement.

An intelligent decision support system must have the ability to process both qualitative and quantitative data and use reasoning to transform data to opinions/evaluations/alternatives [16]. Since we design our decision support system as knowledge based system, the methodology used for the functionality description of the system is CommonKADS methodology [20]. COMMONKADS methodology is used as elicitation techniques and platform for designing a knowledge-based system. The purpose of applying CommonKADS methodology is set out in two compartments: first as methodical support for extracting the knowledge from literature and domain experts, specifying the issue detailed above and also for providing suitable solution to the related issue; secondly as support for finding out the relevant tools for the concept development.

This approach facilitates the transformation of the experts’ knowledge into a computer program and also strictly defines the knowledge flow and the roles of actors (knowledge provider, knowledge analysts, knowledge manager, knowledge designer and knowledge user) [ref. fig.2].

The validation stage will be executed via interviews of the “subject matter experts” (for instance public authorities, business organizations, researchers, etc……).

The interviews and literature review on certified research papers are main part of the validation process.

The fact that this thesis is a case-study will help us in the validation stage and tractability analysis (how much the conclusions are close to the real life?)
1.5 Research Outcome

Many researches conducted in trade exchange had shown the increase of frequencies of goods deliveries [8], implicitly creating an increase in the commodity volume transportation, that’s why the congestion in terminals, traffic congestion and environmental problems are unavoidable, the lead delivery time will increase, which will create an increase of indirect costs to the company. There is a necessity to establish a “joint” view among actors for transport infrastructure development.

The outcome of this research is an integrated /collaborative decision support system at the strategic level for the government. There is an opportunity, at the tactical and operational level(s) for a better execution of supply chain(s) operations, provided by the balanced intermodal transport infrastructure. Technically, the outcome of this study is a conceptual intelligent Decision Support System for transport Infrastructure Investment (IDSST2I), based on discrete event simulation and optimization methods, and constituted by a storage database component, model component and feedback link.

This integrated/joint logistic solution for global supply chain management at the level of government/local authorities, enables better planning, visibility, effective and efficient use of resources, better transport environmental and sustainable performances, decrease total running costs, improving the legal commitment along the GSCM partners.

In this part of the thesis we have stated the issue, which deals with information and financial sharing resources between the private and public stakeholders for better transport investment decision, in continuation we detailed and analyzed the issue into threats and opportunities and finally come up with a conceptual intelligent decision support system as a solution for the described problem.
2. GOVERNMENTAL INFRASTRUCTURE POLICY

2.1 Government and other stakeholders

The government played the traditional role of predominant actor among the different stakeholders in the society. Its main actions are involved in the social, environmental and economical domains of the society. The role of the government is to provide a controlled structure (regulation, laws, rules etc…) to the society in order to improve quality criteria of the environment in different aspects:

- Social (welfare, education, health)
- Environmental (better air quality, safety, nature protection)
- Economic (increase Gross Domestic Product, infrastructure for region/country development).

Today there is tendency/needs to establish more cooperation among the different stakeholders in the society, referring to the words of John Hulten (employee in Swedish Road Administration), who said “The traditional view is that the government is the dominant actor in society and is able to steer the development. More recent theories (so called governance theory) question this assumption saying that the government is one among many actors in society and therefore needs to cooperate more with others to achieve its goals.” This goes in phase with “e-participation work” developed by Annelie Ekelin, where the different actors involved in the governmental decision-making process contribute in the improvement of the balanced decision via e-communication tools. [19]

Thus, we can consider the government as, the center/platform of a multilink relationship among the different stakeholders, like Business/private sector, citizens, environmental organizations and other stakeholders (i.e. international organizations, other governments etc) (see fig.3)

These stakeholders often are interacting with each other indirectly through the governmental rules/laws and regulations, but of course there do exist kind of, not so important, direct cooperation among actors with less governmental influence.

My thesis is restricted on the link Government - Business (considering as dynamic process), by assuming that the other links are static (see link in blue fig.3), because in this case we consider that the governmental objectives here are already predefined through the interaction with the rest of stakeholders.

From the perspective of better cooperation within the Government-Business link, specifically government-supply chains, we proposed a fundamental different interaction between these two stakeholders, based on the decision-making process illustrated in Fig.4

The fundamental difference of this process is that, we have empowered and shifted the role of the supply chains from the latest steps (financial resources for implementation of the concerned transport infrastructure) of the traditional infrastructure investment approach (Fig.1), described in the further lines, to the earlier steps (design of the suggested transport infrastructure) of “joint/integrated” infrastructure investment decision. In that process, the suggested infrastructure decision by the government is illustrated in Tab.1 and the supply chain feedback in Tab.2, the decision-maker has to consider substantially the supply chain feedbacks, relied on the contested KPI(s), in order to provide another alternative decision.

The “Joint” infrastructure decision, represented in Fig.4, is characterized by sequential steps/events (Ref. section 4.3.2) and forms a loop, in which the numbers of cycle should defined by the system designer with the agreement of the governmental decision maker.
Fig. 3 societal model
Fig 4 Governmental decision Flowchart diagram in the real negotiation process
The transport infrastructure investment, as part of the link government-business, is the domain where public and private parties need each other in order to achieve their respective objectives, such as economical growth of the country, better and sustainable environment, better accessibility and transportation etc.

The transport infrastructure decision is divided into two components:

♦ **Physical component**, it is the infrastructure itself (for instance road, bridge, airport, terminal), even though, in our case, not implemented yet.

♦ **Soft component**, it is the regulatory and fiscal control policies, accompanying the defined infrastructure (tax for Heavy Goods Vehicles (HGV), speed limit on the, CO2 emission rate etc…).

Since the transport regulations and laws are placed in order to achieve the environmental and socio-economical goals, thus the impact of their implementation is obvious on the design of the supply chains; implicitly there is an established strong influence on the supply chain(s) goals [9].

For example a speed limit on the road, will influence the transportation time, the restriction on vehicle weight can force the supply chain to use another mode of transport.

According to Peirson et al (1998)[8], even though the private sector will have a greater role in financing transport initiatives in the future the public sector is likely to maintain an important role in funding public sector transport systems and investing in transport infrastructure in general in order to reach their designed goals.

These goals are represented by the following Key Performance Indicators (KPI), based on transport system KPI defined by Pierson et al [8]:

- Supply chain Participation rate
- Congestion rate (accident/incident rate)
- Speed limit (SpL)
- Environmental KPI (pollution rate, noise)
- Infrastructure utilization cost
- Taxes and fees
- Infrastructure Capacity
- Administrative business processing time
- Total taxes and fees revenue.

Some other characteristics are important factors, because they have a strong influence on the output of IDS2I, such as: suggested implementation date, regional development growth rate.

### 2.2.1 Use of Key Performance Indicators

The acronym KPI, which means Key Performance Indicator, are financial and non-financial measurements of the organizational objectives (Ref. Wikipedia encyclopedia). They are mainly concerned with the strategic achievement of the organization.

The use of KPI in this context is based on the fact that we are dealing with strategic investment decision, and the other hand the KPI are evaluated for a sufficient long period of time, which means they are not so much sensitive to changes within that period of time, therefore their reliability of using them in this study.

The KPI, described below based on the KPI(s) in [9], have been selected and created as common basis according to the relevant and influence that they have on both governmental and supply chain decision matter on transport investment,

The use of KPIs is also motivated by the opportunity for benchmarking and evaluating different transport infrastructure decisions.
2.2.2 Governmental Key Performance Indicators

These are the quantitative values used by the governmental decision-maker to track the dynamic of the process and at the same time predict the future/potential bottlenecks and foresee the future needs in transport investment for instance.

We can cite here the most important governmental KPI are:

- **Supply chains participation rate**

  This KPI shows the number of supply chains with positive feedback, regarding the suggested transport infrastructure over the total amount of supply chains registered.

  It is an accessibility criterion, which describes for the public stakeholder how much the infrastructure is utilized by the business community.

- **Congestion rate**

  This KPI is usually utilized along the entire road transport system. The congestion rate is specifically defined and measured at the terminals/hubs, when we are dealing with other transport modes, such as sea, air and rail.

  It defines as the number of vehicles/trains/airplanes used to the nominal capacity of transport mode (road/railway/airport respectively)[10 http://www.csis.u-tokyo.ac.jp/dp/40.pdf].

- **Environmental KPI**

  We distinguish two very important ratios, assuming that they are in the direct way involved in the freight transportation: pollution rate and noise emission rate

  Pollution rate is defined by the rate of carbon dioxide (CO2), hydrocarbons (HC) emission into the atmosphere, produced by the users at the concerned transport infrastructure.

  Noise rate is the number of decibels, allowed in the concerned transport infrastructure.

- **Infrastructure utilization cost (IUC)**

  This KPI can be included either in different types of taxes or fees or can be view as a stand-alone parameter, in order to identify the return of infrastructure investment.

  Thus, we have decided not to include this KPI in the regulation and fiscal context, but we will consider the second alternative, described above

- **Taxes and fees**

  The taxes and fees that we chose to consider are kilometer-taxation, congestion fee, fuel taxation.

  The variable taxes that could be applied on those links are fuel tax(FT), environmental taxes in relation with CO2, pollution tax(PT) and noise vehicle emissions tax(NT), heavy goods vehicle taxation(HGVT) specifically for truck with a certain capacity, pilot fee(PoF) and fairway due(FDF) for sea transportation in Sweden and fuel taxation could be related to congestion issues, associated with toll fees(TF), vehicle registration fee(VRF), commercial traffic fee(CTF), parking fee(PF) etc….

- **Administrative business processing time (ABPT)**

  This KPI is used when the transportation crosses the borders of a country, for instance the time spent at the customs to clear the goods.
It is very crucial factor, which influences the total delivery time to the customer.

- **Infrastructure generated tax revenue (IT)**

This ratio indicates how much tax and fee the government is willing to collect from all the potential infrastructure users including passengers and freight supply chains, to be more concrete transport forwarders. In the common way this ratio is called income tax in many countries.

- **Infrastructure size (IS)**

This KPI defines the length or/and width of the suggested transport infrastructure. It is an important parameter that also defines the capacity of the infrastructure in terms of amount of users, and specifically enables the decision-maker to evaluate the opportunity for an increase of capacity of the transport infrastructure by modifying the size.

- **Capacity**

This KPI reveals the potential maximum number of users of the suggested transport infrastructure in terms of maximum number of vehicles in activity on the transport infrastructure simultaneously.

In accordance to the parameters/KPI cited above, the governmental primary decision will be presented through the web portal to the business community/supply chains as described in the Tab.1, and where each KPI/parameter is a matter of discussion among the private and public stakeholders.

<table>
<thead>
<tr>
<th>Suggested Transport Infrastructure Type(implementation date)</th>
<th>Taxes</th>
<th>Infrastructure utilization Cost(IUC)</th>
<th>Administrative business Processing Time(ABPT)</th>
<th>Capacity</th>
<th>Geographic Location</th>
<th>Infrastructure size(IS)</th>
<th>Fees</th>
<th>Congestion Pollution Noise rate</th>
<th>Speed limit(SpL)</th>
</tr>
</thead>
</table>

Tab1. View of suggested transport infrastructure

### 2.3 Some key characterizations of transport infrastructure

The criteria, stated below, are guidelines for the supply chain and governmental decision-makers for benchmarking (by KPI) among different transport infrastructures in general. For instance the supply chain decision-maker can use these criteria for evaluating the ratio transport cost/criteria (Ref. to Supply Chain veto points section 8) for each transport infrastructure decision in order to undertake the rational and objective feedback.

From the governmental decision-maker, these criteria are useful in terms of providing rational infrastructure decision in the way that the cost of using the infrastructure should be proportional to the related infrastructure criteria.

#### 2.3.1 Quality criteria

The quality of any transport infrastructure/system is one of the key important characteristic; it reveals to be defined in two directions: technical/technological, following some standards and spatial, in terms of accessibility by a certain number of users.
The accessibility component of transport infrastructure aims to improve the traveling condition of the users by decreasing their traveling time (less congestion, refer to Congestion rate KPI, ABPT) and at the same time connecting a large majority of users, situated in different geographical areas (geographic location KPI).

### 2.3.2 Quantitative criteria

The quantitative characteristic of a transport infrastructure is illustrated by the KPIs, such as Infrastructure Size (IS), capacity, infrastructure utilization cost (IUC). This criterion is a key factor that determines the modifications on the concerned transport infrastructure or the design of a new transport infrastructure in order to preserve the cited above and below criteria for the transport infrastructure.

