Centro de Sistemas Urbanos e Regionais - CESUR
Departamento de Engenharia Civil e Arquitectura
Instituto Superior Técnico

CAReFUL - Car fleet renewal as a key role for atmospheric emission reduction

Project reference

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1. Abstract

By the mid and late 70s, the environmental issue came to the fore of transport activity, largely through the item of acidifying substances and ozone precursors. Since then, an interesting process has been going with successive discovery of new types of environmental aggressions and associated risks, followed by technological responses and their introduction in the market. Climate change is a major environmental burden that implied severe restrictive EU policies to the transport sector, and more specifically to the car industry through the EURO regulation. As a prime contributor to atmospheric emissions, much attention is paid to car's technological aspects (mainly emissions and energy consumption). Although problems aren't solved, the situation is improving in general, and in many respects the question of accelerating fleet renewal is now dominant. It is commonly accepted that technology can solve road transportation environmental problems, but there is no precise knowledge on when and how this will happen.

The main goal of this project is to prepare a modelling tool to assess the transport and environmental policies aiming to upgrade current car fleet and diffuse more efficient vehicles due to the environmental restrictions in the near future, for instance, the Kyoto Protocol.

The theoretical ground of the present proposal is based on energy systems and air emission research. Practical motivations refer to the recent government's approval of the National Programme for Climate Change, where a critical diagnosis is drawn for the next 10 years of the national greenhouse gas emissions. If trend line emissions are not curbed, Portugal will embrace an international non-compliance situation with respect to the Kyoto protocol commitment. This situation is even more critical if we consider its EU burden share agreement that implicates Portugal into severe consequences.

The present research proposal brings a model (CAReFUL) that integrates methodologies for the estimation of the evolution of car fleet (CARFLEE), emissions (CAREM) and energy consumption (CAREN) by cars. Life-cycle thinking is considered here.

Moreover, this methodology is complemented by the rack up into a conceptual model of the interrelationships of:

- Major conjuncture factors that influence technological evolution of car fleets;
- Major driving forces that trigger technological innovation; and
- Major improvement paths for innovation (incremental, remanufacturing, rethink, or hybridization of the last two).

Major contributions are the expected results of the case-study applied to the Portuguese situation.

Keywords: Car, Technological renewal, Car recycling, Atmospheric Emissions

2. Objectives

Much research focuses on the environmental efficacy of car abatement, ITS tools and other demand-side-acting instruments (economic and regulatory). Although environmental problems have been identified and technological responses discovered, the success of technology depends largely on accelerating the fleet's renewal rates. The main goal of this project is to prepare a modelling tool to assess the transport and environmental policies aiming to upgrade current car fleet and diffuse more efficient vehicles due to the environmental restrictions in the near future. CAReFul remaining objectives are to:

-identify external factors and driving forces that the technological renewal of car fleet;

-assemble a model in order to simulate the evolution of a car fleet composition, adopting a life-cycle approach;

-analyse which of the available tools best contribute to achieve the fleet's renewal targets;

-run the CAReFUL model for the Portuguese situation, including the assessment of the abatement industry of older vehicles.

3. State-of-the-art

By the mid and late 70s, the environmental issue came to the fore for transports, largely through local and global air pollution (Viegas, 2003). Since then, successive discovery of new environmental aggressions, followed by technological responses and their introduction in the market, has followed. These environmental impacts are likely to increase, which ultimately depends on the balance between efficiency gains and the increase of mobility of people and goods. Although problems are far from solved, the situation is improving in general, partly due to technological improvements and in many respects the question of accelerating fleet renewal is now dominant(Viegas, 2003).

The technological evolution process has been based on four main paths (Figure 1) (Geerlings and Rienstra, 2003):

- Incremental steps (continuous improvement such as the retrofit of vehicle components);
- Remanufacturing of existing models (using new materials or redesigning existing concepts).
- Concept-rethinking, by technological breakthroughs, such as fuel cell.
- Combination of the last two paths, which consists in the hybridization of the 2 concepts (eg, hybrid-cars).

