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Tools for an integrated systems approach to sustainable port city planning

Instrumental para uma abordagem sistêmica e integrada no planejamento de cidades portuárias sustentáveis

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Abstract

Large port cities like Shanghai, Amsterdam and Rio de Janeiro are key cogwheels in international logistics and transport networks but also serve as showcases for the rest of the world; as such, they constitute strategic assets for the host country's economy and international influence. Historically, a city and its port often developed independently, through sometimes contradictory or even confrontational policies. Today, the growing number of usage disputes over increasingly coveted coastal areas is prompting local managers to incorporate urban and port-related issues in overarching planning programs. In particular, planning of the sea front and the buffer zone between the port and the city must contribute decisively to the deployment of more effective, cleaner transport services for the port city as a whole. In general, one of the key global challenges for planners and decision-makers consists in integrating sustainable development goals (environmental and social components, as well as the stimulation of industrial competitiveness) into urban planning. In this context the PHEBUS research group has initiated an international program of research to develop innovative methods and tools that can help territorial stakeholders to design, evaluate, compare and ultimately choose development scenarios for the future of their port cities. The main themes are addressed via a multidisciplinary systems approach on the scale of a coastal urban area with an industrial and port complex. In particular, the themes include sea front planning, the city-port interface, energy optimization (e.g. the introduction and sharing of renewable energies), risk resilience, climate change and multimodal, clean transport.

Keywords: Sustainable city. Port of the future. Collaborative platform. Decision support system.

Resumo

Grandes cidades portuárias como Shangai, Amsterdam e Rio de Janeiro são peças-chave na cadeia internacional de logística e transporte, e, por isso, servem para estudos de caso que repercutem em todo o mundo. Consistem, portanto, em ativos estratégicos para a economia de seus países e repercutem sua influência a nível internacional. Por razões históricas, uma cidade e seu porto podem se desenvolver de forma independente, mas muitas vezes empregam políticas contraditórias ou conflitantes. Hoje em dia, o crescente número de disputas pelo uso do solo nas cobiçadas áreas costeiras está mobilizando os gestores locais para incorporar questões urbanas e portuárias em programas de planejamento sistêmico. De um modo particular, planejar a frente de cais e sua zona circundante de convergência entre cidade e porto pode contribuir decisivamente na implantação de sistemas de transporte mais efetivos, limpos e benéficos para a cidade como um todo. De forma geral, um dos grandes desafios em escala global para planejadores e gestores consiste em integrar metas de desenvolvimento sustentável (meio ambiente, sociedade, competitividade industrial) no planejamento das cidades. Nesse contexto, o grupo de pesquisa PHEBUS iniciou um programa internacional de pesquisa para desenvolver métodos e técnicas inovadoras, visando auxiliar os agentes territoriais a projetar, avaliar e finalmente prospectar cenários de desenvolvimento para o futuro das cidades portuárias. Os temas principais estão direcionados por uma abordagem sistêmica e multidisciplinar na escala da costa urbana com atividades em complexos portuários e industriais. Em particular, os temas abrangem planejamento da frente portuária, otimização de energia, resiliência e gestão de riscos, mudanças climáticas e transporte multimodal com baixo impacto.

Palavras-chave*: Cidade sustentável. Porto do futuro. Plataforma colaborativa. Sistema de suporte à decisão.*

Introduction: the challenge of the sustainable port city of the future

The sustainable development of the biggest cities of the world represents a major challenge for the future of the planet in the 21st century, relatively to the contribution and adaptation to climate change, natural resources consumption, energetic transition (the "after oil" transition), population mobility, welfare and security, pollution, the global economic growth. For historical reasons, a great part of these cities, and especially those of emerging countries like Brazil or China, are located on a coast or on a river, thus including a port and playing a special and major role in the national and the global economy (nodes of logistic chain, concentration of population, touristic attractiveness…).

All over the world, researchers and professional endeavor to develop innovative methods and tools to take up the challenge of the sustainable city of the future, but it seems necessary to adapt this reflection to the special case of port cities which present some specificities with the port-city interface and relationships issues, the evolution of the port itself, and the sea-front urban planning which must take into account the constraints of the port and the littoral.