### 2.3.3 Safety criteria

This key transport system characteristic is concerned by the measures (regulation, safety engineering solutions etc...) undertaken by the government to reduce the number of fatalities/deaths on a given transport system. For instance the speed limit, in my effort is seen as a safety key performance indicator.

### 2.3.4 Sustainable criteria

Sustainability is an attempt to keep the environment alive for the future generation, by reducing the negative impacts of the human being activities. The sustainable policy is regulated by the government and today seems to be a crucial issue for the whole planet. The sustainable criteria of the life emphasize not only the environmental goals but also cultural components of the society.

Sustainability can be viewed through different main angles, economic, ecological and energetic, and cultural/institutional in relation with transport infrastructure:

- Economic sustainability is concerned when a technical cooperation is subsidized by the governmental funds. In the case that the subsidies are established for a very long term, then the economic sustainability has a bad indicator/index.
- Ecological and energetic sustainability is concerned when the technical cooperation/deployment preserves the nature and resource in energy for the next generation. Thus today some organizations provide a “green” ranking for worldwide companies, the companies higher in the ranking, are those whose pollute less the environment (ref. [www.greenpeace.com](http://www.greenpeace.com)).
- Cultural/institutional sustainability is concerned when the technical cooperation is established with the respect of culture and the regulation of the given society. This component of sustainability involves much political aspect.

In our approach we will consider only the environmental and economical targets of the governmental sustainable policy, since they are directly involve in the transport infrastructure investment decision. The Cultural/institutional sustainability is political factor and it is also complex to quantify for the further use in the mathematical model (Ref. section 9), therefore it has been abstracted. Thus the KPIs, such as taxes and fees, pollution rate, noise rate are viewed as sustainable criteria.

The tender today is to switch from the unimodal transport system, specifically road transportation to intermodal (road, sea and air) transport infrastructure (today in Sweden the road transportation is 75% of the total volume of freight and passengers movements [11]). The purpose of this governmental concept, from the environmental perspective is to reduce the negative impacts of the road transportation (the worse
sustainable type of transport) on the nature, by establishing an adequate legacy framework and providing the benefits of intermodal transport system.

Therefore the sustainable criteria, which we can underline, are as follow:
- Pollution
- Noise
- Governmental subsidies

3. SUPPLY CHAIN POLICIES

3.1 Supply chain management

The approach of supply chain management evolved in different configurations from the relationship “suppliers-customers” to “suppliers-transport operators/distributors-customers” (third part logistic concept)[3].

The supply chain management is a business concept, where suppliers, distributors/transport operators and customers are integrated in the chain in the collaborative manner in order to achieve the common objectives. The focus of this concept is to provide a high performing and competitive service to the end customer.

There do exist multiple different strategies, which are driving the supply chain, but the most known and important, are
- Make to stock→push→customers
- Engineer to order (customers)

3.2 Supply chain interactions with the government

In relation to the strategy applied in the supply chain management, and in addition to the fact that majority of supply chains have switched from forecast-driven with the high safety stock of goods (due to the bullwhip effect)[14] to demand-driven with minimum inventory (called Kanban concept), consequently this will result to more freight movement/transportation. Knowing that transportation has a great impact (positive and negative) on the society, environment and sustainable development of the country/region [8], consequently the design of the supply chain strategies can require more transport operations, which means more freight movement, therefore, the strategies, applied in the Supply chain(s), is/are (an) influent factor(s) for the governmental transport and environmental policy and vice versa.

This fact and the performance of the technology open a window for studying this sometimes-conflicting private-public relationship in the framework of transport investment decision, with the respective regulation. In this part, we will illustrate the parameters/KPI of supply chain(s), which are steering the supply chains business. We focus on those KPI below, which are based on the KPI(s) described in [9].

The modern supply chain management is emphasizing on the reduction of the total cost (summation of production cost, inventory cost, transport operating cost, running cost), high service level, which means high fulfill demand rate and fast total delivery time (summation of administrative business processing time and execution processing time).

Rather than using updated values of certain parameters, which are varying within a short time period, we will use the KPI, which are more reliable at the strategic level.

From this perspective, the supply chain(s) KPI, which are related to supply chain objectives, are:
The last two factors have an implication the sustainable development of the region/country. In the future, the global supply chain management will be distinguished on the followings: unity of effort along the chain, domain-wide visibility, fast response time, and decrease running cost, by eliminating redundancies. Nowadays there are several studies/approaches and computer-based system/software application, such as ERP (Enterprise Resource Planning), VMI (Vendor Managed Inventory), which have been developed to optimize the use of resources, consequently increasing the performances of the supply chains.

### 3.3 Supply chain KPI definitions

The purpose of studying the supply chain KPIs, presented below, is to build up the “virtual negotiation process”, based on agent technology for developing a computer agent, called “Supply Chain Controller (SCC)” (Ref. section 4.4.3).

- **Total variable cost**

  This rate encounters all the costs that directly (variable) influence the supply chains performances. We found relevant here the cost, which constitute the total variable cost, such as production cost, operating transportation costs, taxes and fees for using the suggested infrastructure. It is an important quantitative performance factor [9].

- **Service level rate**

  This KPI shows how many customers for which the demand can be fulfilled, by using this infrastructure. He can be defined by the number of customers served divided by the total amount of customers. It is an important quality performance factor for the supply chains.

- **Total delivery time**

  This KPI is a quality performance, encompassing transport delivery time and administrative business processing time (ABPT). The replenishment time order (time between an order reception and the order processing ended), loading and unloading time are considered as internal factors, and thus they are not relevant for our case.

- **Freight volume rate**

  This KPI, quantity performance, is used to compute the Gross Domestic Product (GDP). It is the unit of goods lifted times the Average Length of Haul. He measures in tones-kilometers [8].
Average length of haul (ALH)

This KPI, quantity performance, is defined as the average distance traveled per unit of goods (ref. http://www.cn.ca/PDF/07-28_ang.pdf).

This ratio clarifies how we can relate the productivity and the need of transport infrastructure. Therefore the resulted feedback from the supply chains to the government is presented as follow in the Tab.2, in this perspective these supply chain parameters enable the government to review with more accuracy and information the primary transport system decision or in case of an agreement (OK from the majority of the supply chains) finalize the primary decision.

<table>
<thead>
<tr>
<th>Supply chain feedback to i-th transport infrastructure</th>
<th>Taxes</th>
<th>Infrastructure utilization Cost(IUC)</th>
<th>Administrative business Processing Time(ABPT)</th>
<th>Capacity</th>
<th>Geographic Location</th>
<th>Average length of haul(ALH)</th>
<th>Fees</th>
<th>Congestion Pollution Noise rate</th>
<th>Speed limit(SpL)</th>
</tr>
</thead>
</table>

Tab.2 View of the supply chain feedback

The majority of the decision support systems, designed today for improving the supply chain activities, are particularly focused on the internal processes of the supply chains. From this point of view we can observe that the inputs, relating to the regulation of transport system, are considered as raw data without real influence/interaction with them for the supply chain decision-maker, and in evidence that the outputs of the supply chain systems are strongly dependent of these inputs cited earlier. (See Fig.1).

Therefore the suggested solution, based on application of ICT (information and communication technology), where the supply chains are involved in the elaboration of the input data, concerning the transport system infrastructure and regulation, is a new state-of-art that contributes to improve the transport system decision for both stakeholders.

4. AN INTELLIGENT DECISION SUPPORT SYSTEM-IDSST2I

4.1 Development of IDSST2I, based on a potential real application

The East West Intermodal corridor (Fig.5, Fig.6) is the case study that constituted the platform for our proof of concept.

In the project we focus only on the transport infrastructures (road, railway, sea) with the related regulations. In the following lines we are presenting the transport infrastructures involved in the East West intermodal corridor with their specific KPIs, as infrastructure decisions illustrated in tab.1:

Road1 is viewed as the “suggested primary infrastructure decision”,
Road 2 and Road 3 are operational transport infrastructures, and they are the basis of the historical data (See section.8) for comparison with Road1 (“suggested primary infrastructure decision”) via criteria, described in section 2.3, in the defined objectives and constraints.

Road1 (speed limit, capacity, length, (taxes+fees), congestion rate, pollution rate, noise rate, infrastructure utilization cost, administrative business processing time (ABPT))

Sea1 (speed limit, capacity (maximum number of ships at the time), length, (taxes+fees), congestion rate, pollution rate, noise rate, infrastructure utilization cost, ABPT)

Road2 (speed limit, capacity, length, (taxes+fees), congestion rate, pollution rate, noise rate, infrastructure utilization cost, administrative business processing time (ABPT))
The need of establishing/implementing such of transport infrastructure is based on the governments’ priorities like: economic region growth, sustainable, safe environment and attractive infrastructures for the supply chains.

The objectives followed by designing the link1 are the same as described in the governmental policy paragraph, but in addition to that there is also a competitive factor in term of costs and services from the customer perspectives.

Therefore the issues to handle here, which are more predominant, are attractively, accessible, sustainable (environmental friendly), safe and cost-service competitive transport system (link1-EastWest corridor, ref. http://www.eastwesttc.org).

Any governmental transport decision inside and outside a country/region has a political connotation and can also involves economic aspect. This enables the difficulties to model a political decision, which is not always rational, meaning that the decision can not follow only the economic profit, but also the social life improvement, for instance the government/regional authorities can decide to establish a transport link between the main town and surrounding cities, which might not lead to a profit, but improve the accessibility and communication within the region.

According to the statement above, we have decided to focus within the East West project on the economic objective- Return On Investment (ROI), but constraining that objective with political and social aspects (sustainable, environmental factors).

The East West intermodal corridor is presented in the figures below:

---

Fig.5 East West Intermodal corridor (Link1)
4.2 Abstractions

As we have stated earlier in the lines above, the transport infrastructure investment decision is a very complex and wide domain, by its multidisciplinary dimension. From this perspective and for the objectivity of the study, it is necessary to apply in this thesis a process determining what part of the transport infrastructure decision will be modeled and at what level of detail; this process is called abstraction. In this paragraph we will enumerate, the abstractions that have been made in order to identify and clarify the boundaries of our problem.

Fig.6 Illustration of alternative transport Infrastructures, links 1-3
4.2.1 Freight concern

The governmental investment decisions are applied for freight and passengers transportation with more or less differentiation, but in our case study, we will restrict on freight transportation. Therefore, all the KPI, described above, are directly applied to the link Government-Private sector and are only concerning the freight activities.

4.2.2 The elaboration of the primary decision

The transport infrastructure investment decision, emphasizing multidisciplinary aspects of human activities, such as social, political, economical, geographical and civil and environmental, is a very complex thematic due to that multidimensional fundamentals and in addition to that there is not always existence of rational behavior in terms of profitability of the transport infrastructure, since the goals could be social, for instance the socio-profitability of road transport project constitutes 66.66% (10 projects over 15 are socio-profitable) [12], therefore, the process describing how a certain number of parameters (marginal cost of an infrastructure, the design of that infrastructure etc …) are taking into account in order to arrive at a concrete transport infrastructure primary decision is out of my scope, because mostly the elaboration of any governmental decision is political colored.

We assume that there is a given primary infrastructure decision, and what is the mechanism to build in order to improve this decision and strongly considering the private sector objectives.

4.2.3 Supply chain concern

In this study, we do not consider the relationship among the supply chain actors and the government with each actor, but the whole supply chain, thus we define the common objectives, regarding the concerned supply chain.

The platform where, government and supply chains are closely interacting is at the level of intermodal/modal freight transportation. We will then focus on this stage, but at the same moment analyzing the impacts of the proposed solution(s).

4.2.4 The supply chain strategy

Referring to the supply chains paragraph 4, we know that there are existing different designs steering the supply chains.

Since we are concerned with the factors, which have strong influence on both stakeholders (private and public) and considering the fact that the government is driven by the sustainable economic development of the country, thus the environmental aspect is prioritized. That leads us to restrict our study with the supply chain designs (lean logistic, Just-In-Time, Vendor-Managed-Inventory), because these strategies have direct impact (negative and/or positive) on the environment. The specificity of those supply chain strategies is that more freight movements/frequent transportation activities and less inventories are involved, therefore we can neglect the inventory cost in the total variable cost.