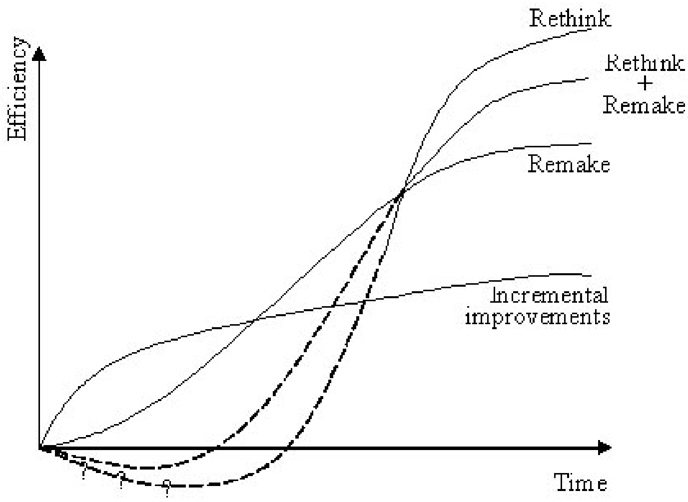

Figure 1 – Illustrative diagram of the potential technological evolution in terms of energy and environmental efficiency

(Adapted from Geerlings, H.; Rienstra, S., 2003)

In the past 200 years, the system has embraced a new means of transport every 50 years or so, according to the Kondratieff cycles of technological evolution and each cycle's takeoff appear to be clustered within certain historical epochs (Andersen, 1999, Ausubel et al., 1998). It is therefore interesting to understand which factors (if any) determine these technological breakthroughs.

These are:

- Economic, since technological improvements should have a return on investment sufficiently attractive and car industry is quite sensitive to market fluctuations;
- Institutional, since car industry is directly affected by regulation, despite the State is less and less interferer, and can be affected by institutional reorganization.
- Social and spatial organization, which relates to behavioural changes in society and evolution of land use organization.

As referred before, since the 70s, environmental decay, in pair with safety, became the driver of the car technological improvements. It has conduced to very tight EU car-production regulations (EURO). These result from the EU policies, with effective responses by the car industry (Auto-Oil Programme/ACEA voluntary agreement) (European Commission, 1996). It is of utmost importance to refer here the EU strategy to progressively shift the taxes from technology purchasing to technology use, combined with fuel taxation strategies, in order to foster fleet's technological renewal. These pretend to contribute to the internalization of environmental cost, giving the correct signals to the market (COWI, 2002). Governments can also influence car industry through pricing mechanisms, such as "feebates", that also induce faster technological renewal of fleets (McCarthy et al., 2001, Nederveen et al., 2003). Pricing acceptability of citizens is here an important issue to be considered (PATS, AFFORD, CAPRI).

Global car fleet emissions depend on technological renewal rates, before overall efficacy is achieved. It depends mostly on the balance between new technology penetration and vehicles' retirement. Older and medium-aged vehicles were shown to contribute a significant share of the pollution(Dill, 2004). Many countries introduced old cars scrapping programs. However, reducing the age of the current car fleet may result in an increase of life-cycle CO2 emissions (especially in the stage of scrapping old vehicles) (Dill, 2004, Kim et al., 2004, Jorgensen and Wentzel-Larson, 1990). Again EU Directives have been introduced to compensate a probable increase in car scrappage, by imposing car producers to increase the recyclable components of new vehicles.

Hence, the questions are: 1) Is there any societal context that can restrain the technological renewal of car fleets? 2) Attending to these external constraints, what have been the car industry options? 3) Assuming trend line technological improvements (paths 1,2,4), what is the optimized fleet structure that meet the atmospheric emissions targets, considering life-cycle emissions (Kim et al., 2004)?

4. Results and Repercussions

4.1. Diffusion of Results

The main expected results are:

- Detailed analysis of the major factors that determine the technological renewal of car fleet;

- A model which was named after CAReFUL, which is composed by three modules that pretend to estimate the fleet size and structure (CARFLEE), emissions (CAREM) and energy consumption (CAREN) of the car fleet. This model includes the inputs (emissions and energy consumption) from the LCA of fuel refinement and delivery, vehicle production and vehicle scrappage industries.

- The definition of instrument packages to promote technological renewal of car fleet attending to atmospheric emission reduction targets.

- An application of the CAReFUL model that defines the optimized age-distribution of the Portuguese car fleet, in order to achieve the required atmospheric emissions.

- A regionalized assessment of the car fleet size and technological structure, which allows regionalized intervention to achieve the national objective of reducing atmospheric emissions.