In France, recent debate among stakeholders on the key issues for the "port of the future" has overlapped to a great extent with more general concerns in sustainability — notably in terms of energy, transport, environmentally friendly design and planning and risk resilience. In a generalized, integrated systems approach, these issues must be thought through in terms of network optimization and network interconnection.

In this context, PHEBUS is a multidisciplinary research team recently created through an agreement between the research lab in urban engineering of the University of Technology of Compiègne (called AVENUES) and the national technical service for maritime and waterway issues of the French ministry of sustainable development (called CETMEF). The aim of this research group is to tackle port city issues through a systems and sustainable approach and by crossing the competences in urban engineering and planning with port technical knowledge and practice. It is seeking to develop innovative methods and tools that can help territorial stakeholders to design, evaluate, compare and ultimately choose development scenarios for the future of their port cities.

Port city issues and research projects can be tackled through thematic studies or transversal

approaches, both converging and contributing to design a systems view of the sustainable port city of the future. In the first part of this article, three examples of thematic research studies which were recently led by the PHEBUS group, and applied to French (Bordeaux, Le Havre, Dunkerque) and Brazilian cities (Rio de Janeiro), are presented and briefly developed.

In the second part, three kinds of operational tools that contribute to better integrate and link these different topics and local practice in a systems approach are proposed: i) a collaborative platform to share knowledge and best practice at the international level; ii) a GIS platform for the integration, crossing and sharing of local and regional data; and iii) a method for multi-criteria and multi-objectives analysis of port cities through a set of adapted indicators for sustainability and competitiveness.

In the conclusion, a predict tentative to how this core group and these first projects can evolve towards an international network and research program for the port city sustainable development, was presented.

Examples of thematic research studies for port and coastal cities

Transport, accessibility and mobility – The example of Rio de Janeiro

The integrated planning for cities development has to consider the passengers' mobility and the transport of goods as priorities to reach a sustainable growth (MARTELL-FLORES et al., 2009). In the case of the city of Rio de Janeiro, the transports efficiency was neglected in order to satisfy other urban priorities. In fact, the suddenly and massive migration of people from rural zones to the city in the last 30 years as well as the explosion and the mutations of the economic activities have pushed the urban development in an accelerated way. This urban growth occurred without enough time to construct and even to plan the corresponding needed infrastructures as the streets networks and the public transport services.

A city without efficient transports is a scleroses city. The city of Rio de Janeiro is recognized all over the world for its socio-cultural richness as well as its economic growth. A major city can reach and sustain a world class level of economic, politic and tourism activities only if the development of transports and mobility follows its own growth of population and urbanization. The economic development, by using the labour force, the resources and the facilities that the city offers, remains possible until it reaches its own limit of urbanized areas, as well as of housing and transport capacities. Beyond the limit of its infrastructure capacities, any new development of human or economic activities will generate important difficulties to the city systems to continue to function in a normal way, as well as high costs for implementing palliative solutions without a real utility in the long term.

The port of Rio de Janeiro and the associated ones of the metropolitan area like "Angra dos Reis", "Itaguai", and "Niteroi", have recently experimented huge progress and growth, doubling literarily their goods traffics in the last decade (RIO DE JANEIRO PORT AUTHORITY, 2011), and their rank in the world got higher. Nevertheless, the lack of coordination with city projects and authorities and the numerous urban transformations that are led around the port area may cause high risks for port operations and slow down its development, as well as create new constraints for the long-term transports viability into the city and the hinterland. These constraints mainly concern the accessibility to the port and restrictions for the land freight which could limit the ships' operations of "loading and unloading" and provoke future competitiveness disadvantages for the port. For the city and the metropolitan area, an integrated planning with the port is however a necessity in order to organize the traffic circulation and common transport's services, and also to guaranty a general quality of mobility for persons and goods. It is thus necessary to find specific solutions of mobility for persons and goods within the framework of a city-port integrated planning.

In that perspective, the application of theory and simulation tools to model the persons' mobility and the goods fluxes are proposed, in order to better define the location and causalities of current and future bottlenecks of the transport system, considering factors as geographical environment, urban morphology, demographic distribution and its projected evolution. The good understanding of risks linked to mobility and transports in Rio de Janeiro

and the structure of local fluxes represent relevant support tools for decision makers of the city and the port. These information may be used as the basis for the reflexion about an integrated transport system in Rio de Janeiro as well as for establishing "check points" to evaluate, control and compare future evolution scenarios of the transport system.

