TRACAV
TRANUS Calibration And Visualization

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Résumé

Cette ADT (action de développement logiciel) vise la consolidation de travaux scientifiques et de développements logiciels effectués depuis plusieurs années dans notre EPI, autour du modèle TRANUS. TRANUS permet la modélisation intégrée de l'usage des sols et du transport au sein d'un territoire ; il s'agit d'un outil d'aide à la décision dans le domaine de la planification urbaine. L'ADT porte sur des outils pour la calibration d'un tel modèle et pour la visualisation des résultats d'études prospectives effectuées sur sa base, au sein d'un SIG (système d'information géographique).

L'ADT facilitera nos futurs travaux dans ce domaine et surtout, servira de soutien à la diffusion et à la valorisation des travaux déjà effectués.

Note : La suite est rédigée en anglais, afin de pouvoir échanger sur le projet avec notre partenaire Américain, Brian Morton.

Context (Contexte : état des lieux et positionnement avant l'ADT)

General context: LUTI (land use and transportation integrated) models and software. This project concerns urban planning in the wider sense and more concretely, planning of transportation and land use (roughly speaking, where activities - industrial, agricultural, commercial, residential, educational, recreational etc. - are located within a given territory). Transportation models are routinely used by many urban planning agencies of larger cities or metropolitan areas. They consist of dedicated softwares, integrating or interfacing with relevant databases that contain data on the transportation infrastructure (network of roads, rail, bicycle lanes, parking spaces etc.), the transportation service and costs (public transportation lines, frequency of service, fees for transportation and parking, etc.), and various socio-economic data that pertain to transportation demand (for instance, polls on home-to-work, home-to-shopping, freight and other trips). An important usage of transportation models is to assess projects on changes concerning transportation (construction of new roads or tram lines, introduction of speed limits or urban tolls, etc.). Typically, such potential evolutions are fed into an actual mathematical transportation model, which simulates how current transportation demand might be satisfied by the evolved infrastructure, service etc. Indicators such as on congestion, average travel time and cost, CO2 and other emissions, may be generated and used by decision makers in their choice among alternative projects.

A drawback of classical transportation models is that they use *current* transportation demand in their simulations. Alas, practice shows that transportation *demand* is (significantly) altered by modifications in transportation *offer*. A typical phenomenon is that the construction of new roads, intended to resolve traffic jams, practically never improve the situation in the medium to long term and actually often worsen it: the existence of a new road, typically a high-speed road, may incite higher car usage and lead households and also businesses, to relocate to further-away places where land prices are lower. A usual result is that congestion is not resolved but more likely worsened, and that in addition, average trip lengths increase.

In order to make sensible planning decisions, it is thus crucial to take into account the impact of transportation offer, on transportation demand, and in particular, on land use. This is done by so-called LUTI models (land use and transportation *integrated* models), which model the mutual interplay between land use and transportation, based on economic theories of consumer choice, equilibrium between offer and demand etc. They are more complex than mere transportation models, both in terms of theoretical complexity and difficulty of instantiating a model on a new territory. The latter includes tasks such as data collection and processing, model design (e.g. granularity of population categories, of economic and housing types), and parameter estimation and usually requires between one and two years of work.

Whereas transportation models are used routinely by many planning agencies, the dominant business model for LUTI models is still, due their complexity, the usage for large-scale and long-term, but one-shot development studies, such as for the *Grand Paris*. These studies are typically sourced to specialized consultancy firms (often, startups of LUTI researchers) or university departments. Only few LUTI models are distributed as open source software; this is the case for TRANUS (**http://www.tranus.com**), the worldwide most widely used such model, developed at the University of Caracas (Venezuela) and its spinoff company Modelistica.

A brief note on terminology. A LUTI *model*, such as TRANUS, is a mathematical model, usually built on economic theories. A TRANUS *application* is an instantiation of the TRANUS model, on a territory (this involves the definition of spatial and socio-economic scales or categories, etc. and the estimation of typically hundreds of parameters of the model equations). Once the instantiation is completed, the application is used to make forecasts for one or several *scenarios* for the development of the transportation system and/or land use.