4.2. Repercussions

The European Commission's objective for the next 10 years is to refocus Europe's transport policy on the demands and needs of the citizens. In adopting the White Paper "European Transport Policy for 2010: Time to decide", The European Commission is for the first time placing the users needs at the heart of its strategy. With its new Transport Policy White Paper, the Commission is proposing an Action Plan aimed at bringing about substantial improvements in the quality and efficiency of transport in Europe.

Amidst several important measures, the following addresses specifically the issue of efficiency:

"Towards sustainable mobility - Transport in Europe must, as a matter of priority, be compatible with environmental protection. To this end, the Commission is proposing a wide range of measures to develop fair infrastructure charging which takes into account external costs and encourages the use of the least polluting modes of transport, to define sensitive areas, in particular in the Alps and Pyrenees, which should be eligible for additional funding for alternative transport, and to promote clean fuels ..."

The present research is in line with the European objectives. Although it is expectable that present development of car technology will achieve zero-emission levels, environmental decay is still a reality. Therefore, the question at stake is whether or not additional action is needed to make technology more effective? Present research will provide a valuable tool to analyse this issue, and near future direct repercussions could be expected in the case of the Portuguese car fleet.

5. Methodology

The tasks presented hereafter are peaces of the research proposal (Figure 2). Each task of this flow diagram will be described in detail during the following sections. The overall approach to the objectives presented before is split in four major phases, at the end of which, milestones are surpassed.

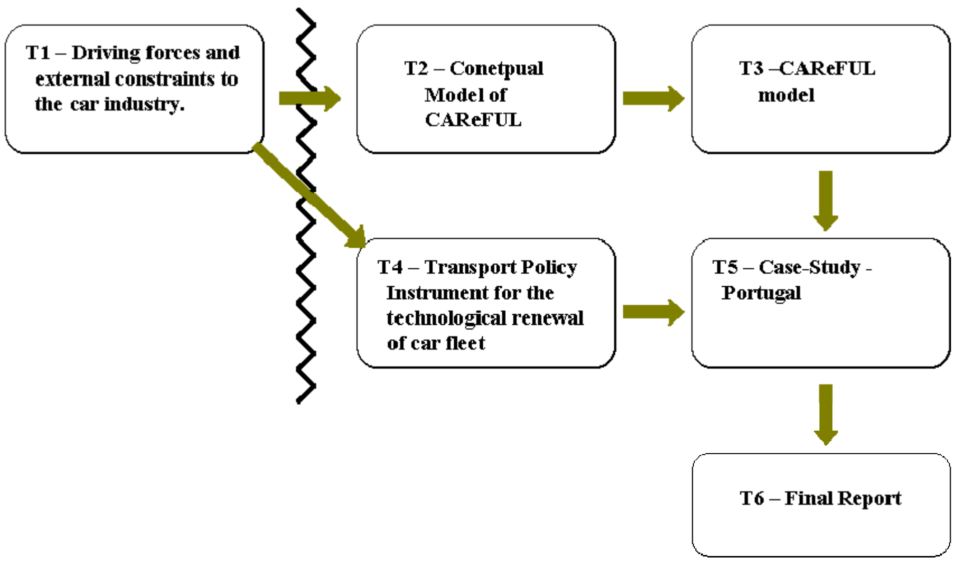

Figure 2 – Global workflow diagram

After the first milestone, a Working Paper (WP) will resume the major external factors and car industry driving forces that influence the technological renewal of national car fleets, and how these variables interrelate. This WP will set the basis for the work thereafter, which focuses on conceptualizing the model of the car fleet dynamic processes. This second stage of the work programme will be completed after the conceptual model is turned into a computer model that pretends to simulate the processes which underlay the dynamic evolution of a national car fleet. Deliverable 1 will then be submitted to FCT with the methodological issues covered, which include the theoretical basis on systems-dynamics and the modules of the CAReFUL mode, i.e. car fleet emission module (CAREM), car fleet energy consumption module (CAREN), and the car fleet composition module (CARFLEE). The second milestone is then overcome, and the analytical tools are then concluded. The next step is to prepare the Portuguese case-study. Surveys on the Portuguese citizens' receptiveness and acceptance to new instruments (regulatory and economic) aiming to promote car renewal will be performed. This survey will also characterize the current Portuguese car fleet composition, by collecting nation-wide information. This survey will be a complement to the existing information existing in government Institutions (for example, ISP, DGV) and other organizations (for example, ACAP, ANECRA, ACP). The structure of CAReFUL will consider the information contained in existing databases for future automatic updating each time a new report is produced. These links will be prepared in collaboration with DGV and ISP. The third milestone corresponds to the analysis of different scenarios of environmental performance (energy and emissions) by the national car fleet. A second WP will be realized. The final report will then be prepared, concluding about all previous issues in an integrated way, and proposing final recommendations. The final report will also include a section on the car abatement industry in Portugal, in order to asses the feasibility of the car fleet renewal targets set before.