4.2.5 Variable or full costs

The factor cost is very important for both stakeholders. We distinguish full cost (variable and fixed costs) and variable cost.
Describing the interaction between private (supply chain) and public (government, regional authorities) partners, the inputs are transport regulation and physical transport infrastructure (ref. Tab.1) and impact of transportation/business activities respectively for supply chain and public authorities (ref. fig.1). From this perspective it is relevant only to consider the costs, which are directly influenced by those (external) inputs, called variable costs, respectively total variable cost for each supply chain using a concrete transport infrastructure and investment cost of the concerned transport infrastructure, assume to be only variable. The full cost implies the costs of internal and external inputs/outputs; therefore it is cumbersome and redundant to use this factor.

### 4.2.6 The web portal

The expansion today of internet and information technology all around the world, is a great opportunity for us to make the transport infrastructure investment decision accessible to every small and large supply chains (no selective methods). The web portal, as a technology mean for sharing the access to information with other stakeholders in the transparent way; consequently we are able to establish a trust atmosphere, to improve the communication among the different stakeholders and also reduce the redundancies, and business processing time, which was spent via ordinary mails within the communication between the private and public stakeholders (ref. to the words of John Hulten, employee in SRA-Vagverket).

Since my thesis work it is a proof of concept, basically relying on the model and the database, the design of the web portal can be considered as additional/more advanced step in my work, therefore, the design of a web portal is out of my scope, i just underlined the opportunity to design one, but i consider the database (storing and retrieving data) part of my thesis work.

### 4.3 Modeling Process

By modeling the Supply chain into the IDSST2I, we will consider the cases, where more freight movements are involved, in other words will consider the “lean” Supply Chain (ref. “Transport and Environment”), for instance, one of the more suitable examples for that is the Just-In-Time delivery or Vendor Managed Inventory approaches.

This process is the starting point of the development of the “virtual negotiation process”, where the supply chain decision-maker is replaced by a computer agent.

The aim of the design of our model is to support the public decision-maker in improving or achieving a balanced infrastructure decision by taking into consideration the simulated supply chain feedback and enable a learning process (simulate different possibilities) via quantitative methods; For instance in the case of East-West intermodal corridor Make the corridor attractive, in the economic sense, meaning that relatively equitable ratio between provided services and costs, minimum leading time and fast delivery.

The transport infrastructures (TI) into the corridor (Ref. to Fig.6), considered here for illustration of the “joint” intermodal infrastructure investment decision, are as follow:

- **TI1- Road 1**: it is a road infrastructure inside Lithuania, which is leading to the port of Klaipeda.
- **TI2- Sea transport mode between Karlshamn (Sweden) and Klaipeda (Lithuania)**

The investment encountered here in this part, are those which have been done/are executing in the both part.

That leads us to assign the investment costs to the utilization cost of TI2, and the parameters that described this infrastructure are integrated with the parameters from the both ports.

- **TI3- Road infrastructure joining Karlshamn (Sweden) and Esbjerg (Denmark)**
- **TI4: it is an alternative for TI3, rail infrastructure joining Karlshamn (Sweden) and Esbjerg (Denmark)**
We must have in mind that these hubs/ports above are intermodal and consequently have their alternatives, which are not parts of the East West corridor.

### 4.3.1 Mathematical modeling approach

The fact that the inputs and outputs of the system (ref.tab.1 and tab.2) are quantifiable values; we do consider a mathematical modeling as a suitable approach (abstract model) for designing this decision support system. It enables the knowledge engineer to simplify the reality, obtaining from the knowledge expert, for a better understanding of the phenomenon, and also introduce some elements of control combining with simulation and optimization techniques to improve the decision-making process. The mathematical model, representing the behaviors of the public and private actors and described in the appendix section, is the “intelligence” of the system that materialize the decision algorithm, represented in Fig.4.

The large number of parameters and variables has brought us to build the linear relationships in the model in order to avoid the complexity, but at the same we have attempted to be close to the reality.

The purpose of the application of mathematical modeling in this effort is to transform the infrastructure decision-making process from the unpredictable perspective to predictable. According to Gwo-Hshuing Tzeng and Jun Yuan-Teng “the transportation infrastructure investment planning is characterized by being multi-objective and fuzzy (uncertain)”

### 4.3.2 Computational simulation and optimization model

A computer simulation model is a computer program that attempts to duplicate or simulate an abstract model of a particular real life or unreal system [11]. There are several types of simulation models, but what have been applied are steady-state, stochastic and discrete-event simulation models.

The last one, applied for the overall system was our focus in this thesis by his significance and importance, is specified the following events, describing the “real negotiation process” (See Fig.4):

#### First event: Initiate/suggest a primary infrastructure decision

The decision-maker (human agent) inputs this event by introducing into the system (first into the database and then through the web portal) the primary infrastructure decision, as represented in Tab.1.

#### Second event: The supply chain feedback

The input of this event is the suggested governmental primary decision, and the resulted output, “OK” or “NOT OK with HCKPI (Highly Contested KPI)”, is the Supply Chain Feedbacks in the shape of tab.2.

In this event, the supply chain decision-maker processes the primary decision as presented in step 2 of the decision algorithm, by computing and assessing the supply chain veto points (ref. section 8) in order to make a decision. The result is the value of Highly Contested KPI (HCKPI), whenever there is/ are rejections of KPI (s) of the suggested infrastructure decision, otherwise the primary decision turns into the final decision. The Supply Chain feedback is then placed into the database.

#### Third event: Computation of ROI

At this step the input is the supply chain feedback, considered as “primary infrastructure decision” by replacing the governmental primary infrastructure decision (first event); this input processed by a computer
agent GROIO (Governmental Return On Investment Optimizer) (Ref. section 4.4.3) and the resulted output is the value of ROI (positive or negative).

**Fourth event: Governmental alternative decision**

At this last step, the input is the value of ROI, in the case where ROI > 0 the output is “primary infrastructure decision” (third event), considered as “final infrastructure decision”; in the case where ROI < 0 the output is either an “alternative infrastructure decision”, processed by a computer agent CIM (Computational Inference Mechanism) (Ref. section 4.4.3) and placed into the database for access via web portal, suggested by the government or a “delay” of process. The outputs are respectively the optimal values of HCKPI, CI and the alternative transport decision including the value of ROI according to the supply chain feedbacks.

In the aspect of “virtual negotiation process”, the number of events and their specificities remain the same with the difference that we replace the supply chain decision-makers by a computer agent “Supply Chain Controller (SCC)” (See section 4.4.3). The optimization approach allows us to discover the best values of the presented decision variables, while the simulation methods enable us to establish a learning process by retrieving and analyzing different virtual decision scenarios without the risk of failure.

### 4.3.3 Handling of pitfalls in the modeling process

The theoretical concept of “joint” transport infrastructure decision, as described in section 2, has the fundamentals on the operations research methodologies (in this case analytical/mathematical modeling) and decision and negotiation theories. In fact the theoretical approach is not enough for the physical design of the IDSS, there is also an essential part(practical approach), including computer tools and techniques, which makes the outputs of the system reliable, close to the reality and makes the system itself robust.

In the following lines the techniques and computer tools will be discussed.

The depth analysis of the cited theoretical concept enables us to foresee some pitfalls, which can be handled by the suitable and reliable techniques used in operations research area, such as optimization, computer simulation and agent-based technology. Some of those pitfalls/weak points in the decision-making process are: non-deterministic supply chain participation rate, generation of alternative decisions (loop design) and queuing process.

- **Non-deterministic supply chain participation rate**

The supply chain participation rate is non-deterministic; because we can’t assess accurately the internal processes and targets of their businesses. This fact makes in his turn the suggested TI decision a primary decision, ready for changes or modifications; implicitly the impact analysis (evaluation of KPI) of the primary TI decision can not be accurate and reliable.

The consequences of that, is the unilateral use of the system by the governmental decision-maker, which does not provide any SC feedback, therefore the “joint” TI decision concept return to the traditional approach, described in section 2.

For handling the pitfall described above, we thought of computer agent based on mathematical relationships(steady-state simulation model, see 15-1 in appendix), which represents the choice step of the supply chain decision process in terms of use/not use of the suggested TI.

Considering that the model is tractable, we can certainly state that at this point the decision process is deterministic, therefore the results, “rejected” value(s) of HCKPI whenever the TI decision is contested, are reliable.
So far the applied techniques and methodology, utilized to handle this pitfall, are steady-state simulation model and agent based technology.

- **Generation of alternative decisions and queuing process**

The generation of alternative decisions is the core element of the “virtual negotiation process”. Its importance is more so as, the reliability of its mechanism makes it possible to reach a consensus between public and private actors. Subsequently the tools (mathematical model, controllers) and techniques (simulation and optimization), described in the lines below and used in this process for the success of the overall concept, are highly important.

The optimization techniques, as support tool for the computer-based agent (GROIO), are used in assessing the strict positive optimality of the governmental veto points, which are the Return On Investment (ROI) and Investment Cost (CI) (ref. 15-2 in appendix) after proceeding the supply chain feedbacks. Thereafter the stochastic computer simulation model based on expert knowledge, using random number generator of CI and calculator of ROI, is applied to generate different alternative transport infrastructure decision in relation the respective ROI and CI.

The queuing process is managed by the discrete-event simulation model, explained above and described in the decision algorithm.

### 4.4 System components

The development of this decision support system, particularly the methods of generating alternative decisions, is bounded by the rationality of the behavior of each stakeholder and the lack of real information. The requirements of the decision support system include the support from the decision theory and mixed up with the constraints imposed by the government and private policies. The decision support system is aimed to be a web-based application; in other terms the communication between the different stakeholders, through their computer systems, is done via a web portal.

The decision support system is constituted by a web portal, database, knowledge base and the simulator components (see Fig.7).

The scenario, describing the “real negotiation decision process” is as follow:

1. The supply chains through the transport carriers can be connected via the web page and have access to the suggested infrastructure investment decisions (array1 in Fig.7), with the related KPI (see tab.1), in the next the supply chain decision-makers (Human agent) send the feedback, either “OK” or “not OK with Highly contested KPI” (see tab.2) via the web to the database (array 2 in Fig.7). The parameters, sent from the supply chains to the database, are computed (in the case of “NOT OK HCKPI” feedback) in the simulator (array 3 in Fig.7) and from that result automatically by inference mechanism, connecting knowledge base and simulator, the alternative infrastructure investment decision(s) or “delay”, which are sent to the database for the next use by the supply chains (array 4 in Fig.7).
4.4.1 Web portal component

The existence of a web portal is a characteristic of use of information and communication technology (ICT). The supply chains log in and have access to the transport infrastructure decision. By this mean we achieve the easiest accessibility to the transport infrastructure decision by the potential users; this enables the opportunity to connect other stakeholders (such as environmental organizations, political organizations etc…. ) into the decision-making process in order to provide suggestions to alternative decisions.

The web portal will provide clear and descriptive information about the transport policy, and also allows the connection of maximum potential users, since today the development of ICT has reached his peak stage. By enhancing the numbers of potential users to the transport decision-making process, we develop and improve the common view of all stakeholders toward transport policy development.

4.4.2 Database component
This component is built for storing and retrieving data. The types of data used in this thesis are Boolean, numerical and string. They concern by the historical data for the historical infrastructure investment, the new processed data from the public and private decision-makers and infrastructure investment decisions. This component is directly connected to the web portal, the simulator and the knowledgebase components (see Fig.7).

The design of the database requires a lot of effort in the implementation of the data model, query language and raise the issue of information security.

The relational model, as data model, can be suitable to represent data and facilitate the updating process. The data are represented under the form of tables with their values, called “attributes” and classified under a specific domain.

The structured query language (SQL) can be one example of the types of query language that can be implemented in the conceptual decision support system.

The details of how to achieve these specifications are out of the scope; therefore we have just underlined the opportunities and choices.

By doing this it is possible to reach a powerful, reliable, and accessible for user database management system.

### 4.4.3 Simulator and knowledgebase component

The knowledgebase component contains and retrieves the investment decisions and different alternatives decisions to each suggested infrastructure investment decision, for instance the primary decision A has alternative decisions A1….An, where n is number of cycles.

The knowledgebase is the materialization of the experts and domain knowledge; it is directly connected with the simulator and database components (see Fig.7), in such way that: the simulator computing optimal ROI and cost of investment (CI), matches these parameters/KPI with the corresponding infrastructure investment decision using automated rule/deductive reasoning; in his turn the knowledgebase is linked with database in the manner that the infrastructure investment decision is sent automatically to the database for supply chain evaluation or as final decision.

