

# Estimating public transport congestion in UK urban areas with open transport models

J. Raimbault<sup>1,2,3,\*</sup> and M. Batty<sup>1</sup>

\*[j.raimbault@ucl.ac.uk](mailto:j.raimbault@ucl.ac.uk)

<sup>1</sup>Center for Advanced Spatial Analysis, University College London

<sup>2</sup>UPS CNRS 3611 Complex Systems Institute Paris

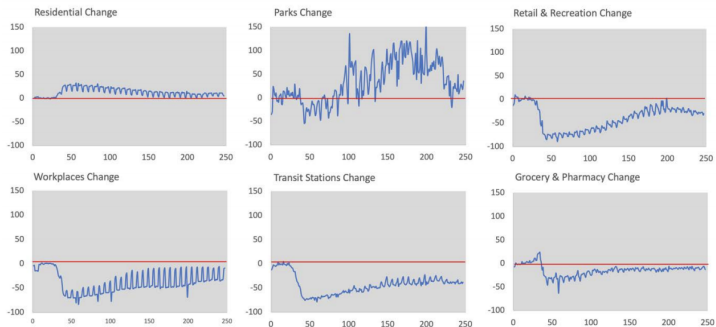
<sup>3</sup>UMR CNRS 8504 Géographie-cités

GISRUK 2021

Session Transport I: Analysis and Modelling

April 14th, 2021

- Public transport and COVID-19 transmission [Tirachini and Cats, 2020] [Gutiérrez et al., 2020]
- Changes in mobility patterns [Batty et al., 2020]

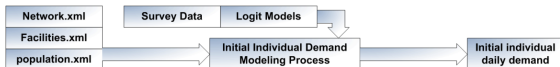


→ *Need for open and reproducible transport models to study public transport congestion and associated policies*

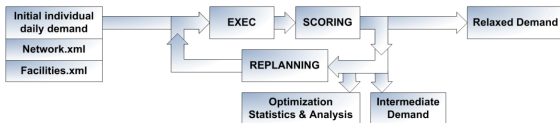
## MATSim model: heterogenous data and integration of many sub-models



(a) scenario creation: transport network / locations, capacities and opentimes for activities / synthetic population



(b) initial individual demand modeling: complete daily demand for each individual of the scenario



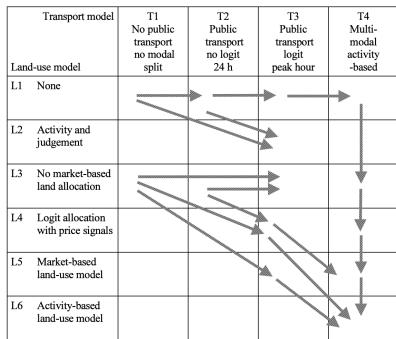
(c) demand optimization: systematic relaxation process to optimize user specified parts of the daily demand, i.e. route, departure time and activity duration choice



(d) statistical analysis: dynamic traffic volumes / work place occupation density / spider analysis / winner-looser statistics / dynamic traffic visualization / counts comparison / etc.

Source: [Balmer et al., 2009]

## *Land-use transport models as a progressive complexification through coupling of detailed sub-models*



Models	Speed of change							
	Very slow Networks	Land use	Slow Work-places	Housing	Fast Employment	Population	Immediate Goods transport	Travel
BOYCE	+				+	+		+
CUFM		+	+	+	+	+		
DELTA/START	+	+	+	+	+	+	+	+
HUDES				+	+	+		
IMREL	+	+	+	+	+	+		+
IRPUD	+	+	+	+	+	+		+
ITLUP	+	+			+	+		+
KIM	+				+	+	+	+
LILT	+	+	+	+	+	+		+
MEPLAN	+	+	+	+	+	+	+	+
METROSIM	+	+	+	+	+	+		+
MUSSA	+	+			+	+		+
POLIS		+			+	+		+
RURBAN		+			+	+		+
STASA	+	+	+	+	+	+	+	+
TRANUS	+	+	+	+	+	+	+	+
URBANSIM		+	+	+	+	+		+

Source: [Wegener and Fürst, 2004]

*Large scale urban models are intrinsically flawed and do not reach their goals of long-term application to planning: **Requiem for large scale models in 1973*** [Lee Jr, 1973]

*Urban analytics and Smart Cities approaches may follow the same path if they ignore the past and the complexity of cities* [Batty, 2014]

To foster relevance of large urban models:

- Transparency on data and implementation, reproducibility
- Validation of models and sub-models: from small simple models well validated to larger integrated models