Then following sections present the research tasks in detail

5.1. Technological innovation and car fleet evolution (Task 1)

The main expected result of Task 1 is a complete analysis of the main factors that determine the technological renewal of car fleet. International literature review will be performed and a synthesis on which might be the external conditions (social, economic and institutional) that determine success or failure in technological penetration in national car fleets. This synthesis will provide important information for task 2 (see figure 2).

Although environmental problems associated to transport activity by no means are solved, the situation is improving in general, partly due to technological improvements, and in many respects the question of accelerating fleet renewal is now dominant. However, many constraints have been influencing technological development in pair with the renewal of national transport fleets. Although it is not the purpose of the present research to go into much detail, we could not avoid understanding on the social, economic and institutional constraints that determine the probable success or failure of any initiative to promote the technological renewal of a national car fleet. This task has a high level of desk research. Thus, the main resources used will be related to literature review.

As referred previously, the most important constraints to car fleet evolution are directly linked to the level of environmental decay of modern societies. It has driven to very tight car-production regulations, for example the USA’s Clean Air Act in 1990. Looking at the European situation, the EURO regulation has produced important emission reductions, leading to very effective responses to environmental problems.

In the past, the technological evolution process has been processed based in four main paths:

A – Improvements through incremental steps: it refers to the process of continuous improvement, through the accomplishment of small technological steps, frequently by the replacement of vehicle components, where risks of failure are low;

B - Improvements through remanufacturing of the existing models, namely using of new materials (aluminium cars) or regenerating existing models and vehicle concepts (high-speed train). This technological progress can lead to a desired trend-break, but where the risks of success on renewing fleets could be modest, attending to the ambitious commitments on stake.

C - Improvements through concepts rethinking, by technological breakthroughs, as it is the case of the Hydrogen Society. In this context, the risks of failure can be high and, usually, suggest high costs associated to project-building, assembly of the producing-chains and commercialization.

D - Improvements by a combination of the last two paths, which consists in the hybridization of the two concepts, i.e. the upgrading of traditional concepts with the introduction, in a n easily-controllable scale, of new technological breakthrough (e.g., hybrid cars).

Each of these paths is subject to major driving forces of the car industry that trigger innovation. The most important triggers for innovation are:

1-Safety

2-Comfort and quality (functional attractiveness)

3-Image and design (aesthetical attractiveness)

4-Energy and Environment intensity (covers the performance of vehicles both I terms of energy consumption and environmental impacts)

5-Costs-technology and operation costs

The present task pretends to draw a diagram that systematizes the relationships between the forces at stake that have been driving the car industry strategies, in the past: external factors referred previously, car industry driving forces and paths for technological improvements. The sub-tasks to be developed are the following:

- To perform literature review on the major technological breakthroughs in the past, both in car industry but also in other dynamic technological sectors, that influenced nowadays way of life.
- To prepare a synthesis of principal conclusions, which will be systematized through the diagram, referred previously.

The main expected results are:

- A list of the major technological breakthroughs in car industry, in the past;
- Typical innovation paths (incremental, remanufacturing, or rethink), associated to major technological breakthroughs.
- A brief characterization of the historical conjuncture associated to each item of the list referred here above.
- A conceptual diagram that systematizes how the car-industry driving forces, conjuncture factors, and strategies for technological improvements interrelate.

We also intend to prepare a paper for submission to an international conference. The content of this article will include, besides the results of tasks 1 (i.e. identification of the internal driving forces that determine the technological development of the automobile industry and the external conditions that made it happen), the definition of the basis for the construction of the conceptual model that represent the evolution of car fleet (in terms of fuel use, capacity, cylinder capacity, end of line treatment devices, etc). This article will bridge Task 1 and 2.