The search engine and the collection of knowledge are the crucial elements of the design of a robust and reliable knowledgebase.

The first element is computational aspect that helps in easily mapping the KPI cited above with the infrastructure decision. It is very important factor for the implementation of the system.

The second element can be elaborated by connecting the system to other bodies, such as environmental groups/organizations, police department and local/regional authorities for the purpose of increasing the information and improving the quality of the collected information, situated in the knowledgebase.

The large amount of data and its connection with outside systems make the knowledgebase a very complex component. As for the database, the classification of the information and its security in the knowledgebase are fundamentally important.

We have highlighted these elements in a conceptual way; the details are left out for the implementation stage.

The simulator component is partitioned into three modules: the supply chain controller (SCC), the governmental ROI optimizer (GROIO) and the computational and inference mechanism (CIM) (Fig.8).

The simulator component, based on the mathematical model, simulates the supply chain feedback through SCC, computes the ROI of suggested infrastructure according to the SC feedback, if ROI is positive it finds out the relative investment cost, next the investment cost is mapped with the specific infrastructure, situated in the knowledgebase.

This method, of designing a system into modules, enables flexibility and eases the update process when it is needed.
a) The supply chain controller (SCC)

The supply chain controller computes automatically the total variable cost (TVC) and the ratios describing the supply chains veto points (SCVP1 and SCVP2) for each j-th supply chain, compare them with the historical ratios and sent a feedback (“OK” or “NOT OK with contested KPI-need to be reduced/increased”) according to the results of the comparison.

The contested KPI by all supply chains are divided into highly contested (HCKPI), quite contested (QCKPI), contested (CKPI) and less contested (LCKPI).

The highly contested KPI (HCKPI), which has to be reduced or to be increased depending on the case, is selected and sent to the government ROI optimizer (GROIO).

b) The government ROI optimizer (GROIO)

This control element, based on optimization techniques, maximizes the Return On Investment (ROI) of i-th infrastructure by varying randomly each HCKPI one by one and the investment cost (CI). But of course this optimization problem is bounded by the availability of resources, for instance financial, and norms, prevailing in the domain knowledge. The new optimal values of \( HCKPI = HCKPI_{opt} \) and \( CI = CI_{opt} \) are obtained, and sent to the computational and inference mechanism (CIM).

c) The computational and inference mechanism (CIM)

As the name indicated first of all, we compute different values of ROI corresponding to the values of \( CI_i \) generated randomly within the interval \([ CI_{ibp}, CI_{opt} ]\);

Where the parameter, \( CI_{ibp} \) is the break-even point, for which the Return On Investment \( ROI_i \) equals to zero.

Mathematically, this looks as follow:

\[
CI_i = CI_{ibp} \rightarrow ROI_i = 0 , \text{ for each } i.
\]

Secondly we build a cognitive map, so called bi-directional investment cognitive map, between the investment cost \( CI_i \) and the alternative decisions.

This inference mechanism, which provides the alternative decision to the supply chains, is relied on the expert knowledge, norms existing in the domain.

Since the IDSS is designed to be a support tool and not a replacement tool for the public decision-maker, thus the suggested alternative decisions before the supply chains evaluation will be subjected under the appreciation of the public decision-maker.

The simulator and knowledgebase component are where the “intelligence” occurs. The intelligence is considered as artificial and is materialized by the computational inference mechanism, the controller elements (SCC and GROIO) with the combination of operation research techniques, cited below.

The techniques, use in order to generate alternative decisions, are the combination of local optimization and simulation. Since the system will be designed from the governmental decision maker’s perspective, we then locally apply the optimization techniques for the governmental objective function, infrastructure Return On Investment (ROI).

As we state above the system will be able to provide some alternative decisions, based on expert knowledge and logical and rational reasoning, also retrieve some alternatives from the knowledgebase, which are known ultimate or without any alternatives. This fact enables the reuse process and help to avoid reinventing the wheel.
The decision/reasoning algorithm of the “virtual negotiation process”, describing a sequential/step by step process, is based on simulation and optimization techniques and the simulation techniques, applied here, are discrete event simulation.

Fig. 8 Activity Diagram of IDSST2I in a “virtual negotiation process”

The decision/reasoning algorithm of “virtual negotiation process” is constituted by different steps as follow:

**Step 0: initialization**

- No primary decision in process
- Simulation time = 0
- All decision variables = 0
- Total amount of supply chains \( j = N_{\text{max}} \)
Total amount of KPI $k = \max_k$
Total transport infrastructure $i = \max_i$
Investment cost $CI = \max_CI$

**Step 1: primary decision (PD)**

Primary decision = suggested infrastructure investment decision, as presented in tab.1

\[
\begin{align*}
&\begin{aligned}
IUC_i \\
IT_i \\
HGVT_i \\
FT_i \\
CT_i \\
PT_i \\
NT_i \\
ALH_i \\
SpL_i \\
ABPT_i \\
Capac_i \\
TF_i \\
PF_i \\
VRF_i \\
PF_i \\
CTF_i \\
ToF_i \\
FDF_i
\end{aligned}
\end{align*}
\]

Set of taxes

\[
\begin{align*}
&\begin{aligned}
\text{Set of fees}
\end{aligned}
\end{align*}
\]

**Step 2: supply chain feedback**

- Compute $SCVP_{1ji} = TVC_{ji}/SL_{ji}$, $SCVP_{2ji} = TVC_{ji}/Td_{ji}$
- compare

  if $SCVP_{1ji} \leq SCVP_{1hist_{ji}}$ or $SCVP_{1ji} \leq SCVP_{2hist_{ji}}$, send “YES” goto step 3, otherwise send “NO with contested KPI, need to be reduced/increased” goto step 4.

**Step 3: supply chain participation rate (SCPR) and investment decision**
- Count \( X_{ji} \), “YES”), for each j, i

- update \( SCPR_i = \sum_j X_{ji} \) and maximize ROI

- Investment decision: if \( ROI_i > 0 \) then update PD to FD goto end
  Otherwise goto step 8.

**Step 4: selection of highly contested KPI(HCKPI)**

- Count \( HCKPI_{ki} \), j), for each k, j, i

- Compute \( \sum_j HCKPI_{ki} \), for each k, i

- \( \exists K, (HCKPI_{Ki}, j) = \max, \) for each i, for all j

- select \( KPI_{Ki} = HCKPI_{ki} \) to be reduced/increased

**Step 5: Maximize ROI**

- bound \( HCKPI \in [0, \ CKPI_{max}] \) “need to be reduced”
  or
- bound \( HCKPI \geq CKPI_{min} \) for “need to be increased”

- maximize ROI
  \[ ROI = ROI_{opt} \]

- update \( CI = CI_{opt} \) and \( HCKPI = KPI_{opt} \)

**Step 6: Break-even point \( CI_{ibp} \)**

- find \( CI_i = CI_{ibp} \), so that \( ROI_i = 0 \)
- generate randomly \( CI_i \in [CI_{ibp}, CI_{iopt}] \) and compute ROI

**Step 7: bi-directional investment cognitive map**

- Match \( CI_i \in [CI_{ibp}, CI_{iopt}] \) corresponding ROI \( \in [0, ROI_{opt}] \)

  With corresponding “Alternative n”

- update “alternative decision n” with maximum ROI to PD and goto step1

**Step 8: stopping criteria**

- “delay investment i-th transport infrastructure”
- n iterations = nmax
- no alternatives
4.5 Case study: IDSST2I in the framework/context of East-West intermodal corridor.

4.5.1 East-West presentation

The East-West intermodal corridor is an intermodal transport system linking today many countries (Sweden, Denmark, Lithuania, Russia etc.) in the Baltic Sea Region.

The concept, lying on the East-West corridor, is to provide to the user community an accessible, sustainable and reliable with a common view/policy defined by the stakeholders in a long term perspective (ref. http://www.eastwesttc.org), and for the stakeholders a profitable, environmental friendly intermodal corridor.

The essence of making this existing transport system, the “East-West intermodal corridor” takes place with the phenomenal growth of the transportation activities (for instance the experts estimate the maritime transport growth by 64% and road and rail by 27% between 2003 and 2020)[21] and the potential increase of the environmental and security issues in the region.

From the point of view of the leaders of the project, there is no doubt that the corridor will be a profitable transport system in the future (as it is today), but the crucial problems considered by the leaders, are the common regulation applied equally in all the concerned countries (this is most important object of discussion today among the stakeholders) and the eventual environmental issues. Therefore the economical analysis (profitability/ROI) of the investment in the corridor in this case, which could be done by the IDSST2I, is not relevant, but possible.

What we can study here is the transport regulation (taxes, fees, congestion, pollution rates etc.) that could be suitable for private and public sectors in order to establish a compromised/balanced transport policy in a long term perspective.

For instance, by using IDSST2I we could study common taxes related to the heavy goods vehicles, applied in the corridor.

This object of negotiation tends to be conflictive, because the flow of road transportation differs in each country, as well as the different income rate obtained from that activity by each government. Therefore the inclusion of the HGVT can discourage the private sector of using the truck transportation (from their perspective is the more suitable type of transport by his flexibility and minimum loading/unloading costs) and redirect them to other types of transport (more environmental friendly).

This decision if it is taken without a negotiation process involving all the stakeholders at the earlier stages can lead to unexpected negative impacts, like for instance increase of congestion in rail and sea transportation, the disruption of road transportation, which implies the decrease of the Infrastructure generated tax revenue.

Thus the questions are, if this tax is really needed? If yes, what should be the range of the values acceptable for both stakeholders? And what is the corresponding investment decision to each value of the proposed tax?

In the following lines we present a clear picture of a negotiation scenario on this matter. The objective is to involve them in the corridor project as well as public community in each country.

4.5.2 Illustrative scenario

We assume that there are 3 supply chains acting in the BSR. Our motivation to select three supply chains is based on the fact that there are three links, as the basis choice of those chains.
Supply chain A: producer is situated in Klaipeda (Lithuania)
Customer is situated in Esbjerg (Denmark)

Supply chain B: producer is situated in Kaunas (Lithuania)
Customer is situated in Esbjerg (Denmark)

Supply chain C: producer is situated in Poland
Customer is situated in Esbjerg (Denmark)

The introduction of the Heavy Goods Vehicles Tax (HGVT) will automatically carry the physical modifications of the concerned transport infrastructure (TI), because TI needs to be equipped, for example by the weighting places/weight checkpoints, toll; implicitly HGVT as transport decision, generates investment cost for the modifications of the concerned TI.

The purpose of the concept is to achieve, whenever it’s possible, a trade-off between the desired governmental and private goals with the optimal investment cost, in order to make the transport infrastructure economically profitable, environmental friendly, attractive and sustainable, based on a fairly applied transport regulation.

There is a suggestion today in Sweden to introduce the tax, called Heavy Goods Vehicles Tax (HGVT). Since the given transport system is conceived as a corridor, this means logically that the regulation and pricing are considered at the beginning different in some points from the transport regulation applied in each country (even do those countries constitute EU community, the transport regulations are different).

HGVT is considered as Highly Contested KPI (HCKPI) by the supply chains; now let’s look at the negotiation process in the figure below Fig.9.

Within this scenario it had been admitted that for any investment in a transport infrastructure, if the Supply Chain Participation Rate (SCPR) is less than 60% then Return On Investment (ROI) of the given transport infrastructure is less than zero, because the taxes and fees are fairly applied with respect to individual use of the transport infrastructure. In other words, the supply chains, executing less freight forwarding operations, it is known, have less environmental impacts on the transport infrastructure; therefore their environmental tax expenditures will not be significant, but corresponding to the frequency of their transportation activities.

As we had stated earlier, if the tax HGVT is applied specifically in the corridor, then the total variable costs (TVC) respectively for the supply chains B and C will be greater, whenever they will use East-West corridor, than the one if they use the alternatives (see Fig.6), therefore it is obvious that they will send “NOT OK, HGVT”.

Regarding the supply chain A there are two alternatives if HGVT is not applied in all over the country: Either uses the road 1 to the port of Klaipeda and then enter E-W corridor (see Fig.6) or train from Klaipeda to Kaunas and then use the link 3 (see Fig.6).

let’s considered the first alternative, which means that the supply chain A sends”YES”.

Consequently the Supply Chain Participation Rate (SCPR) equals to 33%, which less than the required 60%, thus ROI <0.