The *Porto Maravilha* project is a great private/public partnership consortium for urban intervention at harbour area that takes place in Rio de Janeiro under great events organization pressures (2014 World Cup and 2016 Olympic Games). Although it could represent an excellent opportunity to develop more integrated transportation system, what can be observed is a set of isolated and undefined projects, such an elevated roadway demolition, some street enhancing and tunnels opening, and a surface light train system (similar to European tramway). Various authors studied this entrepreneurial models and classified them as "city marketing" and "eventism", as the results are focused on marketing the city at an international scale and use the events to justify large–scale urban regeneration projects (CASTRO-COMA, 2011).

Other lack of the project is not take the large budgets opportunity to improve sustainable energy policies as observed in port and cities relationship on Europe and described in the next paragraphs.

The evolution of energy consumption and production in European port cities

The energy issue appears as a major challenge for ports and industrialized port cities nowadays and in the next decades. The global change that begun at the end of the 20th century, and that will probably continue all along the current century, is made of several drivers that encourage the port authorities to envisage evolution scenarios of energy management in the near and far future. Indeed, the two main drivers that urge specialists and politics to program an "after oil" scenario are, firstly, the necessity to limit greenhouse gas emissions and climate change and, secondly, the growing scarcity of fossil energies and the continuous raising of their price that represent an obstacle to the economic growth.

Ports are at the crossroad of those issues, because on one hand they are heavy users of fossil energies to feed the industrial activities in their areas and their own operations and could benefit from optimizations of their consumptions, and on the other hand their location at the interface between sea and land puts at their hands a huge deposit of renewable energies (from sea, wind...) that is still under-exploited.

Energetic strategies of the future at the scale of a port or a port city can be adapted in two complementary approaches and projects. The first one, which can be implemented in a short or middle term perspective, consists in producing an accurate diagnosis of the current energy consumption and then proposing technical and/or organizational solutions to reduce this consumption and its global cost. The second kind of strategy, which takes place in a middle or long-term time scale, consists in studying the possibility to develop and use renewable energies at the regional and local scale as an alternative to progressively replace the traditional and remote sources of energy supply.

These two complementary objectives have been recently studied by the common research team PHEBUS (UTC and CETMEF) and a group of twenty UTC students, in collaboration with the port of Dunkerque and the AREVA-Corys company (MOREL; MARTELL-FLORES; ANTALUCA, 2013).

Firstly, a new and original idea for energy consumption reduction in industrialized areas previously emerged from the EFFORTS (Effective Operations in Ports) EU project (http://www.efforts-project.org/). It mainly consists in doing a more accurate acquisition and diagnosis of data energy consumption for industrial and port activities, in order to better understand the correlation between each specific activity and its energy consumption. Once this correlation is made, an adaptation of the activity implementation can be proposed in order to save energy. Solutions can be technical and/or organizational, but specialists of AREVA estimate that an additional benefit of 15% energy saving can be expected by this way (in addition to classical reduction approaches), which actually represents big amounts of money when high consuming activities are concerned.

To illustrate and test this approach in the port of Dunkerque, it has been first applied to the equipments and activities of the port locks. Ports terminals in Dunkerque are accessible through channels

where water levels may be different from the sea level. Therefore, the ships coming from the sea or the inner waterways have to pass through one or several locks, thus triggering the locks mechanism and the energy consumption of several big pumps for the water volumes transfer.

The detailed study of both the physical mechanism of water transfers and the process of ships passing through the locks, and the correlation of these processes with the energy consumed by the pumps enabled to envisage different scenarios to drastically save energy. One of the solutions among others consists in grouping the passage of several ships when the waiting time remains acceptable. In order to assess and compare scenarios in a cost-benefit approach, simulation models can be used, like those developed by Corys during the EFFORTS project. Before applying numerical models for energy optimization, an object and adapted data model must be designed to correctly represent the process and the correlation. UML models have been elaborated both for the lock case and also for the buildings in the port area. The first results of this study are encouraging and this example is a good illustration of the activity-consumption approach. It should be extended to a set of industries in Dunkerque and other types of port activities.