→ Open, reproducible urban models can be shared, coupled into modular integrated models, tested and validated [Banos, 2013]

## Scientific workflow systems

[Yu and Buyya, 2005] [Barker and Van Hemert, 2007]

- Execution of numerical experiments and data processing in a systematic, reproducible and domain-specific way
- Often coupled to High Performance Computing infrastructures
- Flexibility with scripting languages and easier collaboration

## Proposed approach

*Build modular urban transportation models from the bottom-up using workflow systems, open source sub-models and open data*

- Sub-models coupled into the workflow, can be easily replaced
- Reproducibility and transparency
- Easier transferability of model application
- Application of model validation methods

**Case study:** *Construct a modular four-step multimodal transportation model using open source projects and data*

## Integrated models:

- MATSim model (MATSim Community) for the transportation system  
<https://www.matsim.org/> [Horni et al., 2016]
- SPENSER model (University of Leeds) for the synthetic population  
<https://github.com/nismod/microsimulation>
- QUANT model (CASA, University College London) for spatial interactions to generate home-work plans  
<http://quant.casa.ucl.ac.uk/> [Milton and Roumpani, 2019]
- spatialdata library (OpenMOLE community) for data processing  
<https://github.com/openmole/spatialdata>  
[Raimbault et al., 2020]

## Data:

Generic for any Functional Urban Area (GHSL [Florczyk et al., 2019]) or any arbitrary area in the UK: NOMIS census, OrdnanceSurvey roads, Traveline National Dataset for public transport

## Workflow systems:

- DAFNI facility funded by UKCRIC <https://dafni.ac.uk>
- OpenMOLE software <https://openmole.org/> [Reuillon et al., 2013]

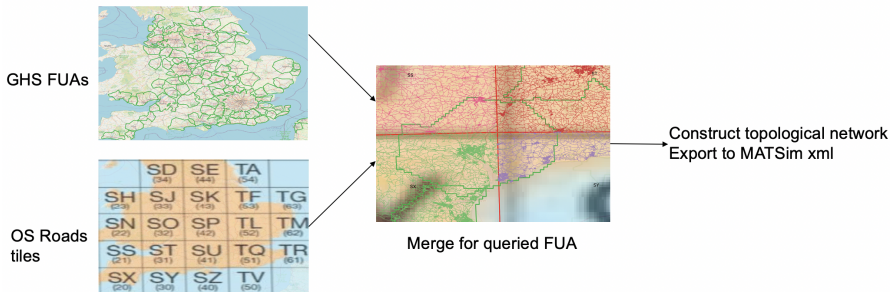
## Implementation

Currently integrated into the DAFNI platform:

- synthetic SPENSER population with uniform job locations
- QUANT model to generate home-work commuting flows
- network and plans prepared into MATSim xml files and fed into a one-mode MATSim (multimodal version still tested locally)
- models integrated as Docker containers



→ Road network preprocessing: implemented into the `spatialdata` scala library [Raimbault et al., 2020]



→ Public transport data: from TransXchange (TNDS) to GTFS using UK2GTFS R package [Morgan, 2021]; GTFS to MATSim xml schedule using `pt2matsim` library

*Platform developed for infrastructure research, providing dataset sharing, model upload, High-performance group computing, workflow system.*

<https://dafni.ac.uk>

The screenshot shows the DAFNI web application interface. At the top, there is a navigation bar with the DAFNI logo and a hamburger menu icon. Below the navigation bar is a sidebar menu with the following items: Home, Data, Models, Workflows, MANAGE ASSETS, Public, and Groups. The main content area is titled "Home" and "Welcome to DAFNI". It features four main action cards: "Data" (Find and add Data to help build products and services), "Model" (Find and publish Models to DAFNI), "Workflow" (Create a sequence of steps and visualise results), and "Manage Assets" (Choose who can see the data you upload). Below these cards is a "Release notes" section for version 1.14.0, dated January 19th 2021. The release notes include a "New" section with the following bullet points: "Group details (name and description) can now be edited by group administrators", "Added versioning functionality for Models", "Model Owners can now see an edit button on the Model details page that will allow them to upload a new Model Version", "When uploading a new Model Version for an existing Model you can provide a Model Definition, Model Image or both", "To support Model Versioning users are now required to add a version message when uploading a Model", and "Added version flags to Model Versions: these flags are available - latest (automatically)". To the right of the release notes is a "Follow us on Twitter" section showing a tweet from @DAFNIfacility retweeted by @SAGN and @STFC\_AGN. The tweet text reads: "How does #SocialResearch link to @STFC\_Motors? @DAFNIfacility very interested in linking data platforms from @citizen\_science with DAFNI and @codanews".