Previous and current works of STEEP on LUTI modeling. An important part of our research is dedicated to improving the ease of use of LUTI models. We have adopted TRANUS for our research, since it is the most widely used LUTI model and one of the rare ones coming as an open source software. Our works include “numerical” contributions, to parameter estimation (for conciseness called **calibration** in the following) and sensitivity analysis; the aim is to alleviate the urban modeler's work on LUTI model calibration and validation, to complement the current, highly interactive trial-and-error approaches, with systematic approaches and workflows, rendering automatic as much as possible, and as much as is acceptable by the urban modeler. This work is done by two PhD students (Thomas Capelle and Laurent Gilquin), funded by the ANR project CITiES which we coordinate, and is done in collaboration with Brian Morton from U North Carolina and the AIRSEA project-team. We also currently employ an intern who develops a GUI (graphical user interface) dedicated to the calibration process of TRANUS. The current status of these works is (softwares cited below are currently only used internally):

- **Automatic calibration methods:** a set of methods dedicated to estimating several sets of parameters of the TRANUS model have been developed (latest publications are http://hal.inria.fr/hal-01237639, http://hal.inria.fr/hal-01237628, http://hal.inria.fr/hal-01291774). They are implemented in python (about 2,000 lines of code will be exploited in the ADT). These methods are highly original for LUTI models; nearly all existing methods are *ad hoc* or only dedicated to a few parameters. This work entailed a partial rewriting of the TRANUS core, from Fortran into python. While the former is an appropriate language for such a model, it is today an obstacle to its wider distribution.
- **Calibration GUI:** it currently seems out of reach to completely automize the calibration process. Currently, users of TRANUS (and other LUTI models), tweak parameters one by one by hand until they are satisfied (how the instantiation fits observations and how “plausible” outputs are, for which no observations exist). We are currently implementing a GUI that will ease this trial-and-error approach, by proposing the user to explore parameters more systematically and to analyze the instantiation more systematically too. The GUI is developed by an intern; a first complete version will be achieved by June 2016.

A second work carried out in STEEP is the design and implementation, from scratch, of a complete TRANUS application for the Grenoble metropolitan area (covering the city of Grenoble and its catchment area, with a radius of approximately 50km). This includes various activities on data collection and processing, application of econometric methods for parameter estimation, parameter estimation using methods developed within STEEP and last but not least, a very close interaction with our end user and data provider, the AURG (*Agence d'Urbanisme de la Région Grenobloise*). This work is performed by a post-doc (Fausto Lo Feudo), also funded by the CITiES ANR project, is also done in collaboration with Brian Morton, and it also benefits from support by the SMTC (*Syndicat Mixte des Transports en Commun*) of Grenoble. The entire TRANUS application will be instantiated by June 2016. In the second half of 2016, urban development scenarios will be specified together with the AURG, and implemented by us. Their assessment will then be performed by the AURG and its stakeholders (transportation and territorial authorities of the Grenoble Region).

This work is fundamental for us and our future research in the area, since it results in a real-world and fully operational LUTI instantiation. It enables to carry out detailed analyses on calibration, validation, and sensitivity analysis and allows us to advance in our understanding of the place of numerical models in the decision support for territorial policy making. Finally, it will strengthen our exchanges and partnerships with territorial stakeholders (from urban planning “technicians”, through planning agencies, up to decision makers) and will give us a showcase to attract new collaborations.

Finally, we have been developing several software tools aimed at facilitating the urban modeler's use of TRANUS, including a bridge to a GIS (Geographic Information System), to ease the visualization of forecast results for urban development scenarios and to actually do so within a framework that has become a standard in urban planning agencies in the last years, in what concerns data handling and visualization. We chose QGIS (**http://www.qgis.org**) for this purpose, since it is probably the most complete open source GIS (we think that it is strategic to use open source software in the area of urban planning: while there are still many proprietary softwares in use, their cost is significant for planning agencies and political efforts towards open data cities and sometimes, open source software, are on the increase).

- A first complete QGIS plugin for this purpose, has been implemented (3,000 lines of python code) and deposited at the APP (**http://bil.inria.fr/fr/software/view/2382/tab**).

Altogether, these research and development activities correspond to about 10 person-years of effort so far, spread over the last 6 years. The ADT is extremely timely, due to the convergence of our research efforts on “numerical” contributions and on creating the Grenoble TRANUS application. No member of STEEP has applied for an ADT before.

Objectives (Objectifs de l'ADT)

- Consolidation of our automatic calibration methods
- Extension of a GUI (graphical user interface) for TRANUS calibration, allowing to document each calibration stage and explore different branches of calibration stages
- Visualization of TRANUS forecasts, within a GIS (geographical information system)
- Dissemination to the scientific community, of the above items

Positioning after ADT (Sortie de l'ADT, positionnement après l’ADT)

Our general roadmap.

The TRANUS application for Grenoble (see above) will be completed by Q2 2016. During Q3 and Q4 of 2016, the model will be used to implement and then assess long-term urban development scenarios elaborated with the AURG (*Agence d'Urbanisme de la Région Grenobloise*) and some of their stakeholders (transportation and territorial authorities of the Grenoble Region). During 2017, the application will be transferred to the AURG (transfer of its software embodiment and of documentation).