The second strategic approach consists in studying the potential of a pilot site for developing and distributing renewable energies. At the scale of the whole French littoral, a national study and report have been produced to identify the best potential for marine energies, especially in coastal cities (BOYE et al., 2013). Firstly, a complete catalog of referenced renewable energies (not only marine) that can be applied and adapted to port cities (solar, wind, wave, marine current…) have been produced by a team of UTC students. Then a multicriteria support method has been elaborated to help decision makers to identify and chose the best scenarios of energy reduction and production at the local scale. These scenarios can include several types and sources of energies (mixed-energy solutions), that can be organized within smart-grids in order to manage and optimize their production and distribution in a local network.

These methodological proposals for global energy scenarios of the future in port cities still have to be confronted to the reality and other pilot sites. The potential difficulties and constraints are not only technical but also concern economic, political and regulation issues. That's why a lot of actors must be associated to this kind of project in order to correctly take into account the national and local context. The final political decision is all the more difficult to take for long term planning strategy that a lot of uncertainties can intervene in the process, relative to climate change, economic parameters, etc.

Security and resilience of coastal cities within climate change

Coastal and port cities are particularly vulnerable to natural risks and climate change impacts. The global raise of temperature all over the world has a double negative effect on the risk of littoral submersion: it causes a progressive rise of the sea level and it is also suspected of increasing the frequency and intensity of severe maritime storms (HALLEGATTE et al., 2011).

On the western coasts of Europe, this is the conjunction of a high tide and a severe maritime storm which recently caused dramatic submersions of the French Atlantic littoral, like in the case of the 2010 Xynthia storm with a consequence of 47 dead people. This risk will continue to increase during the next decades, not only due to the physical effect of climate change, but also with the growth of coastal cities which continue to attract more and more population. The partial and unexpected submersion of Manhattan (New York City, USA) in 2012, also due to a maritime storm, seems to confirm the increasing vulnerability of coastal cities all over the world.

To prevent and anticipate this high risk and increase the resilience of coastal cities, two complementary approaches can be studied and put in place. Firstly, a prevention strategy aims at proposing long terms and structural measures to limit the level of hazard – by reinforcing the costal protections – or to limit the vulnerability of risk prone areas with and adapted urban planning regulation. Nevertheless, in case of some extreme events, this kind of solutions can prove not to be sufficient to ensure the security of the population. Then, a provisional mass evacuation or a definitive withdrawal of most dangerous coastal zones is the ultimate measure that must be envisaged by authorities. All

these kinds of adaptation strategies have to be prepared and planed in advance to respond to a set of possible short and middle term scenarios that must be previously established. Some general methods and case studies have been developed within recent French and EU research and experimented in cities like Le Havre or Bordeaux in France.

SAO POLO is a French national research project (GICC program, ministry of sustainable development) which studied the possibility of reinforcing existing coastal protections (dikes and other infrastructures) against the consequences of climate change on coastal submersions. On the pilot case of Le Havre City, a method for assessing and comparing different scenarios of submersion and sea level rise has been developed and tested, based on an economical damage calculation, mainly on buildings (NDIAYE; MOREL, 2012). For that, the annual benefit of two active adaptation strategies (protection reinforcement and strategic withdrawal) has been compared with the cost of damage without any preventive action. Hazard scenarios and submersion maps have been made taking into account the different maritime parameters (including tide, waves, sea over-height due to storms and different hypothesis of sea level rise) and an accurate ground elevation model of the city (LIDAR data). This proposal has been implemented with ArcGIS and economical results proved to be relevant indicators for decision makers, especially to estimate the provisional benefit of dikes reinforcement against climate change scenarios. On the contrary, a global strategic withdrawal reveal not to be relevant for urban areas as far as social and economical issues are concerned, and it would need to develop further research to assess and optimize the definition of vulnerable coastal zones that ultimately would need to be withdrawn and relocated.