As resulting a “delay” of the suggested decision suggests by the system and the potential step to do is to apply HGVT in all the Baltic countries, consequently delay of the corresponding transport investment- link1 as a corridor and then the discussion will move forward to the suitable value of the given tax to be applied: HGVT<=15? Or HGVT> 15? And we run the process again similarly as defined in the first case.
P.D:
HGVT = 15 kr/km
For truck capacity >= 20 tons

SC-C feedback

yes

no

SC-B feedback

no

SC-A feedback

SCPR = 33% < 60%
(required)

ROI < 0

Delay

Alternative decision:
Apply HGVT in all Baltic countries
4.5.3 IDSST2I in the East-West project secretariat

In this paragraph we study the influences and benefits of IDSST2I within the organization “East-West project secretariat”.

The E-W project team is the potential user of the presented system, thus it is necessary to analyze the possible organizational modifications that can bring the application of IDSST2I in the team project, this is done via CommonKADS methodology by the help of CommonKADS worksheets, presented as follow:

1) Organizational models

Worksheet OM1-1

This worksheet enables to identify the knowledge-oriented problems, open a room for opportunities and suggest possible solution(s) to the potential user of the system

<table>
<thead>
<tr>
<th>Organization Model</th>
<th>Problems and Opportunities Worksheet OM1-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problems and Opportunities</td>
<td>Problems:</td>
</tr>
<tr>
<td></td>
<td>less business satisfaction about transport infrastructure policy</td>
</tr>
<tr>
<td></td>
<td>passive participation(participation at later stage of decision-making process) of private partners in transport decision-making process</td>
</tr>
<tr>
<td></td>
<td>long processing time(communication via standard mails)</td>
</tr>
<tr>
<td></td>
<td>selective method, consists of representing the interests of business community by few high positioned companies</td>
</tr>
<tr>
<td></td>
<td>Lack of common view on transport policy by the majority of stakeholders, implies often readjusting the transport regulation to minimize the negative effects of transportation activities.</td>
</tr>
<tr>
<td></td>
<td>Unclear picture of the transport decision-making process, consequently lack of trust.</td>
</tr>
<tr>
<td></td>
<td>Opportunities:</td>
</tr>
<tr>
<td></td>
<td>involve actively the supply chains at the “intelligence” level of the transport policy making</td>
</tr>
<tr>
<td></td>
<td>build an e-support (increase the part of ICT) for interaction between private and public partners</td>
</tr>
<tr>
<td></td>
<td>involve the maximum supply chains in the transport decision process, which means avoid selective methods</td>
</tr>
<tr>
<td></td>
<td>clarify the transport policy making, that enables a shared common view of the majority of the private stakeholders</td>
</tr>
<tr>
<td></td>
<td>reduce the processing/negotiation time and cost</td>
</tr>
</tbody>
</table>
establish a learning process

Organizational Context
Refer to OM1-2 and fig.2.1.

Solutions
Followed by a brainstorming, the suggested solution is a decision support system for transport infrastructure investment, built on the concept knowledge-based system.

OM1-2:

<table>
<thead>
<tr>
<th>Organization Model</th>
<th>Variant Aspects Worksheet OM1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>Parliament</td>
</tr>
<tr>
<td>Ministry Of Transport</td>
<td>Environmental, business and other organizations</td>
</tr>
<tr>
<td>Regional authorities</td>
<td></td>
</tr>
<tr>
<td>Transport department</td>
<td>Social department</td>
</tr>
</tbody>
</table>

Fig. 2.1 small scale of transport organizational chart

Process
Refer Fig.4

People
project management (Mattias Alisch)
Transport chief department (Anders Wiberg) research groups (ITS, etc…)
enGINEERS
business managers

Resources
Computer systems, such as accounting and simulation software ("arena")
Internet and communication facilities, web-
Human resources
- Transport domain experts

Knowledge
- Assessment of the supply chains participation rate
- Veto points(supply chain and governmental), defining decision criteria
- Experts knowledge from both stakeholders (financial, social, technical and environmental)
- Domain standard norms, such as safety, regulation etc…

Culture and Power
- Hierarchical organization
- Multiple steps in decision process
- Formal and informal workshops/meetings

OM1-3:

<table>
<thead>
<tr>
<th>Organization Model</th>
<th>Process Breakdown Worksheet OM-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Task</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>1.</td>
<td>Primary Transport infrastructure decision</td>
</tr>
<tr>
<td>2</td>
<td>Supply chains feedback</td>
</tr>
<tr>
<td>3</td>
<td>Evaluation of the supply chains participation rate</td>
</tr>
<tr>
<td>4</td>
<td>Investment decision</td>
</tr>
<tr>
<td>5</td>
<td>Alternative/final transport infrastructure decision</td>
</tr>
</tbody>
</table>

2) Task models
We present here in a descriptive way to the management the executed tasks by the system and the value of each task. The tasks, described in the tables below, represent the steps/sequences of the “virtual negotiation process” that are carried out by the controllers.

**TM-2.1:**

<table>
<thead>
<tr>
<th>Task Model</th>
<th>Task Analysis Worksheet TM-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task</td>
<td>Ref. OM-3</td>
</tr>
<tr>
<td>Organization</td>
<td>Ref. OM-2</td>
</tr>
<tr>
<td>Goal and Value</td>
<td>3. Evaluation of the supply chains participation rate</td>
</tr>
<tr>
<td></td>
<td>Goal: we build up a fair approach that enables us to compare the quality parameters of i-th TI with others and assess the number of users.</td>
</tr>
<tr>
<td></td>
<td>Value: determine the participation/no-participation of the supply chain in the usage of i-th TI.</td>
</tr>
<tr>
<td>Dependency and Flow</td>
<td>Preceding task:</td>
</tr>
<tr>
<td></td>
<td>1. Primary transport infrastructure decision.</td>
</tr>
<tr>
<td></td>
<td>2. KPI entry</td>
</tr>
<tr>
<td></td>
<td>Following task:</td>
</tr>
<tr>
<td></td>
<td>1. investment decision</td>
</tr>
<tr>
<td>Objects Handled</td>
<td>● input objects: primary transport infrastructure decision with KPI data</td>
</tr>
<tr>
<td></td>
<td>● output objects: “OK/NOT OK, with HCKPI”</td>
</tr>
<tr>
<td></td>
<td>● internal objects:</td>
</tr>
<tr>
<td></td>
<td>1. supply chain total variable cost</td>
</tr>
<tr>
<td></td>
<td>2. supply chain’s service level/delivery time</td>
</tr>
<tr>
<td>Timing and Control</td>
<td>1. Frequency and duration:</td>
</tr>
<tr>
<td></td>
<td>discrete event, depending on the input objects</td>
</tr>
<tr>
<td><strong>Agents</strong></td>
<td>Performing the task SCPR controller</td>
</tr>
<tr>
<td><strong>Knowledge and Competence</strong></td>
<td>Assessment criteria</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
<td>1. Information about previous supply chain activities in the other transport infrastructures 2. rules and transport regulation applied previously</td>
</tr>
<tr>
<td><strong>Quality and Performance</strong></td>
<td>This task is a quantitative measurement performance for the government decision-maker</td>
</tr>
</tbody>
</table>

TM 2-2:

<table>
<thead>
<tr>
<th>Task Model</th>
<th>Task Analysis Worksheet TM2-2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task</strong></td>
<td>cf. OM-3</td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>cf. OM-2</td>
</tr>
<tr>
<td><strong>Goal and Value</strong></td>
<td>Goal: assess profit/loss status of i-th transport infrastructure Value: this task forms a basis decision for the governmental decision-maker</td>
</tr>
<tr>
<td><strong>Dependency and Flow</strong></td>
<td>Preceding Tasks: task 3 Follow-up Tasks: alternative transport infrastructure decision</td>
</tr>
<tr>
<td><strong>Objects handled</strong></td>
<td>Input Objects: supply chain feedbacks with contested KPI</td>
</tr>
<tr>
<td>Output Objects: investment decision(ROI)</td>
<td>Time and Control</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>1. amount of potential supply chains</td>
<td>Frequency and Duration: it occurs discretely after the supply chain feedbacks</td>
</tr>
<tr>
<td>2. supply chain total variable cost</td>
<td>Control and constraints/conditions: ref to government veto points</td>
</tr>
<tr>
<td>3. investment cost of i-th TI</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Internal Objects:</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Time and Control</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency and Duration: it occurs discretely after the supply chain feedbacks</td>
<td></td>
</tr>
<tr>
<td>Control and constraints/conditions: ref to government veto points</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Agents</th>
<th>Performing the task: GVP controller</th>
<th>Ref. OM-3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Knowledge and Competence</th>
<th>Assessment criteria</th>
<th>Government veto points</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Resources</th>
<th>Detailing of OM-2</th>
<th>.- estimation of the investment cost of the primary infrastructure decision economic knowledge estimate the supply chain total variable cost</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Quality and Performance</th>
<th>This task is a quantitative measurement performance to decide whether invest/not invest in which type of transport infrastructure and regulation to apply</th>
</tr>
</thead>
</table>

TM2-3:

<p>| Task Model | Task Analysis Worksheet TM2-3 |</p>
<table>
<thead>
<tr>
<th><strong>Task</strong></th>
<th>cf. OM-3</th>
<th>5. alternative/final transport infrastructure decision</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organization</strong></td>
<td>cf. OM-2</td>
<td></td>
</tr>
<tr>
<td><strong>Goal and Value</strong></td>
<td>Goal: provide a compromised/balanced transport infrastructure decision to the majority of the supply chains. <strong>Values:</strong> - this task: - democratizes the transport decision-making process; - Transfers the expert knowledge to a computer program; - Establishes a learning process - Speed-up the decision-making process</td>
<td></td>
</tr>
<tr>
<td><strong>Dependency and Flow</strong></td>
<td>Preceding Tasks: task 4 Follow-up Tasks: task3 or delay of the investment of the current transport infrastructure.</td>
<td></td>
</tr>
<tr>
<td><strong>Objects handled</strong></td>
<td>Input Objects: investment cost of i-th transport infrastructure Output Objects: transport infrastructure decision Internal Objects: maximization of ROI(ROI opt, CI opt )</td>
<td></td>
</tr>
<tr>
<td><strong>Time and Control</strong></td>
<td>Frequency and Duration: discrete event, depending on the investment decision dynamic Control and constraints/conditions: ref. to computational and inference mechanism</td>
<td></td>
</tr>
<tr>
<td><strong>Agents</strong></td>
<td>knowledge expert inference engine</td>
<td>Ref. OM-3</td>
</tr>
</tbody>
</table>
### Knowledge and Competence

<table>
<thead>
<tr>
<th>Assignment criteria</th>
<th>domain knowledge technical knowledge economic and laws knowledge need to perform this task</th>
</tr>
</thead>
</table>

### Resources

| Detailing of OM-2 | Resources needed:  
- Human staff  
- Financial resources  
- equipment |

### Quality and Performance

| This is a qualitative measurement performance | It shows how much the supply chains interests had been included in the infrastructure decision-making process. In other words how much effectively have being shifted to the earlier stage of the decision process the supply chain feedbacks. |

---

In the following lines we will discuss and choose the suitable computer and software tools that enable us to realize and achieve the described tasks in this section.

### 5. TECHNOLOGY DISCUSSIONS

In the section above we have analyzed the East West project goals and studied how they can be efficiently and effectively achieved by the support of IDSST2I, this is the bottom line of the case-study, but the form, which is the set of tools, will be presented in the further lines under technology discussion.

Technology is seen as a structure/ set of tools and methodologies that enables us to realize our concept and open a window for the future implementation of the elaborated decision support system (IDSST2I).

Leaving from the point that the system is designed to be connected to supply chain systems in the almost real time, but it is also can be used to provide autonomously a specific investment decision (whenever it is possible) to the government decision-maker, that brings us to conceive the system by integrating agent-based technology (the crucial agents are both controllers and inference mechanism/engine) and modular approach for the system components (ref.AM-1).

Along this effort, we had included some tools and approaches that we will enounce here and then deeply look at their contribution/insides in different components of the system.

The support tools are discrete-event simulation and optimization techniques used respectively in supply chain controller (SCC) and government ROI optimizer (GROIO) and the inference engine (CIM) used in the alternative decision choices.

In the other hand we built our thesis on mathematical modeling (quantitative methods) and artificial intelligence elements, proposed in CIM system component, also called in general knowledge base component.