Home / Workflows / Workflow Status

## Workflow Status

Key

Iterator

Template

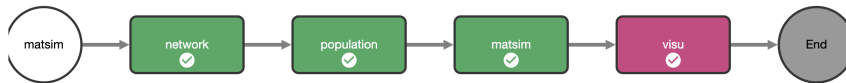
Model

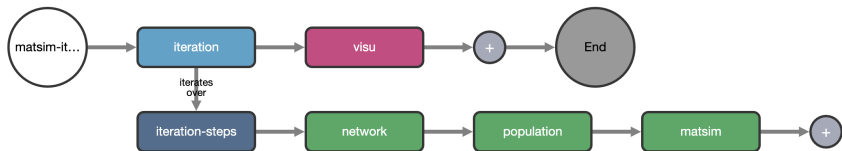
Publisher

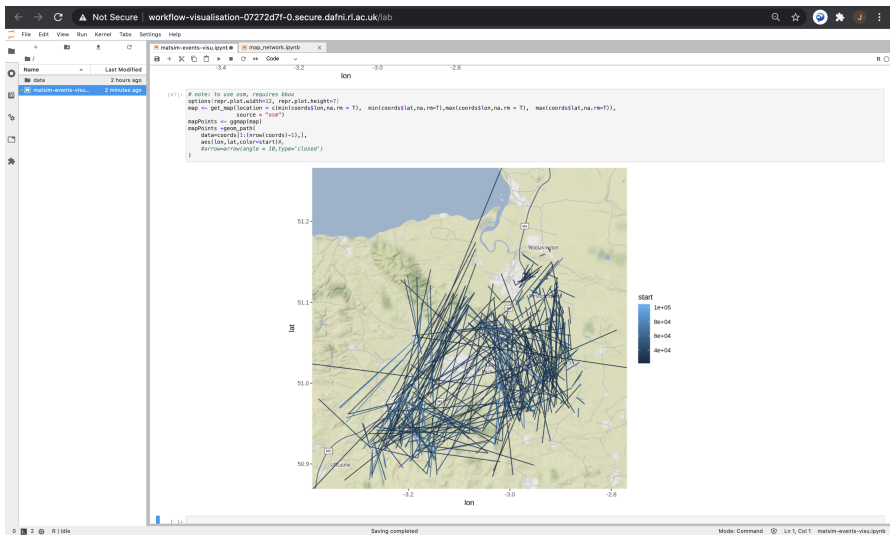
Visualisation

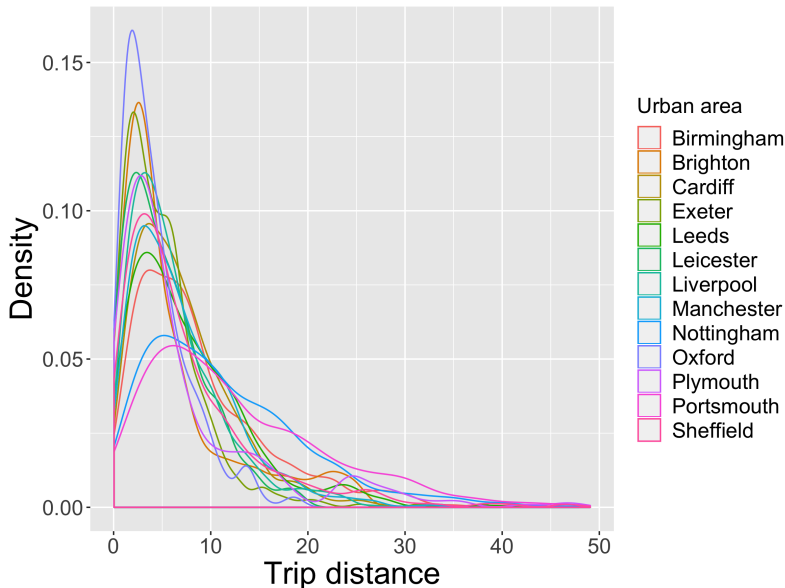
Reset position

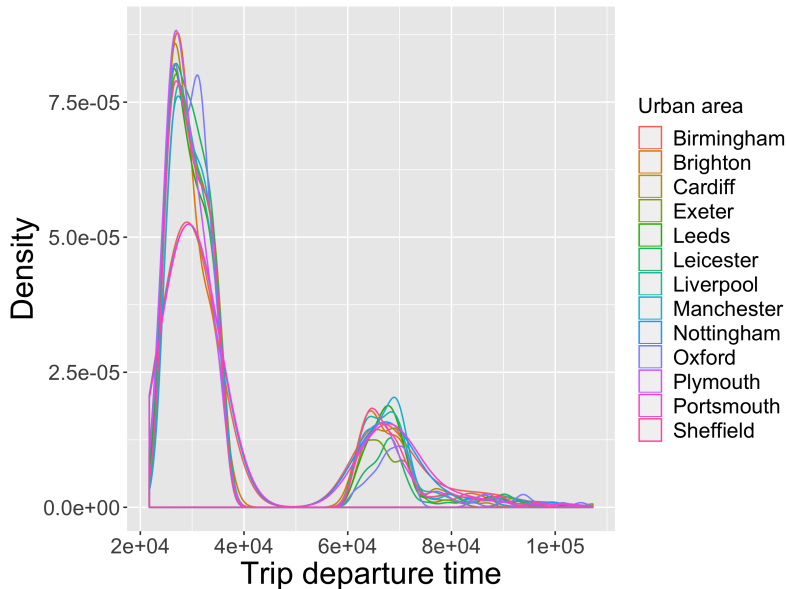
Click and drag on the white area around the Workflow to pan the canvas.



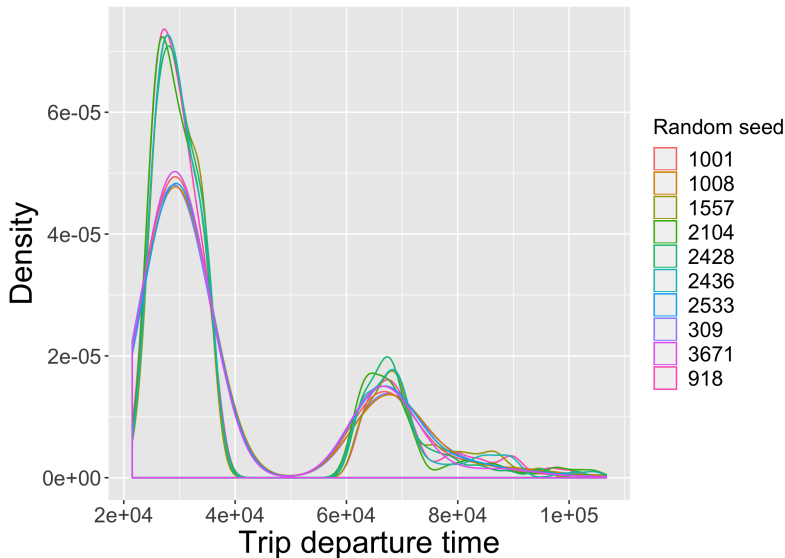




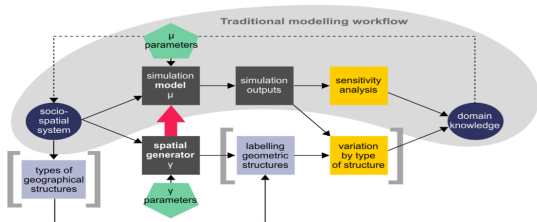




FUA: Taunton

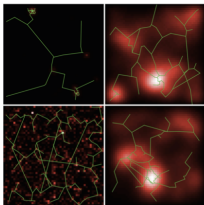




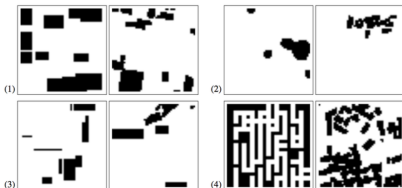


Raimbault, J., Cottineau, C., Le Texier, M., Le Nechet, F., Reuillon, R. (2019). Space Matters: Extending Sensitivity Analysis to Initial Spatial Conditions in Geosimulation Models. *Journal of Artificial Societies and Social Simulation*, 22(4).

Raimbault, J., Perret, J., & Reuillon, R. (2020). A scala library for spatial sensitivity analysis. *GISRUK 2020 Proceedings*, 32.



Raimbault, J. (2019). Second-order control of complex systems with correlated synthetic data. *Complex Adaptive Systems Modeling*, 7(1), 1-19.



Raimbault, J., Perret, J. (2019). Generating urban morphologies at large scales. In *Artificial Life Conference Proceedings* (pp. 179-186).