5.2. CARFLEE module - Elements for the optimization of the car fleet composition for atmospheric emissions reduction (Task 2)

Besides the analysis presented above, other variables must be taken into consideration to set the basis for a conceptual model which anticipates the CAReFUL model. We remind that the ultimate objective of this research proposal is to determine the possible age-distributions of the car fleet that can satisfy the national air emissions target in the future. However, the life-cycle of a car encompasses complementary activities that are also intensive in atmospheric emissions. Using the Life-Cycle (LC) concept, through what has become known as “life-cycle thinking”, is a unique way of addressing environmental problems from a systems or holistic perspective (Todd and Curran, 1999). The approach of the present research is inspired in the LC concept, whereby emissions are not solely measured for one phase of vehicles’ LC, but it also includes other stages such as the refining, transportation and distribution of fuel (“Well to wheel”) and vehicle production and scrapping (“Cradle to grave”). However, it is important to highlight that this work does not intend to perform a Life-Cycle Assessment (LCA) of a car, but instead to use existing research to include important variables in the conceptual model of CAReFUL. Kim *et* *al* (Kim et al., 2003, Kim et al., 2004) have produced valuable research that will be used to incorporate the LC dimension in the present research.

Therefore the main steps of the present task are:

- To define the boundaries of the life cycle of a car
- To identify the elements that constitute the life-cycle of a car, which are basically the important variables of: the refinement, transport and delivery of fuels; raw material extraction and delivery; car production industry; car use; and car scrappage. As referred here above, it is not intended to perform LCA, but instead to use results of previous research to perform this task (http://www.eiolca.net/; http://www.gdrc.org, http://www.dtsc.ca.gov; and many other sources of information).
- To determine how these elements related between each other. These relationships will be characterized on a basis of car-equivalent emission coefficients. Otherwise, except for the car use stage, other LC stages emissions can be modelled using existing LCA-software packages that can interoperate with the CAReFUL model, through VBA programming. Jönbrink *et al* (2000) performed a LCA software survey that compares all available products. This survey will certainly help to decide between one of the available packages, or instead perform an extra module in the CAReFUL model to cover this issue. Here, a first data collection and structuring will be performed in order to start building up the basis for the next task, which we recall is to model the car fleet renewal, and its respective emissions and energy consumption.
- Draw the causal-loop diagram of the inter-relationships of the car fleet dynamic system
- Set the conceptual basis to program the CAReFUL dynamic model.

The present task aimed at defining the elements for the optimization of the car fleet for atmospheric emissions reduction. Therefore, the expected results will cover the main life cycle stages that directly, or indirectly, induce atmospheric emissions. The main expected results are:

- a diagram that depicts the boundaries of the life cycle of a car;
- a list of the elements that constitute each stage of the car's life-cycle, both in the "Well to wheel" and "Cradle to grave" streams;
- a causal-loop diagram that represents the interrelationship between all elements and defines the conceptual model of the a car fleet dynamic system;
- a first data-base of information that covers all emissions factors of each element identified previously; or in alternative, the selection of a LCA software application.

The outcomes of this task will serve as inputs to Task 4 and Task 6, to set the basis for the CAReFUL model and collect information useful to perform the Case-Study on the Portuguese car fleet, respectively.

5.3. Model of CAR Fleet EvoLUtion (CAReFUL) (Task 3)

Systems dynamics research has produced many outcomes covering issues of the car industry. These are manifold, starting from modelling the dynamics of some components of a vehicle, like Chantranuwathana *et al* (2004) did to analyse marketing strategies attending to the potential consumers' needs and receptiveness to new technologies, among others (Gärling, 2001, Kim et al., 2003, Kim et al., 2004).

CAReFUL is a simulation model of the car fleet evolution for future scenario analysis. As referred previously, its main objective is to determine possible car fleet distributions, according to energy and environmental efficiency targets to achieve at the national level. This tool will support decision-making on the selection of transport policy instrument for technological renewal of the national car fleet.

CAReFUL model includes a model to estimate CAR FLEEt's dimension and structure (CARFLEE), a CAR Emission (CAREM) and CAR ENergy consumption (CAREN) estimators.

Hence, the present task will begin with the review of existing system dynamic research addressing issues related to the car industry and technology, and maybe other technological domains (e.g., telecommunications) from which lessons could be learned.

The next step will be to select, or adapt (if none perfectly fits with the car fleet evolution system), a model to prepare the CARFLEE module.

Meanwhile, the complementary modules of CAReFUL (CAREM and CAREN) will be developed by the research team. CAREM and CAREN will be based on existing methodologies, for example the EMEP/CORINAIR methodology provided by the Environmental European Agency, which is currently being reviewed. Inputs will also be considered from the EU research projects of COST 319 action (Methodologies for Estimating Air Pollutant Emissions from Transport-MEET). These modules will include the results of literature review to be made on emission and fuel consumption factors of new and future technologies.