Adaption strategies studied by the THESEUS project (part of the 7th European framework program for research in environment) also emphasize on improving prevention by the reinforcement of structural protections like dikes. Nevertheless, this kind of measure won't be sufficient to avoid new disasters for which crisis preparation and management is the ultimate solution. In order to better respond to French and European decision makers tackling coastal risks, a support method for preparing evacuation plans in case of a submersion was developed (MOREL; HISSEL; JIA, 2011). This method is based on the modeling of the building plan process with the SADT language and a catalog of classified data and criteria to be used through this process. This method has been experimented on the French THESEUS pilot site, the Gironde estuary and the city of Bordeaux. This work is going on with the perspective of providing to the very same partakers a support method to help them take the decision of evacuation in real-time, during a pre-alert phase, using a multicriteria approach and a fuzzy-logic method (JIA et al., 2012).

Transversal and integrated support tools for port cities

A collaborative platform to share knowledge and best practice

The sustainable development approach applied to city planning makes new ideas and concepts emerge, that have to be clarified, experimented on pilot cases, shared and discussed among researchers and professionals. However, these emerging concepts, best practice and innovative projects are scattered all over the world and not structured, thus making difficult for an individual to rapidly have a global view of the "sustainable city" subject, and to identify who are the people and groups currently working on this topic. Therefore, the development of a common knowledge base accessible through a WEB platform can help actors in the domain to capitalize, structure and share their projects and experience at a national or international scale in a logic of a collaborative network.

UTC and CETMEF developed a prototype of collaborative platform for the "sustainable port of the future", around the main issues and priorities which have been identified by a French national group of experts and the ministry of ecology and sustainable development (LECOMTE, 2010): eco-design of infrastructures, sustainable transport and supply chain, the off-shore port, the city-port relation, port and energies.

The first phase of this project consisted in identifying and acquiring existing documentation in these fields and writing summaries or synthesis for a document or a set of documents. Then, a knowledge base framework has been designed from this

corpus in the perspective of implementing services for the integration, sharing and optimized research of the documents with the open-source platform Alfresco (Enterprise Content Management tool). The indexation and research of documents is based on several, complementary and powerful mechanisms: multi-criteria research with metadata, automatic indexation of the content ("Google like" research), classification in a tree of topics, physical organization in "spaces" which correspond to the nature of document (project, article…). In addition to the general knowledge and documentation relative to the issues of the port of the future, most interesting projects and practice have been identified in every continents (like the off-shore port of Venice, Italy) and referenced with an interactive cartographic input which complete the panel of advanced research services.

One of the main contribution of this work, on the scientific point of view, is the construction of a classification of topics and concepts. This core of a domain ontology can be very useful to structure and better understand such complex concepts like "sustainable city" or "port of the future", especially in a systems approach.

This collaborative platform has first been evaluated by the experts of CETMEF and PHEBUS as a tool to better capitalize and organize their knowledge on the port of the future, both for an internal use and also in the perspective of sharing this knowledge within a national and international network. The interest of such a tool has been confirmed to better structure such a complex and multidisciplinary topic. The return of experience of the first version of this knowledge base led the teams to specify a second version of this framework in order to simplify it and better fit to the specialists and end-users' point of view and daily use.

Indicators for the sustainable development and competitiveness of port cities

The collaborative platform first aims at providing partakers of the sustainable port city a set of services to facilitate the sharing of information and the exchange of best practice. Further development should propose a model and a set of indicators to help evaluate the current situation and evolution scenarios of the city, the port and their relationships, in a double perspective of sustainability and economical competitiveness. It is actually a major challenge for the port city of the future to find a positive synergy between these two objectives, even if they can seem contradictory at a first glance (RODRIGUES-MALTA, 2003).

The city of Rio de Janeiro is a representative example of the necessity to find compromises between sustainable development, quality of life and competitiveness of industry and services. The port and the city evolved, from the beginnings in a necessary symbiosis with complementary functions and objectives, to the current situation of hyper-specialized port functions and also with progressively a specialization in urban functions (HOILES, 2000; HOILES et al., 1998).

Nowadays, the continuous progress of port activities seems often in contradiction with the city development objectives and vision of its evolution. The city's objectives are the development of the tertiary sector of the economy, finance and international trade, tourism, the attraction of companies, the improvement of the city's image and the increase of its political influence. Then, the contradiction becomes obvious. How planning urban developments in order to satisfy on one side the new way of life, the respect of environment and cultural traditions, and on the other side the industrial and port's activities, the necessities of land freight transports and storage infrastructures? The actual challenge of planning is to establish the main orientations of urban development for the city and for the port through integrated solutions discussed by all the concerned actors. In that perspective, multi-criteria indicators and analysis should help local managers to assess strategic urban planning and take decision.