Finally the system interacts with the external world through a web portal, which means that it aims to be a web-based application.
The purpose of making IDSST2I as knowledge based system is strengthening by the strong influence of many rules/regulations in transport infrastructure planning and the presence/interaction of multidisciplinary fields.
The IDSST2I is kind of a rule oriented system simulation tool, which paradigm refers to actor-message-actor paradigm [17].
The first actor, the sender conceives a message, transmitted to the second actor, the receiver. In his turn he sends a feedback to the first actor, and according to his feedback and the existence of a mapping pattern, the right decision will be taken from the decision list, or else denied “review/delay the investment”
The decision will depend on the current case, particularly on the supply chain feedback, the predominance of the veto points, and the rules/norms existing in the domain.
The notion of “participatory design” (it is an approach, Scandinavian specificity/tradition of systems development, which “involves the future users in systems development work activities in ways that enable them to influence decisions that will affect the resulting system and through this the activities in which the system will be used”) [19] is also applied in the DSS development, in terms of representation of the supply chains behavior in the suggested system.
And with the web portal support, the real involvement of the supply chains, through their feedbacks.
The specificity of a knowledge based system is that it significantly bases on the existed domain knowledge (from the experts, other participants) and the new innovating knowledge (initiating from the mathematical model). Technologically we relate this different knowledge through an inference mechanism/cognitive mapping, in order to suggest automatically a balanced decision to the supply chains (see inference structure of assignment task).
This approach takes into consideration the history of the domain and brings a wind of modernization and innovation, to improve the decision process in this case.

5-2 why discrete - event simulation combined with optimization?

Discrete-event simulation is a technique used to imitate the behavior of a real system that changes his states sequentially/discretely.
According to Rardin “simulation models often possess high validity because they track the system behavior fairly accurately” [ref. operations research].
From that perspective, discrete-event simulation taken from operations research field, is a descriptive model, used as a technique to evaluate/assess the supply chain feedback through the prism of the ratios, called supply chain veto points
Optimization technique is a quantitative method, occurring in the designed system in maximizing the Return On Investment (objective function) value by optimizing the investment cost (CI), according to the supply chain feedback.
Following this structure we included in optimization process, as the part of the reasoning some elements of artificial intelligence field, here called “minmax” approaches.
This approach consists of, in relation with the supply chain feedbacks either increasing or decreasing the value of decision variable(s), maximizing ROI objective value.
For instance, the increase of certain decision variables, such as capacity, implicitly increases the cost of investment of the infrastructure and this in his turn leads to the decrease of the ROI value, therefore the “minmax” approach is relevant.
How this is done practically?
5-3 Description of how the variables or parameters are manipulated either randomly or not? Which probability distribution is used?

The investment decision process can be simulated by the user/government decision-maker according to the following description:
The user inputs manually the lowest and highest values of the decision variables/KPI to the system in the form of interval.
The decision variables/KPI(s), described in the modeling process, are randomly generated within that interval and with the uniform probability distribution. This is done in order to simulate a large number of alternative investment decisions.

The parameters related to the internal supply chain business, such as driver costs, driver break time, vehicle capacity etc…, and those related to the internal government business, such as cost of investment, described in the modeling process, are estimated, but in the manner that it is close to the reality.
The manipulation and update of these parameters and variables are ease by the fact that the implementation of the system should be based on the object-oriented and modular approaches.
In other words the decision variables and parameters are designed as classes, within other classes such as decision class, in which each variable is an object with his attributes (Boolean, value), name, and class, and described in the list of tables (modules).
With this framework, the communication between different agents reveals to be extremely important.

5.4 who are the agents? How agents are communicating each other?

The multi-agent approach has played a key role in the elaboration of the “virtual negotiation process” in IDSST2I, as fundament of this system development since it enables us to model and control the behaviors of both actors, particularly the supply chain stakeholders.
We distinguish in this work two types of agents:
    ■ Human agents- public and supply chain decision-makers involved in the “real negotiation process”.
    ■ Computer agents- controllers involved in the “virtual negotiation process”.
In the following lines we will relate the types and roles of every agent (reactive) and describe the communication activities within the system using communication models from CommonKADS methodology in the next tables and fig.10 below:

5.4.1 Agent models

The tables below present depth information about agent activities, such as communication, task performances, types of agents etc.

<table>
<thead>
<tr>
<th>Agent Model</th>
<th>Agent Worksheet AM-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>User</td>
</tr>
<tr>
<td>Organization</td>
<td>Supply chain</td>
</tr>
<tr>
<td>Involved In</td>
<td>Data entry</td>
</tr>
<tr>
<td></td>
<td>supply chain feedback</td>
</tr>
<tr>
<td>AM-2:</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Agent Model</strong></td>
<td>Agent Worksheet AM-2</td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td>Supply chain controller (SCC)</td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>East-West project secretariat</td>
</tr>
<tr>
<td><strong>Involved In</strong></td>
<td>Supply chain feedback assessment</td>
</tr>
<tr>
<td><strong>Communicates With</strong></td>
<td>The storage and relational database GROIO</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>Assessment criteria</td>
</tr>
<tr>
<td><strong>Other Competencies</strong></td>
<td>Computer program, simulation techniques</td>
</tr>
<tr>
<td><strong>Responsibilities and Constraints</strong></td>
<td>Track the supply chain feedbacks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AM-3:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agent Model</strong></td>
<td>Agent Worksheet AM-3</td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td>Government ROI optimizer</td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>East-West project secretariat</td>
</tr>
<tr>
<td><strong>Involved In</strong></td>
<td>Optimizing (maximizing) the Return On Investment (ROI)</td>
</tr>
<tr>
<td><strong>Communicates With</strong></td>
<td>SCC, CIM</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>Optimization techniques (minmax approach)</td>
</tr>
<tr>
<td><strong>Other Competencies</strong></td>
<td>Computer program, simulation techniques</td>
</tr>
<tr>
<td><strong>Responsibilities and Constraints</strong></td>
<td>Whenever it is possible, he figures out the cost of investment according to the supply chain feedbacks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AM-4:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agent Model</strong></td>
<td>Agent Worksheet AM-4</td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td>Computational and inference mapping (CIM)</td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>East-West project secretariat</td>
</tr>
<tr>
<td>Involved In</td>
<td>Bidirectional mapping</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Investment decision</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communicates With</th>
<th>GROIO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Storage and relational database</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Transport policy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>economical knowledge assignment criteria</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Competencies</th>
<th>Computer program</th>
</tr>
</thead>
</table>

| Responsibilities and Constraints | Whenever it is possible, he figures out an alternative investment decision or a delay. |

### 5.4.2 Communication models

CM-1.1:

<table>
<thead>
<tr>
<th>Communication model</th>
<th>Transaction description worksheet CM-1-1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transaction Identifier/name</strong></td>
<td>Supply chain feedback evaluation.</td>
</tr>
<tr>
<td></td>
<td>Supply chains participation rate</td>
</tr>
<tr>
<td>Information object</td>
<td>Data entry/human agent + supply chain controller (SCC) + government ROI optimizer (GROIO)</td>
</tr>
<tr>
<td>Agents involved</td>
<td>Ref. to Fig.10</td>
</tr>
<tr>
<td>Communication plan</td>
<td>Constraints</td>
</tr>
<tr>
<td></td>
<td>In the prototyping phase the system will interact with the user/decision-maker (a human agent). In the future, the system will be part of a fully automated system and interact with the data entry system.</td>
</tr>
<tr>
<td>Information exchange specification</td>
<td>This transaction is of the request-agree/reject-propose type messages. There are no specific requirements for this information exchange.</td>
</tr>
</tbody>
</table>

CM-1.2:

<table>
<thead>
<tr>
<th>Communication model</th>
<th>Transaction description worksheet CM-1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transaction</td>
<td>Transport infrastructure assignment</td>
</tr>
<tr>
<td>Identifier/name</td>
<td>Government investment decision</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Information object</td>
<td>Supply chain controller(SCC) +</td>
</tr>
<tr>
<td>Agents involved</td>
<td>government ROI optimizer(GROIO) + computational and inference mechanism(CIM)</td>
</tr>
<tr>
<td>Communication plan</td>
<td>Ref. to Fig.10</td>
</tr>
<tr>
<td>Constraints</td>
<td>In the prototyping phase the system will interact with the user/decision-maker. In the future the transport infrastructure decision will be placed automatically in a database, and the supply chain user will have access to the decision by logging into the web portal. In addition to that the security issue of the web portal must be ensured.</td>
</tr>
<tr>
<td>Information exchange specification</td>
<td>This transaction is of the request-order/reject type messages. The requirements for this information exchange are the high level of security in the network.</td>
</tr>
</tbody>
</table>
Fig. 10 layout of dialogue diagram [20]
5-5 what is/are the events, leading to possible system failure?

The flexibility approach (object-oriented) chosen for the system development, allows the system to be highly reliable and robust, consequently with a very small margin for the potential system failure. When we recall the decision algorithm attentively, we observed that after the supply chain feedbacks the system, through a counter, selects the Highly Contested KPI, and then generates randomly the concerned KPI within an interval. That means the negotiation process starts by that the system really works, whenever we do have a Highly Contested KPI. If the KPI are equally contested by the supply chains, in other words there is no majority KPI, then this even is considered as system failure, because no negotiation involved.

5-5-1 Design Models

The architectural design of IDSST2I will rely on MVC (Model-View-Controller) model architectural pattern (Fig.11).

DM-1:

<table>
<thead>
<tr>
<th>Design model</th>
<th>Worksheet DM-1: system architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture decision</td>
<td>Format</td>
</tr>
<tr>
<td>Subsystem structure</td>
<td>Refer to Fig.11. The architecture is a derivative of MVC (Model-View-Controller) model.</td>
</tr>
<tr>
<td>Control model</td>
<td>Event-driven system control</td>
</tr>
<tr>
<td>Sub-system decomposition</td>
<td>Refer to Fig.11 The paradigm underlying the decomposition of the system into three subsystems, is as follow: Controller subsystem is an object-oriented subsystem Application model subsystem is a function-oriented subsystem Views subsystem is an object-oriented subsystem</td>
</tr>
</tbody>
</table>

DM-2:

<table>
<thead>
<tr>
<th>Design model</th>
<th>Worksheet DM-2: Target implementation platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software package</td>
<td>JADE(JavaAgentDevelopmentFramework) with FIPA standard communicative</td>
</tr>
<tr>
<td>Potential hardware</td>
<td>Grid computing.</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Target hardware</td>
<td>Not implemented yet.</td>
</tr>
<tr>
<td>Visualization library</td>
<td>library “view” objects must be available</td>
</tr>
<tr>
<td>Language typing</td>
<td>An object-oriented programming language, such as JAVA.</td>
</tr>
<tr>
<td>Knowledge representation</td>
<td>Declarative knowledge: in form of rules, easier to update and refine. And procedural knowledge in the form of mathematical functions</td>
</tr>
<tr>
<td>Interaction protocols</td>
<td>Since the access to the database is frequent, and in addition we are dealing with a distributed system, the suitable interaction protocol is ODBC (Open Database Connectivity).</td>
</tr>
<tr>
<td>Control flow</td>
<td>Since the system is a web-based application, he should support the message-passing approach</td>
</tr>
</tbody>
</table>

DM-3:

<table>
<thead>
<tr>
<th>Design model</th>
<th>Worksheet DM-3: architecture specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture component</td>
<td>Typical decision points</td>
</tr>
<tr>
<td>Task</td>
<td>Ref. paragraph 6.5</td>
</tr>
<tr>
<td>Task method</td>
<td>The control structure is deployed</td>
</tr>
</tbody>
</table>
within the execution of all described
tasks: declarative and procedural.
Declarative or procedural.

<table>
<thead>
<tr>
<th>Inference</th>
<th>Ref to the decision algorithm. The state variable should be met after task completion. The operations execution: operation retrieves the static and dynamic inference inputs. Has-solution and new-solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inference method</td>
<td>Ref. to the decision algorithm Cognitive mapping</td>
</tr>
<tr>
<td>Dynamic role</td>
<td>Data types for roles: single elements and sets. Access/modification operations for each data type: select and replace element(s) into a set.</td>
</tr>
<tr>
<td>Static role</td>
<td>Access operations: give all instances.</td>
</tr>
<tr>
<td>Knowledge base</td>
<td>The knowledge base representation in the form of relational-table list, built on JAVA and PROLOG with emphasis on O-O approach.</td>
</tr>
<tr>
<td>Views</td>
<td>Both graphical user interface (GUI) for expert and end-user based on HTML.</td>
</tr>
</tbody>
</table>
6. RECOMMENDATIONS AND CONCLUSIONS

It is known that every process having a feedback link is always better than the one without feedback, since it enables to readjust the inputs and at the end obtain a much better output.