In order to be usable in the long run, the TRANUS application must be embedded within a GIS. A first step in this direction, is the visualization of TRANUS outputs in QGIS. This is already operational but some necessary extensions are being developed (see below). This development is absolutely necessary in order for the AURG to adopt the TRANUS application in real-life operation (it would be the first ever operational LUTI application in France, previous one having been used for one-shot studies only, as already mentioned).

A second issue is the dissemination of our works on calibration. The combination of automatic methods and a GUI for the general calibration workflow, might well turn our works into *de facto* standard tools for the calibration of TRANUS applications. In order to achieve the required dissemination and take-up by others, we chose to move from the historical choice of programming language of TRANUS (Fortran) to python (more modern, more adapted to collaborative development, graphical interfaces, more trained students, …). This is now also considered by the community as a whole and TRANUS' creator (Tomas de la Barra).

We are currently preparing two scientific projects that would greatly benefit from this ADT:

- QAMECS project, in preparation with EDDEN (lab on the economics of sustainable development and energy, http://edden.upmf-grenoble.fr/spip.php?article2&lang=fr), INSERM (Rémy Slama, studying the long-term impacts of local atmospheric pollution on health), and Air Rhône-Alpes (the Rhône-Alpes observatory of air quality, http://www.air-rhonealpes.fr). In a nutshell, the project will be based on a coupling of our Grenoble TRANUS application, with a pollution dispersion model developed and routinely used by Air Rhône-Alpes: TRANUS allows to output, among others, expected traffic patterns induced by planning decisions. EDDEN has the expertise to convert traffic data into emission maps (based on emission characteristics of different transportation modes, topography of terrain, etc.). Air Rhône-Alpes already uses such emission maps as input to an atmospheric dispersion model (depending on the urban topography and the dominant weather conditions), generating effective urban pollution maps. INSERM is running a study on the impact of different types of atmospheric pollution, on health. The long-term goal of our project is to contribute to incorporating health considerations into urban planning.
- We are discussing on a pilot study with one of the largest French environmental consultancy firms, BURGEAP (http://burgeap.fr). BURGEAP has developed a platform (équitée, http://www.equitee.fr) designed to accompany local and regional authorities in defining their strategies on territorial transitions. The heart of the équitée platform is a questionnaire-based system allowing the various stakeholders to discuss, shape, and formalize envisaged transitions (be it in terms of industrial or residential development, social policies, etc.), and to compute a battery of indicators allowing to inform a multi-criteria decision process. équitée and other such systems are lacking a LUTI component: evolution scenarios have typically to be defined by providing numbers in tables, an exercise that makes it difficult to have an integrated discussion among stakeholders, or by simply extrapolating population distribution, transportation patterns, job distribution etc. proportionally to the current observed situation. This is unrealistic due to non-linear feedback loops among these territorial characteristics (see also the discussion on insufficiency of pure transportation models, at the beginning of this document).
  The objectives of our collaboration with BURGEAP are threefold. First, to use their platform in defining scenarios for the Grenoble TRANUS application, in cooperation with AURG and their stakeholders. This will, on the one hand, make scenario definition and indicator specifications faster and, on the other, will increase synergy around the Grenoble TRANUS application, within the AURG and the local authorities, facilitating its transfer to AURG. Finally, BURGEAP may, in a second stage, represent a possibility for an industrial transfer of our works on TRANUS.

Positioning at the end of the ADT (Q4 2017).
In terms of software, the planned positioning is:

- The entire land use part of TRANUS is implemented in python.
- The Grenoble TRANUS application has been transferred to the AURG. It is operational (the first operational LUTI application in France), which means:
  - The AURG has the documentation required to define/modify urban development scenarios, to run them and to visualize (QGIS) and analyze the results.
  - AURG personnel has been trained in these tasks by STEEP.
- Our calibration methods are part of the official distribution of TRANUS.
- The calibration GUI is finalized and part of the official distribution of TRANUS.
- These contributions will put us in a unique position, relative to the scientific

community: a research group having achieved an operational LUTI application actually in use at a planning agency and having contributed sophisticated calibration methodology.

All software we develop (this includes the TRANUS application of Grenoble) will be deposited to the APP before any transfer/dissemination. The precise software license to be used for the dissemination (e.g. possibility of a dual license, research/commercial), will be discussed with STIP.