Thereafter, CAREM, CAREN and CARFLEE will be assembled into the CAReFUL model. Programming language is yet to be decided upon, although MS EXCEL-based application (using VBA programming codes) appears to be an adequate tool for the task. This task is definitely the cornerstone of this project. Researchers of the team will carry out short term visits to 2 important European research centres of the TRANSPORTNET network.

Finally, the CAReFUL Model will be tested and validated.

The main expected results of this task are:

- Synthesis report of the main conclusions obtained from literature review on systems dynamics review.
- Selection of a model that will be used to model the dynamic system of the car fleet dimension and structure.
- Build the CARFLEE module.

- Review of existing methodologies that, on the one hand, upgrade existing emission and consumption factors of present technologies, and on the other, bring new information on future technologies, which result from incremental and remanufacturing technological improvements.
- Assemblage of the CAReFUL model in MS EXCEL-based application (using VBA programming codes), including the inputs (emissions and energy consumption) from the LCA of fuel refinement and delivery, vehicle production and vehicle scrappage industries.
- Data-base of all the information needed to run the CAReFUL model.

5.4. Transport policy instrument to promote car fleet renewal (Task 4)

Vehicle emissions result from a complex function involving a considerable amount of variables: amount of driving, the type of use (urban, rural and highway), vehicle ownership, technical characteristics of vehicles and fuels, among others. The objective of the present task is to analyse how economic and regulatory instruments can promote the technological renewal of a car fleet. Hence, this requires the analysis to include the instrument impacts on all potentially affected determinants of the model.

Policy options, and instrument packages for implementation, are very heterogeneous in nature, as they range from setting technical standards for vehicles and fuels (regulation) to traffic management approaches (transport supply) or market-based instruments (economic instruments). Many countries are now advocating integrated approaches to these problems, in which the full range of transport policy interventions surpass those presented here above, combining infrastructure, traffic management, regulation, information and pricing, with land use, environmental and wider social policy instruments. Despite the lack of detailed understanding of the impacts of many of these policy instruments and of their transferability to different contexts, much research on these issues has been performed lately in the EU research framework.

Attending to the present proposal objectives of technological renewal, this task will focus on the selection of the more effective instruments amidst all available options that can effectively promote technological renewal of car fleets.

Some research projects will be reviewed, in order to provide a set of instruments that will be selected and combined to achieve the required objective. The selection criteria are yet to be defined, but they will focus on integrating instruments to achieve synergistic results, which would not be achieved if instruments were to be implemented separately.

Moreover, each instrument must be characterized along the following issues:

- Which of the model variables does the instrument have an impact on?
- What is the nature, probability and magnitude of the instrument's impact?

On this issue, the work of Goodwin, P,. (1992), Michaelis, L. (1996) and Vieira (2005) are particularly important since they provide elasticity coefficient of price-related instruments and also analysis of the potential benefits on policy integration.

The projects are:

- PROSPECTS - Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems;
- KonSULT – Knowledgebase on Sustainable Landuse Transport, which includes 60 types of policy instrument including those related sectors which influence transports;
- SPECTRUM - Study of Policies regarding Economic instruments Complementing Transport Regulation and the Undertaking of physical Measures. SPECTRUM is seeking to tackle the specific issue of integration, which is particularly interesting for the present project

The main expected results of the present task are:

- Synthesis on the practice of policy instrument application in the transport, obtained through literature review;
- The definition of instrument packages to promote technological renewal of car fleet attending to atmospheric emission reduction targets;
- Field survey to assess the national receptiveness and acceptance to the set of instrument packages aiming to the technological car fleet renewal. In this case, among available instruments, pricing mechanisms are commonly used, but there effective implementation is not always successful.
- Synthesis report of the instrument packages as input to the Case-Study.

5.5. Case-Study: Determination of the Portuguese car fleet evolution as a contribution to the PNAC (Task 5)

According to the National Emissions Inventory Reports, the Portuguese situation is of severe decay, although technological renewal was noticeable for the last 15 years. In fact, after the EU integration of Portugal, a considerable boom occurred in private car purchasing, inducing a noticeable renewal of the national car fleet. This was due to the late economic development of the country, presenting low rates of motorization in the 80s. Although older vehicles were still in use, the large penetration of up-to-date technology, balanced this handicap. After the 90s, car fleet renewal diminished considerably and the average car age started getting older again.