Lots of methods and tools have been recently developed to propose sustainable indicators for the territory, the city or the district, especially in Europe. Concerning port cities, PHEBUS partners participated to a project which proposed a large set of indicators to understand the relationships between the port's activities and its traffics, the economical activities of the city, the life quality of inhabitants, the tourism development and the city's image improvement (MARTELL-FLORES et al., 2004). These indicators were designed by a multidisciplinary team of researchers and applied on a large sample of European port cities. The results permitted the

characterisation of relationships between ports, cities and their economic interrelations.

Even if this set of indicators were designed for European ports, their nature let to apply them independently of the geographical location. The deep understanding of the city-port relationships for the particular case as Rio de Janeiro would permit to detect the most important improvements to realize and to prioritize them on the time. The indicators could constitute the base to find practical solutions for the specific urban projects involving contradictions of interests. Always in respecting the priorities of the city-port development and the particularities of each project, they could be used as a set of impartial and objective parameters to support decisions about urban projects in respecting as most as possible the different actors interests and in accomplishing the main purposes at same time.

A multi-source and multi-use GIS database for sustainable planning

In order to apply indicators to the sustainable city and port, a collaborative platform needs to include not only general knowledge and documents, but also more detailed data on the local context and projects (LIMA; MOREL; MORAES, 2012). These data can be general statistics on a global site or georeferenced data.

A GIS database is particularly interesting for establishing spatial and topologic relations between sustainable indicators and their basic parameters: environmental, social and economic (COSENZA; LIMA; NEVES, 2010). This relationships can be process by GIS functions to analyze perceived objects (people, buildings, squares, all sort of administrative boundaries) belonging to multiples domains (demography, infrastructure, health, culture, development, environment, history, etc.) at different scale levels.

A successful multi-source and multi-use platform for sustainable planning purposes must have a satisfactory connection with GIS resources following the complete database lifecycle: information gathering and selection, dataset structure and organization, specific data recovery and visualization, application of comparison and analyses methods, development of processing routines for model design and search engines, integrating demands from users and developers, generating decision support data, charting for domain related scenarios, and finally self-adaption during its lifetime.

In the case of ports and cities, a GIS database could store local data as facilities, infrastructures, productive activities and population data suitable for building social/economic development indicators, as well as topographic, hydrological and climatic parameters (temperatures, precipitation, humidity etc.) useful for environmental purposes. Both sets could be correlated under spatial and statistics analysis tools, in order to obtain more appropriated indicators. The great issue for sustainable indicators is how to apply them on innovative methods, as planning smart grid solutions and defining integrated public policies.

A GIS database application for sustainable purposes can be illustrated by searching solar energy supply indicators relating demography (census statistics data), climate (environmental data), topography (geographic data) and construction profile (municipality data). Although this data could be expressed in various levels, accuracy and scales, the use of geoprocessing techniques can help solving this issue and present a result, discretized under any desired territorial unit (census sectors or any other assemblage). Figure 1 shows a classified density distribution for census sectors on Rio de Janeiro harbor area.

On this example, demographic census sectors data (density, number of inhabitants and income at housing units) could be applied to estimate the solar energy supply potential of a neighborhood (monthly or yearly). The global analysis must also integrate the local organizations and actors (government, companies, etc.) and policies conducting the initiatives (public inversions on low class welfare, private clients' choice, etc.). In some high and middle class housing areas, great part of the energy consumption comes from illumination, leisure and air conditioning system. In lower classes, the provision could be ruled by basic rates based on essential energy supply. The central question is how a solar generation housing system could fit the various demand levels identified on the site, and connect itself with the available energy systems.