In terms of scientific projects:

- We apply the Grenoble TRANUS application in the QAMECS project on the linkage between urban planning/pollution/health (subject to obtaining the necessary funding: a submission to local funding schemes, e.g. AGIR, will be done this year).
- The pilot study with BURGEAP and AURG will be centered around the Grenoble TRANUS application. An initial proof-of-concept experiment will be carried out in Q3 2016, mainly by our post-doc Fausto Lo Feudo. If conclusive, a longer-term project will be established.

After the ADT.
Long-term maintenance of the software and of the support to the AURG will be assured by the permanent members of STEEP working on TRANUS (mainly Peter Sturm, also Emmanuel Prados). Further evolutions are expected to be contributed by the open source community and through future research projects and associated recruitments.

Provisional planning (Planification prévisionnelle)

Milestones: The ADT is structured into two work-packages, the first one concerning calibration methods and GUI for TRANUS, the second one concerning the coupling with QGIS. Each of these work-packages terminates with a task on documentation and dissemination (release as open source software) of the developments made. The ADT thus has two natural milestones:

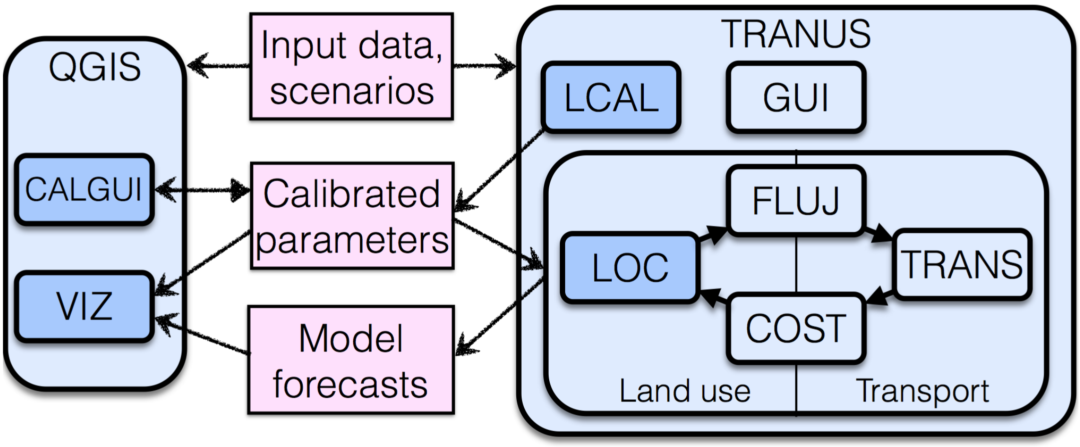
- Month 8: developments on calibration methods and GUI complete and disseminated
- Month 12: developments on coupling TRANUS – QGIS complete and disseminated

Description of softwares to be developed and their links.
The softwares concerned by the project and their interactions, are sketched in the following figure. The softwares that are to be developed or extended, are shown like this, others like this. The figure also shows different databases.

- To set up a TRANUS application on a study area, one requires a host of input data (socioeconomic data, transportation infrastructure, etc.) including the definition of forecast scenarios. These data are used by all the programs inside TRANUS.
- TRANUS consists of several programs. LCAL performs the calibration of some land use parameters; its output is a set of calibrated parameters, which form, together with the input data, the input for the following. Running the model through forecast scenarios then consists in iterating through four programs, until equilibrium: LOC performs all the calculations related to the location of activities and land use. TRANS assigns travel demand originating from the location process, to the network (including

modal choice and multi-modal trips). FLUJ and COST transform outputs of the previous two programs into inputs of the respective other program. After an equilibrium is attained, the data corresponding to the equilibrium (location of activities and land use, transportation flows, etc.), are output as model forecasts.

- TRANUS also has a GUI (graphical user interface) that allows to edit the transportation network, import data, specify some technical parameters and run the forecasts. The actual GUI developed in TRANUS does not provide any functionality and interface for the calibration stage.
- This project includes the development of two plugins for QGIS:
  - CALGUI: a GUI specifically designed to ease calibration tasks of TRANUS.
  - VIZ: visualization of the outputs of runs of the implemented model (forecast results) and meaningful composite indicators based on them.



The project is structured into two work-packages, each one with several tasks. Start and end-times of tasks: [x → y] means a duration from the beginning of month T0+x, to the end of month T0+y. Note that we do not include tasks on specification of the softwares to be developed; this will indeed be done before the start of the ADT, by the coordinator of the ADT. Further, note that the current development status of softwares considered below, is also described in section "Contexte : état des lieux et positionnement avant l'ADT".

Work-package 1: Calibration

Task 1.1: Training with the TRANUS system **[0 → 0.5]**
The engineer will learn how TRANUS is structured and how it functions.