The sensitivity analysis has his place in the East-West case-study, and also relevant in the framework of the specific transport infrastructure investments, which are easier to compare to each other such as toll investment, port terminal investment.

The joint logistic concept and e-governance principles allow us to capture and share the maximum needed information at the earlier stages of investment decision process in order to provide to the users and community a good enough transport infrastructure decision.

In the other hand the different approaches, for instance the shift of the integration of business community from the later stage” financial contribution” to the earlier stage “elaboration” of transport infrastructure decision, and also the withdrawal of the “selective method” applied by the government on the business community, combined with the applications of ICT make the decision process clear and available for every stakeholder, in particularly for the government give the opportunity to foresee the bottlenecks and the number of the potential users of TI. Consequently the decision-maker can easily assess the impacts of the transportation activities, which means in the long term better quantify/measure the KPI related to security, economical and environmental fields.

After all we can obviously state that the studied proof of concept and the conceptual Intelligent Decision Support System (IDSST2I) can better function as IDSS in the public transport investment domain. The methodology followed here to model the supply chains was the macro-level approach, and also assuming the concept of the supply chain management is well established in the business community.
The use of macro-level approach is justified by the fact that the chosen KPI driving the supply chain activities are the common denominator for the individual actors in the chain. For instance, the driver cost is setting out to the different individual actors in the chain, as result the prices of supply chain final products include the driver costs; therefore in this case the decision taken will have the impacts on the whole chain, which are expected and uniformly spread on each actor of the chain.

In addition to that the impacts of transport decision can almost be accurately evaluated before the implementation of the transport infrastructure.

For the business stakeholders in which the supply chain management concept is not well established, the impacts of the transport decision are directly carried by the transport carriers and can be evaluated before implementation, meanwhile for the other actors (suppliers, producers, customers) the impacts are not predictable and not possible to assess before implementation.

But the positive side of the proof concept applied is his fairness (the more a supply chain uses the transport infrastructure more will be his transport operational cost), since the transportation operations are not so frequent compared to the one cited above the fluctuations of the transport cost are not very important, implicitly the supply chain veto points defined earlier not so relevant in this case.

As we have presented earlier the application of ICT in this effort has a crucial role.

ICT:
- provides a high level of accessibility to the public transport decision
- allow the reduction of the numbers of discussion meetings, instead real-time online interaction among the stakeholders. Implicitly reduces the cost of business processing operations
- provides a clear picture of the infrastructure investment decision process, this enables to clarify and capture the key information for improving the negotiation process.

The availability of this type of decision support system will ensure the unbiased long-term of common regulatory policy and long life cycle of TI. In addition to that it will be economically benefit by escaping the schedule of numerous meetings between stakeholders and reducing the cost of standard mails communication

Benefits:
1) Strengthen the common view of environmental friendly transport system
2) Enable the decision-maker to foresee at the earlier stages the possible fallacies, such as boycott of the TS by the users, lack of financial resources
3) Establish a learning process

In this part we must have in mind that there is no system that could be considered universal in the large sense, but the application domains can be large as much as possible.

In the case of IDSST2I, the application domain studied here was the governmental transport policy and investment.

The conceptual system built on negotiation platform can be used in other issues involving decision-making with a primary decision and stakeholders having direct influence on each other, simply by reviewing/readapting whenever it is necessary the following milestones of my paper:

1) The common view sharing by all the stakeholders toward environmental and high quality transport system development
2) The supply chain feedback as important factor of the government transport policy
3) Veto points model into a computer program
4) Not reinventing the wheel, reuse of the expert knowledge in the domain in order to generate alternative decisions in relation with the veto points and investment cost of the transport infrastructure
5) Hardware and software choices

For example, by taking into consideration the passenger transportation instead of freight the veto points can be the same as in the freight transportation, but very important the first one called, SCVP1 explicitly this parameter could be prioritized against SCVP2, the freight capacity can be replaced by the number of the people, the environmental pollution rate of the people can be added.
7. FUTURE WORK

The suggested system is designed at the conceptual level, and then it is obvious that the coming step is the implementation. In his turn the implementation will involve several procedures/aspects that are fundamentals for the reliability/robustness, quality and safety of the decision support system:

- The validation of the thesis has been done through contacts with domain experts via emails. In perspective the validation of the system must be done in the real world domain.
- The sensitivity analysis must be done during the data processing in order to provide to our system a robust quality.
- In the next step, the security issues in the network (since grid computing application) should be handled and deeply analyzed, although the concerned software (JADE) proposed some directives toward that issue.
- At the end the designer should come up with an acceptable Graphical User Interface (GUI) for the users.

The approach outlines here is based on the project management techniques, this implicitly means that the different project steps must be coordinated by the project manager.

8. APPENDIX: Mathematical Model

Set $TI = \{TI_i\}$: i-th Transport infrastructure, $i=1...n$
Set $KPI = \{KPI_{ki}\}$: k-th KPI for i-th TI
Set $VH = \{V_{nj}\}$ - types of vehicles in j-th vehicle fleet
Set $SC = \{SC_j\}$: j-th Supply chain
Set $D = \{D_{lj}\}$: l-th driver in j-th supply chain
Set $Cust = \{Cust_{mj}\}$: m-th customer in j-th supply chain

The variables are defined as follow:

- $X_{ji}$ - decision variable representing j-th supply chain, as potential user of i-th TI
- $P_{ji}$ - j-th supply chain using i-th infrastructure, binary (“0”-“1”) variable. $P_{ji} = 0$ means that the supply chain j is not a potential user of the Transport infrastructure i, otherwise supply chain j is a potential user of Transport infrastructure i ($P_{ji} = 1$)
- $Y_{lj}$ - integer variable, amount of drivers in use by j-th supply chain
- $O_{mji}$ - Binary (“0”-“1”) variable, representing m-th customer in j-th supply chain to be serviced/or not via i-th transport infrastructure. $O_{mji} = 1$ means that the customer demand m has been fulfilled by the supply chain j using transport infrastructure i, otherwise the customer requirement m has not been fulfilled by the supply chain j using transport infrastructure i ($O_{mji} = 0$).

The input parameters are defined as follow:

- $V_{ji}$ - Input parameter, representing the number of vehicles need to be used by j-th supply chain in i-th TI
- $CI_i$ - Decision variable, investment cost of i-th infrastructure
Z_{mj} - input parameter, representing m-th customer demand in j-th supply chain.

The main objective function is defined for the government perspective, since it targets the economic aspect, for this reason that objective function can be the Return On Investment (ROI) or the profit of the total infrastructure. On the other hand the constraints represent the governmental environmental and sustainable objectives and supply chain goals.

We will focus on the ROI, rather than the profit since the ROI is a long term economic performance indicator, that usually attributes to the long term investment. Consequently the main objective function is to:

Maximize \[ \text{ROI} = \sum_i ROI_i \]

\[ \sum_i \left( \frac{\text{total infrastructure receipts + fees}}{\text{cost investment}} - 1 \right) \]

(1) for all i

The secondary objective function is defined from the supply chain perspective. Therefore the objective function, in general without abstraction, is defined as follow:

Minimize \[ \text{Total Variable Cost}_j (TVC_j) = \text{production cost + inventory cost + transportation variable operating cost + running cost + infrastructure utilization cost + penalty cost} = \]

\[ \sum_i \text{Transportation Variable Operating Cost}_ij + \sum_i \text{Running Cost}_ij + \sum_i \text{Infrastructure Utilization Cost}_ij + \sum_i \sum_m \text{Penalty Cost}_m_j, \text{ for each } j \]

(2)

In the first place, we will provide some key definitions, regarding the transportation variable operating cost, the supply chain running costs, standing costs and the supply chain penalty costs.

- **Transportation operating costs** are the costs, which occurred during the transportation itself, such as fuel/petrol costs, toll fees in some cases driver costs if the transport vehicle is rented by the transport operators. They are almost variable costs.

- **Running costs** are the expenses, which occurred before and after the business operations, such as maintenance costs for vehicles and buildings, administrative costs. They are often variable and fixed costs, but here the focus is on variable transportation cost.

- **Penalty costs** are costs that have to pay the distributor or producer to the customer if there is a delay/deviation in the delivery schedule. It is also considered as a variable cost.

- **Transportation standing cost** is the costs that incurred when establishing transportation business, such as vehicles purchase, drivers wages, insurance and so one. It is a subcomponent of the transportation operating costs and restricts to be a driver cost and fuel tax. They are often fixed and variable expenses. Since we only focus on variable costs, we will only consider part of the taxes paid by the Supply chain from the driver’s revenues, so called revenue tax, to the government on the basis of trip payment.

Using the same logic, we do consider only the tax contribution, so called fuel tax, in the fuel cost.

Let’s denote:

- \( T_{ki} \) - input variable, k-th tax applied for using i-th infrastructure
- \( F_{ki} \) - input variable, k-th fee applied for using i-th infrastructure
- \( T_{ki} \) and \( F_{ki} \) are elements of KPI set.

p - Price of product

We assume that there is a unique product for the scenario.

- \( Td_{mji} \) - output variable, delivery time to m-th customer by j-th supply chain using i-th transport infrastructure
- \( Tw_{mj} = [OT_{mj}, CT_{mj}] \) - m-th customer time window in j-th supply chain.

The customer time window here is the interval time (opening time “OT” and closing time “CT”) given by the customer to the distributor for unloading the goods to the distributor or/and producer, and also within this time no penalty costs are applicable.

- \( ABPT_i \) - administrative business processing time of i-th infrastructure
- Standing cost - \( STC_{ij} \)
- Running transportation cost - \( RTC_{ij} \)
- Maintenance cost - \( MC_j \)
- Fuel cost - \( FC_{ij} \)
- Infrastructure utilization cost - \( IUC_{ki} \) is an element of the KPI set
- Other running cost - \( ORC_i \)
- Transportation variable operating costs - \( TVOC_j \)
- Total variable cost for j-th supply chain - \( TVC_j \)

We obtained the next relationships:

1) Transportatio Variable Operating Cost (TVOC)

\[
TVOC_j = \sum_i STC_{ij} + \sum_i RTC_{ij} = \sum_i (STC_{ij} + FC_{ij}), \text{ for each } j\text{-th supply chain}
\]

Where

\[
STC_{ij} = \sum_i \sum_m RT \times C_{ij} \times Td_{mji} \times Y_{lj}, \text{ for each } i, j
\]

\[
FC_{ij} = \sum_i \sum_n FT \times Cf \times vfc_{nj} \times ALH_{ji} \times V_{ji}, \text{ for each } j
\]

\( C_{ij} \) - input parameter, l-th driver cost for j-th supply chain

\( RT \) (\%) - input parameter revenue taxation, applied in this case only for drivers wages (\%)

\( Td_{mji} \) - Delivery time to m-th customer using i-th infrastructure for j-th supply chain

\( Cf \) - input parameter, average fuel cost per liter

\( FT \) - input parameter, fuel tax contribution per liter (\%)

The fuel tax is not uniformly applied for all existent types of fuel, since they are polluting differently, therefore less a specific type of fuel pollutes the environment less will be its fuel tax contribution.

\( vfc_{nj} \) - input parameter, n-th vehicle fuel consumption of j-th supply chain
Input parameter, number of vehicles by j-th supply chain per i-th TI

Output variable, average length of haul used by j-th supply chain in i-th TI

Thus replacing in the equation defining the Total Variable Operating Cost, the formulas of Standing and Fuel costs we obtain the following relationship,

\[ TVOC_j = \sum_m \sum_l RT \cdot C_{lj} \cdot T_{mj} \cdot Y_{lj} + \sum_i \sum_n FT \cdot Cf \cdot vfe_{nj} \cdot ALH_{ji} \cdot V_{ji} \], for each j (3)

2) Infrastructure supply chain cost (\( ISC_j \)), considered here as vehicle-km cost

\[ ISC_j = \sum_i IUC_{ki} \cdot ALH_{ji} \cdot V_{ji} \], for each j and k-th KPI (4)

Where \( IUC_{ki} \) - k-th KPI, infrastructure utilization cost of i-th TI

3) Income tax expenses (ITE)

\[ ITE_j = IT \cdot Revenue_j \], for each j-th supply chain (5)

This tax is applied on the revenue generated by j-th supply chain.