These initial considerations must be translated in steps for structuring a geo-processing model that depends on the selected variables and that should produce multiple alternative scenarios as outputs. It can be start from the census GIS organized data

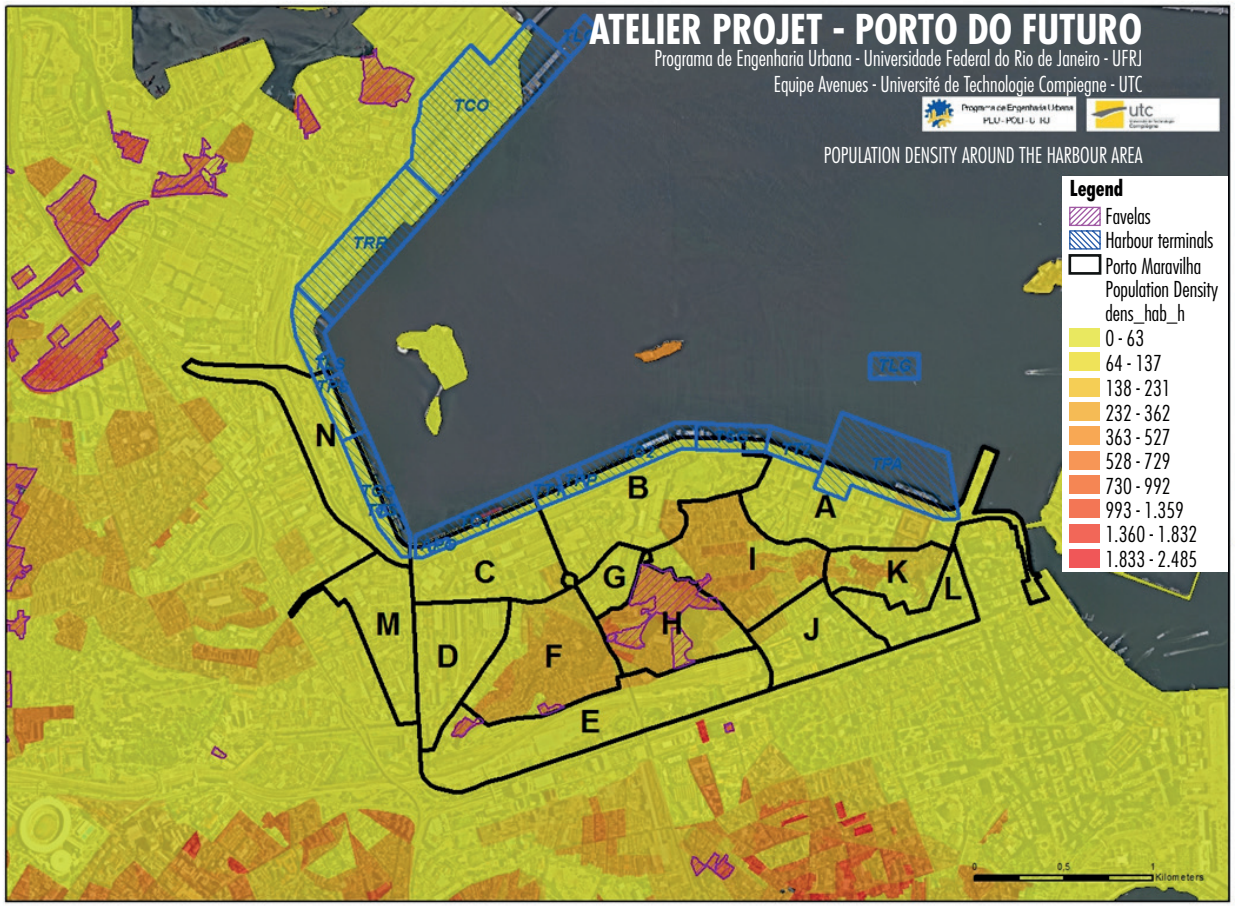

Figure 1 - GIS density data from Rio de Janeiro
Source: Research data.

and apply one built model for assembling other sorted data from our multi-source dataset, as well as: number of sunny hours, solar bright, average temperature records, topography (shadows time) and cloud coverage &precipitation (hidden sun). The demographic data could help us search and spatially classify the various patterns of energy consumption related to the site, and a customized algorithm could process the solar potentials with the spatial requested energy demand, in order to generate typology zones (territorial output) for suitable projects (proposed policies).

Sustainable indicators of existing buildings (3D geometry) and their properties (age, occupation, height, etc.) could also be used to analyze land use and urban planning and study possible future changes and land use expansion. The data is stored on record tables related to the 3D geometric model. On Figure 2 it can be observe a prototype model for studying the Rio de Janeiro harbor area. The records from this observation could be used to validate the timeline of a predicted scenario.