Task 1.2: Translate LCAL and LOC from Fortran into python **[0.5 → 1.5]**
As explained above, it is important to translate these parts of TRANUS (about 1,500 lines of code) from Fortran into python. This has been partly done by a PhD student, but needs to be completed and turned into a professional code (systematic comments, optimization of numerical computations, inclusion of error messages, e.g. for the occasional case of non convergence, etc.). LCAL needs to be modified so that different calibration methods can be incorporated and used.

Task 1.3: Incorporate our calibration methods into LCAL **[1.5 → 4]**
The calibration methods developed in our team (in python), need to be turned into professional code (comments, optimization, etc.) and then incorporated into LCAL.

Task 1.4: Training with QGIS **[4 → 4.5]**

The engineer will get acquainted with QGIS, through one of the several tutorials made available by its user community.

Task 1.5: Consolidation of CALGUI, a GUI for TRANUS calibration **[4.5 → 7]**

As explained earlier, calibrating a TRANUS application is a complicated process; while parts of it can be automized (e.g. the subject of task 1.3), it is overall a lengthy interactive process, for which currently no standard tools other than manual trial-and-error, exist. We have started the development of a GUI (CALGUI) that will ease this process and make it more systematic. This task makes the developed GUI more complete and also integrates it within QGIS.

The basic functions of CALGUI will have been completed before the start of the ADT (an intern is currently working on it). The following describes what will have to be added. Calibration is done in several stages. The existing GUI will be enhanced by the possibility to store the obtained calibration after each stage and to allow the user to document what he has done in each stage. It will be made possible to go back to previous stages and generate forks from these, for alternative calibration trials. Overall, the GUI will enable the exploration of a tree of calibration trials and the export of a consolidated documentation for all stages of a chosen path in this tree. The implementation of these features requires the definition of file formats and a file structure. Further, this task will enable to add the GUI as a plugin to QGIS.

Task 1.6: Documentation, dissemination **[7 → 8]**

The softwares developed in the above tasks are documented (user manuals) and disseminated. The dissemination will be done through the Inria gforge and, as soon as possible, as part of the official TRANUS distribution. Potential users can test them easily, using the sample TRANUS applications provided along with its software distribution.

Work-package 2: Visualization

The objective of this work-package is to create plugins for QGIS (subsumed as VIZ in the above figure), allowing to import model forecasts made by TRANUS, to compute indicators based on them and to visualize forecast results and such indicators. The visualization exploits the rich features of QGIS: definition of layers, containing maps, networks, data, etc. and visualization of superimposed layers in various formats (colored maps, bars, etc.). Basic components have already been developed by interns: procedures to read TRANUS output files and import the contained data into QGIS, generation of series of maps showing these data, generation of 3D maps, etc. The following tasks concern new developments to be made.

Task 2.1: Configuration of indicators **[8 → 9]**

Our current implementation of VIZ only allows to visualize raw TRANUS outputs. However, the user needs to have the possibility to combine such outputs into indicators (for instance, indicators on the social mix in different zones of the study area, on the accessibility of transportation modes to different socio-economic classes, etc.). A QGIS plugin will be developed that allows to define such indicators and store their definition in a dedicated file format, allowing to disseminate them to other TRANUS users.

Task 2.2: Handling the full scenario tree of a TRANUS application **[9 → 10]**

Our current implementation of VIZ only allows to read and visualize TRANUS outputs for a single scenario. This needs to be extended in two main ways: systematic visualization of the outputs of all scenarios and visualization of differences between scenarios, in terms of raw outputs and/or indicators (see previous task).

Task 2.3: Configuration of reports **[10 → 11]**

The outputs produced by TRANUS and the number of indicators built on top of these, are too numerous to be examined each time new scenarios are explored or the calibration is improved. A typical user will wish to streamline his workflow. This task implements a feature allowing to configure a "report" to be generated by pressing a single button (a handpicked set of maps or other visualizations). The structure of such a report canvas will be stored using a dedicated file format, allowing TRANUS users to exchange them amongst them.

The basic functionality has already been implemented by an intern, but needs to be extended along the lines of task 2.2 and to include the visualizations of indicators (task 2.1).

Task 2.4: Documentation, dissemination **[11 → 12]**

Analogous to task 1.6.

Comments

Dependencies (Tx → Ty means that task x depends on task y):

- **WP1: 1.3 → 1.2 → 1.1 1.5 → (1.1 and 1.4) 1.6 → (1.1 to 1.5)**
- **WP2: 2.4 → 2.3 → 2.2 → 2.1**