By 2003, the greenhouse gas emissions already surpassed 15% the limit that is define in the EU burden sharing agreement. A similar burden occurred with acidifying substances and ozone precursors (although in this case, transports are less critical than other sectors of the economy). Therefore, the National Programme for Climate Change (PNAC) and the National Programme of Emission Ceilings (PTEN) were launched by 2001. Both programmes draw a negative diagnostic for Portugal in what regards its international commitments, if trend line emissions are to be followed. In face of these results, a set of measures is recommended and aim to curb the forecasted emission trends.

As referred in the objectives of this call, one of the prime goals for research (climate change scientific area) is to innovate on the instruments to implement measures to reduce atmospheric emissions. PNAC also recommends, as one important measure, to foster technological renewal of road fleets, in order to accelerate the gains in fuel and carbon efficiency. These goals also have an impact on the emissions of acidifying substances and ozone precursors.

Moreover, a major issue in assessing emissions by cars is the lack of statistical information on the precise size and structure of the past, present and future national car fleet.

Therefore, this task is divided into the following steps:

- Field survey to characterize the national car fleet size and structure as an input to the CARFLEE module;
- Collection of necessary data as inputs to the CAREM and CAREN modules;
- Data processing of the results obtained with the survey and preparation of data-base as input to the CAReFUL model;
- Running, testing and validating the CAReFUL model applied to the Portuguese case-study;
- Estimation of the trend line evolution of the Portuguese car fleet;
- Scenario analysis to determine possible car fleet distributions, according to average efficiency targets in the future;
- Determine the instrument packages that can induce the adjustment of the technological car fleet structure in order to reach an “optimized-age” distribution and reach environmental targets.

The main expected results are:

- Characterization of the past, present and future situation with regards to the main air pollutants resulting from car engine combustion (Nitrous Oxides, Particles, Carbon Monoxide, Sulphur, Methane, Volatile Organic Compounds, Carbon Dioxide, among others), according to the National Inventory reports, PNAC and PTEN available information, among others forecasted scenarios of emission evolution;
- Characterization of the past, present and future situation with regards to fuel consumption by cars, according to the PNAC and PTEN forecasted scenarios;
- Complete data set of information on the previous issues and on the size and structure of the currently used car fleet (results from the nation-wide survey);
- Estimation of future trend line evolution of the national car fleet, according to the PNAC and PTEN scenarios;

- Estimation of the future size and structure of the national fleet composition, as a result of the application of the CAReFUL model to the Portuguese situation. These estimates will be realized according to several scenarios of national atmospheric emission targets.
- Assess the impact of the economic and regulatory instrument packages defined in Task 5, on the dimension and structure of the national car fleet.
- Synthesis report on the Portuguese car fleet Case-Study.
- Preparation of a paper to be submitted to an International Journal.

5.6. Final Report: Conclusions and recommendations (Task 6)

- Synthesis section on external factors and car industry driving forces that condition the technological renewal of national car fleets;
- Description on methodological issues associated to the CAReFUL dynamic-model building-process;
- Synthesis on the instrument packages that best contribute to national car fleet renewal;
- Synthesis of the Case-Study on the Portuguese car fleet technological renewal.
- Final recommendations by clarifying which are the necessary improvements to be made on both technological penetration and abatement rates of the national car fleet, especially with respect to the abatement industry and old vehicles retirement incentive programs.

The expected results at this stage are the assemblage of the different stages of this research project that we recall here:

- To identify the external factors and car industry driving forces that influence the technological renewal of national car fleets;
- To understand the relations between these variables and how they influence each other;
- To assemble a dynamic model, which we named CAReFUL, that pretends to simulate the evolution process of a national car fleet, in terms of its composition (CARFLEE module), its emissions factors (CAREM) and its energy consumption (CAREN).
- To identify which are the economic and regulatory instruments packages that can best promote technological car renewal.
- To develop a Case-Study through which the application of CAReFUL will determine what is the optimized age-distribution of the Portuguese car fleet that can meet national air pollution emissions targets.

In addition, an assessment of the Portuguese older vehicles abatement industry will be performed in order to supply decision-makers with some measures that have to be implemented, to support the above referred targets of fleet renewal.