OpenMOLE model exploration open source software  
[Reuillon et al., 2013]



*Enables seamlessly (i) model embedding; (ii) access to HPC resources;  
(iii) exploration and optimization algorithms*

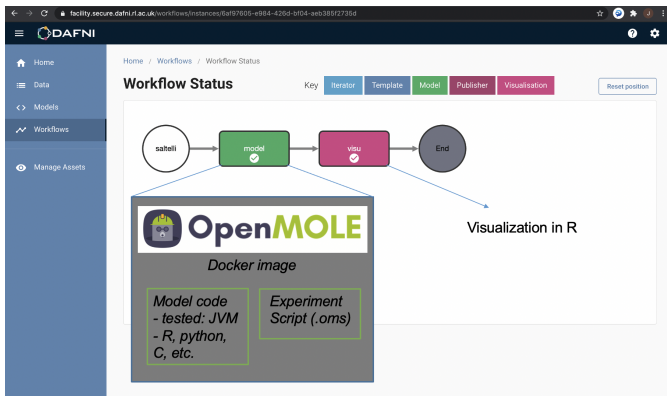
<https://openmole.org/>

# Coupling SPENSER and QUANT with OpenMOLE

```
55 //val indicators = Val[String] // FIXME this is dirty - would be better to have an array and collapse it - better hardcode it anyway?
56 val indicators = "cdfiff.alpha.delta"
57 val cdiff = Val[Array[Double]] // for each year
58 val alpha = Val[Array[Double]]
59 val delta = Val[Array[Double]]
60
61 val quantcommand = "sk -c \"cd /home/quant/QUANTAI/uxr/bis/dotnet run -- /home/pop.csv /home/ew.graphml /home/res.csv \"indicators\"\""
62
63 val quant = ContainerTask {
64   //image = "justerainbault/quant:1.0.4"
65   image = workDirectory / "images" / "justerainbault-quant-1.0.4.tgz",
66   command = quantcommand,
67   containerSystem = Singularity() // FIXME protot seems to have issues resolving symlinks
68 } set {
69   (inputs, outputs) += (region, years),
70   //inputs += (indicators),
71   inputFile += (moseyearlypop, "/home/pop.csv"),
72   inputFile += (mobatages, "/home/ew.graphml"),
73   outputFile += ("/home/res.csv", "quantresults"),
74   subchange += workDirectory / "data" / "testscenario.graphml",
75   //moseyearlypop := workDirectory / "test" / "S1200030.csv"
76 }
77
78 val postprocessquantresults = ScaleTask {
79   //val rswres = quantresults.container.split("\n").takeq.tail.map(_.split("\n").map(_._toDouble)).sortBy(r => r(0))
80   val cdiff = rswres.map(r => r(1)).toArray
81   val alpha = rswres.map(r => r(2)).toArray
82   val delta = rswres.map(r => r(3)).toArray
83   ***_stripMargin
84 } set {
85   (inputs, outputs) += (region, years),
86   inputs += (quantresults),
87   outputs += (cdfiff, alpha, delta)
88 }
89
90 val indica_hook = AppendToCSVFileTask(workDirectory / "exploration" / ((new SimpleDateFormat("yyyyMMd_HHmmss")).format(new Date())) + ".csv", arrayOnRow = true)
91
92 val exploreregions = DirectSampling {
93   evaluation = (spenser -- processpop -- quant -- (postprocessquantresults hook indica_hook)),
94   // @S12111, City of London, Manchester, Birmingham
95   //sampling = (region in Seq("S1200030", "D0900001", "D0800002", "D0800025"))
96   sampling = (region in Seq("S1200030"))
97 }
98
99 exploreregions
100
101
```

13.0-SNAPSHOT Shooting Star  
built the 06/12/2020 17:51:12

**OpenMOLE integrates methods for:** sensitivity analysis, spatial sensitivity analysis, design of experiments, calibration, diversity search, inverse problems, model reduction.