This tax, applied for all types of businesses, has no direct influence on specific i-th transport infrastructure, but he has a strong impact for the government development policy, particularly transport policy.

Since the aim of this effort is to follow the tractability of the concept described above, I do consider this tax, because it has an important contribution on the government income.

4) Other running costs (ORC)

\[ ORC_{ji} = \sum_k (FE_{ki} + TE_{ki}) \], for each j, i (6)

Where \( TE_{ki} \) - sum of k-th taxes (Heavy Goods Vehicle, congestion, noise, pollution taxes) expenses, except fuel and revenue taxation for each i-th TI, each j-th SC

\( FE_{ki} \) - sum of k-th fees expenses(pilot, fairway due, parking, commercial traffic fees) for each i-th TI, each j-th SC

This cost is concerned only by the taxes and fees applied in i-th transport infrastructure and uniformly on the other transport infrastructures, except income tax which is applied for all businesses.

5) Arrival time \( ATM_{mji} \)

This parameter represents the time, when the distributor arrived to the customer by using i-th TI for delivery

\[ ATM_{mji} = \text{traveling time} + \text{break time} + \text{ABPT} + \text{departure hour} = \sum_i \sum_n (ALH_{ji} / vtr_{ni} + BT_{lnji} + ABPT + DH_{lj}) \], for m-th customer, j-th supply chain and i-th TI

\[ Td_{mji} = ALH_{mji} / vtr_{ni} + \sum_i BT_{lnji} + ABPT_i \]
By combining the equations (3), (4), (5), (6) into (2), we obtained the following equation:

\[ TVC_j = \left( \sum_{i} \sum_{m} \sum_{l} RT * C_{lj} * Td_{mji} * Y_{lj} + \sum_{i} \sum_{n} FT * Cf_{ni} * ALH_{ji} * V_{ji} + \sum_{i} \sum_{k} IUC_{ki} * ALH_{ji} * V_{ji} + \sum_{m} IT * p * Z_{mj} * O_{mj} + \sum_{i} \sum_{k} TE_{ki} + FE_{ki} \right) j, \text{ for each } j \] 

Multiplying the equation (7) by the product \( P_{ji} * X_{ji} \), and placing the result into the equation (1), will obtain the next relationship for the Return On Investment:

\[ ROI_i = \left( \left( \sum_{j} (TVC_{ji} * P_{ji} * X_{ji}) / CI_i \right) / CI_i - 1 \right), \text{ for each } i \text{-th TI} \] 

Where,

\( CI_i \) - Investment cost of i-th infrastructure

In the next lines we will define the constraints, which make our model tractable:

6) Infrastructure capacity (IC) constraint

Here we have decided to express IC in relation with the freight volume, as follow:

\[ \sum_{j} FrV_{ji} \leq IC_i, \text{ for each } i \]

Where \( \sum_{j} FrV_{ji} \) - freight volume of j-th supply chain using i-th TI

\( IC_i \) - i-th infrastructure capacity

The infrastructure capacity \( IC_i \) can be less or equal to the capacity of the ports (Klaipeda, Karlshamn, Esbjerg), since we assume that the supply chains are driven by the JIT delivery, meaning that minimum inventories at supply chain facilities as well as the ports.

7) Delivery time and congestion condition

\[ Td_{mji} = \sum_{i} \sum_{n} (ALH_{ji} / vtr_{ni}) + Tload_{ji} + Tunload_{ji} + BT_{mji} + ABPT_i, \text{ for each } m, j, i \]

In the abstraction process, we have considered the loading and unloading time as internal parameters to the ports; they are more dependent on the equipments existing inside the port and the capacity of the port, therefore those parameters don’t have enough influence on the concerned infrastructures.

In addition to the fact that, the capacities of each i-th infrastructure (less or equal) are related to the capacity of each port, in order to avoid high congestion, consequently the loading and unloading times can be set the maximum values (constant), therefore we can neglect the loading and unloading times.

Thus we obtained the next:
\[ Td_{ji} = \sum_{m} \sum_{l} \sum_{n} (ALH_{ji} / vtr_{ni}) + BT_{lnji} + ABPT_i \]
for each \( j, i \)

Where

- \( vtr_{ni} = v_{max, i} \times Cr_i \) - average speed in \( i \)-th infrastructure
- \( v_{max, i} \) - Maximum allowed speed in \( i \)-th infrastructure
- \( Cr_i \) - Congestion rate of \( i \)-th infrastructure, such that \( 0 \leq Cr_i \leq 1 \)

The congestion rate is Key Performance Indicator, which determines the flow of vehicles within a period of time on \( i \)-th transport infrastructure. It can be estimated by dividing the current speed of the vehicles within a particular period of time by the maximum allowed speed on this transport infrastructure. The maximum allowed speed can vary according to the geographic location of the infrastructure in the sense that the location is populated or not.

Thus the congestion rate is a safety criterion, it can be the matter of substantial discussion between the supply chain and government; consequently the congestion rate is a veto point for the government.

From this perspective the congestion condition is defined as follow

\[ 0 \leq Cr_i = vtr_{ni} / v_{max, ni} \leq Cr_{hist, i}, \text{ for each } i \text{-th TI} \ (10) \]

Where

- \( vtr_{ni} \) - decision variable, can vary depending on the physical aspect and mode of the transport infrastructure.

8) Pollution rate constraint

The pollution rate of the environment in the specific area can be estimated by measuring, for instance the part of CO2 in the air composition at that location.

The pollution control is a very important factor of the governmental transport policy. This KPI is not the matter of substantial discussion among the stakeholders; therefore it is also a veto point for the government.

Since we focus on the transportation activities, we can assume that the total pollution rate in the specific location is producing only by the vehicles and their fuel consumption.

From the points cited above, we will define the pollution criterion as follow:

\[ 0 \leq \sum_{j} \sum_{n} (pr_{nj} \times V_{ji} + fpr_{nj} \times Vc_{nj} \times ALH_{nj} \times V_{ji}) \leq PR_{hist, i}, \text{ for each } i \ (11) \]

Where

- \( pr_{nj} \) (g/Kwh)- Pollution rate of \( n \)-th vehicle in \( j \)-th supply chain
- \( PR_{hist, i} \) - Historical pollution rate infrastructure of \( i \)-th previous infrastructure
- \( fpr_{nj} \) (g/l)- Fuel pollution rate, which depends on the type of fuel

9) Noise Rate constraint

The noise rate of the environment in the specific area can be estimated.

The noise emission control is a very important factor of the governmental transport policy.
This KPI is not the matter of substantial discussion among the stakeholders; therefore it is also a veto point for the government.

Since we focus on the transportation activities, we can assume that the total noise rate in the specific location is producing only by the vehicles.

From the points cited above, we will define the pollution criterion as follow:

\[ 0 \leq \sum_j \sum_n N_{nj} * V_{ji} \leq N_{Rhyst}, \text{ for each } i (12) \]

Where

- \( N_{nj} \) (dB)-noise rate of n-th vehicle in j-th supply chain
- \( N_{Rhyst} \)- Estimated historical noise rate of previous infrastructure

10) Delivery criterion

If \( T_{d_{mji}} - T_{w_{mj}} \leq 0 \) then \( O_{mj} = 1 \), otherwise \( O_{mj} = 0 \), for each j (13)

In this constraint we assume that if the arrival time of the distributor to the customer is within the service time window, then the delivery occurs \(( O_{mj} = 1 \)\), if the distributor is late, then no delivery occurs to m-th customer \(( O_{mj} = 0 \)\).

This constraint enables us to assess one of the supply chain’s quantitative criteria, productivity ratio, by showing us how many customers will be serve using i-th TI among the total number of customers.

11) Service level criterion

\[ SL_{ji} = \sum_m (Z_{mj} * O_{mj} / Z_{mj}) \text{ for each } i, j \]

Where

- \( SL_{hist} \) - Historical service level of j-th supply chain
- \( Z_{mj} \) - Demand of m-th customer in j-th supply chain

The service level, defined above, determines how many customers among the total customers will be served by using i-th transport infrastructure.

It is essential factor for the supply chain, defining the nature of the supply chain feedback in relation with the suggested i-th transport infrastructure.

It is subject of comparison between service level provided by i-th TI and those provided by the other alternative TI, which are the basis for comparison.

Therefore it is important from the supply chain perspective that

\[ SL_{hist} \leq SL_{ji} \leq 1, \text{ for each } j, i (14) \]

12) Productivity rate

In this effort we considered only supply chain strategies with low level of inventory, thus the major part of the goods produced are shifted; this leads us to conclude that:

\[ PR_{ji} = SL_{ji}, \text{ for each } j, i (15) \]
Where $PR_{ji}^j$ - Productivity rate for j-th supply chain using i-th TI

In this case we do consider only the goods transportation, but we must have in mind that it could be involved as well the passengers movements, with other parameters to take into consideration.
We specifically limit ourselves on freight transportation activities.

13) **Probability condition**

We are dealing here with decision process with experimentation[10], which implies that the first suggested decision might be rejected by the supply chains(feedback link), therefore the needs of alternatives in order to reach a consensus.
From this angle the alternative decisions sent to the supply chains, will be ranked and chosen by decreasing order of the ROI value. In other words the first alternative decision sent to the supply chain will have the highest value of ROI, the second alternative, the next second highest value etc.…
Since the decision support system is designed for governmental decision-maker, the alternative decisions with the highest value of ROI will have the highest probabilities of occurrence.

14) **Supply chain participation rate (SCPR) criterion**

This factor is a development factor that enables the government to estimate the maximum potential users of i-th transport infrastructure in function with maximum capacity of the given infrastructure. This factor implicitly enables the government to build a long-term and steady transport policy for the given transport infrastructure, because the selection of the contested KPI(s) is done by taking into consideration the majority of the supply chains contesting the same KPI, so called highly contested KPI(HCKPI). In addition to that the Return On Investment (ROI) of i-th transport infrastructure is function of the number of supply chains ready to participate as users of i-th transport infrastructure, which means if the number of supply chains increases then the ROI increase.

15) **Veto points**

The veto points are conditions that strongly influence the decisions of both stakeholders, private and public partners.
And each of the stakeholders have to take into consideration within the negotiation process, thus we have decided to introduce those veto points into the mathematical model of our effort.

15-1) **supply chain veto points**

In order for the supply chain to agree or not to be a user of the suggested i-th transport infrastructure, there are certain conditions that must be reflected by the transport infrastructure.
These conditions (seen as constraints), defined as ratio, defined mathematically in comparison with the alternative transport infrastructures as follow, aim to empower the role of the private actors in the public infrastructure investment decision:

\[
SCVP1_j = \frac{TVC_{ji}}{Td_{ji}} \leq \left( \frac{TVC_{ji}}{Td_{ji}} \right)_{hist}
\]
\[
\text{Or}
\]
\[
SCVP2_j = \frac{TVC_{ji}}{SL_{ji}} \leq \left( \frac{TVC_{ji}}{SL_{ji}} \right)_{hist}
\]

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In other words, whenever the expressions in (16) are true then j-th supply chain is a potential user of i-th infrastructure (send “OK”); otherwise j-th supply chain is not a user of i-th infrastructure (send “NOT OK with HCKPI”)

15-2) government veto points

The government veto points are, as the name indicates, the conditions/constraints that must be strictly satisfied in the infrastructure investment decision process from the public actor perspective. In addition to the constraints 9, 11, 12 which represent the governmental veto points from the environmental and sustainable aspects, we introduce the Return On Investment (ROI) of i-th transport infrastructure in the mathematical model as follow:

If $ROI_i > 0$ then suggest i-th TI with the related transport policy

Otherwise “delay i-th transport infrastructure investment” for each i (17)

The expression (17) represents the governmental veto point from the economical aspect. This model, by its structure, is much close to the negotiation process with a first step standing as transport infrastructure suggestion from one part, a second step characterizing by a rejection or confirmation by the other part, a third step searching for consensus in the rejection case by suggesting another alternative infrastructure decision [16], followed by a decision stage at the end. Since one of the aim of the governmental policy is to make the transport infrastructure accessible, the means suggested by my effort to achieve this objective, is the use of information and communication technology (ICT) in designing our system.
9. REFERENCES

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