6. Budget

DESCRIÇÃO	2004	2005	2006	2007	2008	TOTAL
Human resources	0		6.250	6.250	0	**12.500**
Missions	0		8.500	4.000	0	**12.500**
Consultants	0		0	0	0	**0**
Acquisition of services and maintenance	0		6.000	5.000	0	**11.000**
Other current expenses	0		500	500	0	**1.000**
Overheads	0		5.000	5.000	0	**10.000**
Total current expenses	**0**	**0**	**26.250**	**20.750**	**0**	**47.000**
Equipment	**0**		**3.000**	**0**	**0**	**3.000**
TOTAL	**0**	**0**	**29.250**	**20.750**	**0**	**50.000**

7. References

ANDERSEN, B. (1999) The hunt for S-shaped growth paths in technological innovation; a patent study. *Evolutionary Economics,* 9**,** 487-526.

AUSUBEL, H., MARCHETTI, C. & MEYER, P. S. (1998) Toward green-mobility: The Evolution of Transport. *European Review,* 6**,** 137-156.

CHANTRANUWATHANA (2004) Adaptive robust force control for vehicle active suspensions. *Int. J. Adaptive Control and Signal Processing,* 18**,** 83-102.

COWI, A. S. (2002) Fiscal Measures to reduce CO2 emissions from new passenger cars. Brussels, European Commission.

DILL, J. (2004) Estimating emissions reductions from accelerated vehicle retirement programs. *Transportation Research Part D: Transport and Environment,* 9**,** 87-106.

EUROPEAN COMMISSION (1996) The European Auto Oil Programme. IN DG INDUSTRY ENERGY AND ENVIRONMENT CIVIL PROTECTION AND NUCLEAR SAFETY, E. C. (Ed.) *Brussels.* Brussels, Official Journal of the European Communities

GÄRLING, A. (2001) Marketing of electric vehicles. *Business Strategy and the Environment,* 10**,** 53-65.

GEERLINGS, H. & RIENSTRA, S. (2003) Exploring 'weak signals" as potential challenges in transport: an inventory of potential future technology developments. *Transportation Planning and Technology,* 26**,** 469 - 489.

GOODWIN, P. B. (1992) A Review of Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes. *Journal of Transport Economics and Policy,* 26**,** 155-169.

JÖNBRINK, A. K., WOLF-WATS, C., ERIXON, M., OLSSON, P. & WALLÉN, E. (2000) LCA Software Survey. Stockholm, IVL Svenska Miljöinstitute AB.

JORGENSEN, F. & WENTZEL-LARSON, T. (1990) Forecasting Car Holding, Scrappage and New Car Purchase in Norway. *Journal of Transport Economics and Policy,* 24**,** 139-156.

KIM, H. C., KEOLEIAN, G. A., GRANDE, D. E. & BEAN, J. C. (2003) Life Cycle Optimization of Automobile Replacement: Model and Application. *Environmental Science and Technology,* 37**,** 5407-5413.

KIM, H. C., ROSS, M. H. & KEOLEIAN, G. A. (2004) Optimal fleet conversion policy from a life cycle perspective. *Transportation Research Part D,* 9**,** 229-249.

MCCARTHY, J. J., CANZIANI, O. F., LEARY, N. A., DOKKEN, D. J. & WHITE, K. S. (2001) *Third Assessment Report / Climate Change 2001: Impacts, Adaptation & Vulnerability,* Cambridge, Cambridge University Press.

MICHAELIS, L. & DAVIDSON , O. (1996) GHG mitigation in the transport sector. *Energy Policy,* 24**,** 969-984.

NEDERVEEN, A. A. J., KONINGS, J. W. & STOOP, J. A. (2003) Globalization, International Transport, and The Global Environment: Technological Innovation, Policy Making and the Reduction of Transportation Emissions. *Transportation Planning and Technology*, 26**,** 41-67.

TODD, J. A. & CURRAN, M. A. (1999) Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup. Pensacola, Society of Environmental Toxicology and Chemistry (SETAC).

VIEGAS, J. M. (2003) Transport Policy development in Europe 1950-2020. IN ECMT (Ed.) *50 years of Transport Policy*. Paris, European Conference of Ministers of Transport.

VIEIRA, J. (2005) Aplicação de instrumentos com objectivos ambientais no sector dos transportes: da intervenção regulamentar à multi-instrumentalidade. *DeCivil-IST*. Lisbon, Instituto Superior Técnico.