*Integration of OpenMOLE into DAFNI*

## Developments

- Integration of multi-modal MATSim, calibration of mode choice parameters
- Visualisation of MATSim agents dynamics (MATSim visu features not open)
- Dynamical strong coupling of QUANT and SPENSER to combine population projections with the transport model

## Applications

- Validation of sub-models and integrated models using advanced model validation methods
- Use MATSim outputs to quantify effective densities in public transport: potential exposure indicators in the COVID-19 context
- Impact of policies and interventions on transport system dynamics and potential contaminations

- *No clear link between urban density and COVID-19 transmission [Hamidi et al., 2020], but concern about public transport [Tirachini and Cats, 2020]*
- *MATSim-based full epidemiological model [Müller et al., 2020]: difficulty to validate and systematically explored*

→ Public transport density as proxy for potential transmission

→ To be computed downstream MATSim run using event xml files

→ Possible systematic exploration on all urban areas of home-work policies and modifications of agent schedules using genetic algorithms from OpenMOLE

→ Open, reproducible and validated urban models as elementary bricks towards larger integrated models

→ Open resource for teaching transport models

## Open repositories

<https://github.com/JusteRaimbault/UrbanDynamics/Models/Matsim> for containers and workflows

<https://github.com/openmole/spatialdata> for data processing



## Workflow engines

DAFNI: <https://dafni.ac.uk/>




OpenMOLE: <https://openmole.org>




## Acknowledgements

DAFNI platform/Champions program; Urban Dynamics Lab Grant EPSRC EP/M023583/1

-  Balmer, M., Rieser, M., Meister, K., Charypar, D., Lefebvre, N., and Nagel, K. (2009).  
Matsim-t: Architecture and simulation times.  
*In Multi-agent systems for traffic and transportation engineering*, pages 57–78. IGI Global.
-  Banos, A. (2013).  
*Pour des pratiques de modélisation et de simulation libérées en géographie et SHS*.  
PhD thesis, Université Paris 1 Panthéon Sorbonne.
-  Barker, A. and Van Hemert, J. (2007).  
Scientific workflow: a survey and research directions.  
*In International Conference on Parallel Processing and Applied Mathematics*, pages 746–753. Springer.



-  Batty, M. (2014).  
Can it happen again? planning support, lee's requiem and the rise of the smart cities movement.  
*Environment and Planning B: Planning and Design*, 41(3):388–391.
-  Batty, M., Murcio, R., Iacopini, I., Vanhoof, M., and Milton, R. (2020).  
London in lockdown: Mobility in the pandemic city.  
*arXiv preprint arXiv:2011.07165*.
-  Florczyk, A. J., Corbane, C., Ehrlich, D., Freire, S., Kemper, T., Maffenini, L., Melchiorri, M., Pesaresi, M., Politis, P., Schiavina, M., et al. (2019).  
Ghsl data package 2019.  
*Luxembourg, EUR*, 29788(10.2760):290498.

-  Gutiérrez, A., Miravet, D., and Domènech, A. (2020).  
Covid-19 and urban public transport services: emerging challenges and research agenda.  
*Cities & Health*, pages 1–4.
-  Hamidi, S., Sabouri, S., and Ewing, R. (2020).  
Does density aggravate the covid-19 pandemic? early findings and lessons for planners.  
*Journal of the American Planning Association*, 86(4):495–509.
-  Horni, A., Nagel, K., and Axhausen, K. W. (2016).  
*The multi-agent transport simulation MATSim*.  
Ubiquity Press.



Lee Jr, D. B. (1973).

Requiem for large-scale models.

*Journal of the American Institute of planners*, 39(3):163–178.



Milton, R. and Roumpani, F. (2019).

Accelerating urban modelling algorithms with artificial intelligence.





In *Proceedings of the 5th International Conference on Geographical Information Systems Theory, Applications and Management*, volume 1, pages 105–116. INSTICC.





Morgan, M. (2021).

*UK2GTFS: Converts UK transport timetable datasets to GTFS format.*

<https://github.com/itsleeds/uk2gtfs>, <https://itsleeds.git.io/uk2gtfs/>.

-  Müller, S. A., Balmer, M., Neumann, A., and Nagel, K. (2020). Mobility traces and spreading of covid-19. *medRxiv*.
-  Raimbault, J., Perret, J., and Reuillon, R. (2020). A scala library for spatial sensitivity analysis. *Proceedings of GISRUUK 2020*.
-  Reuillon, R., Leclaire, M., and Rey-Coyrehourcq, S. (2013). Openmole, a workflow engine specifically tailored for the distributed exploration of simulation models. *Future Generation Computer Systems*, 29(8):1981–1990.
-  Tirachini, A. and Cats, O. (2020). Covid-19 and public transportation: Current assessment, prospects, and research needs. *Journal of Public Transportation*, 22(1):1.

-  Wegener, M. and Fürst, F. (2004).  
Land-use transport interaction: State of the art.  
*Available at SSRN 1434678.*
-  Yu, J. and Buyya, R. (2005).  
A taxonomy of scientific workflow systems for grid computing.  
*ACM Sigmod Record*, 34(3):44–49.