Conclusions and perspectives

As was shown in this article, port cities will become a major concern of spatial planners of this century. Economic issues are of course of vital importance because ports, at the heart of the logistic chain, concentrate a lot of industrial activities in their areas and foster the development of large regions or even nations. But at the same time the particular location of those areas, at the interface between sea and land, provides them with a lot of natural resources that must be used in a rational way (among which renewable energies in sufficient amount to meet the needs of the coastal region), and makes them subject to a number of hazards like tsunamis or storm surges

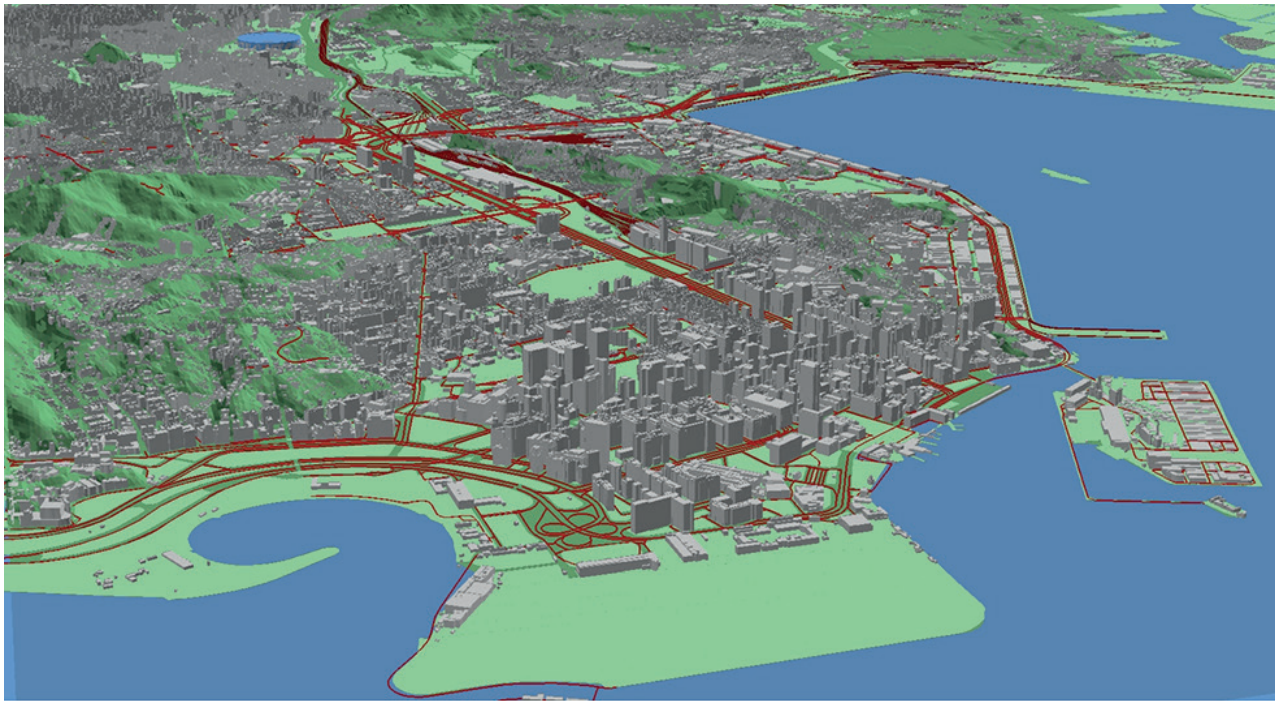

Figure 2 - 3D model on GIS environment of Rio de Janeiro harbor area
Source: Research data.

which have to be dealt with to ensure the safety of neighbouring population.

Those three issues — safety of coastal regions; rational use of renewable energies; and assessment of the interface between the port and the coastal city in terms of spatial planning and transport — are the main themes of PHEBUS research team.

The first results obtained in these fields and within this team in terms of methods (optimizing energy in the port of Dunkerque, impacts of climate change in Le Havre), data and tools (collaborative platform for the challenges of the port of the future, multisource GIS for the city of Rio) must now be proposed and developed in more ambitious and funded research programs at the national (ANR in France) or European and international levels (next European program Horizon 2020), with the collaboration of scientists in different domains and from different countries in Europe and South-America.

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