

# Integration of the MATSim model into a four step transport model, using scientific workflow systems, DAFNI and OpenMOLE

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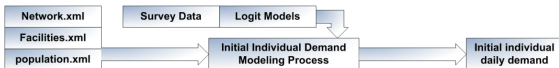
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DAFNI Roadshow - UCL  
November 22nd 2021

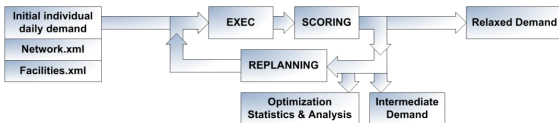
## MATSim model: heterogenous data and integration of many sub-models



(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



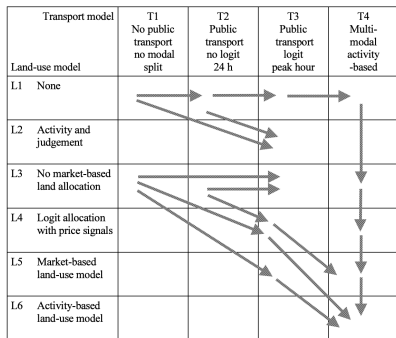
(c) demand optimization: systematic relaxation process to optimize user specified parts of the daily demand, i.e. route, departure time and activity duration choice



(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	Land use	Slow		Fast	Immediate		
	Networks		Work-places	Housing	Employment	Population	Goods transport	Travel
BOYCE	+				+	+		+
CUFM		+	+	+	+	+		
DELTA/START	+	+	+	+	+	+	+	+
HUDS				+	+	+		
IMREL	+	+	+	+	+	+		+
IRPUD	+	+	+	+	+	+		+
ITLUP	+	+			+	+		+
KIM	+				+	+	+	+
LILT	+	+	+	+	+	+		+
MEPLAN	+	+	+	+	+	+	+	+
METROSIM	+	+	+	+	+	+		+
MUSSA	+	+			+	+		+
POLIS		+			+	+		+
RURBAN		+			+	+		+
STASA	+	+	+	+	+	+	+	+
TRANUS	+	+	+	+	+	+	+	+
URBANSIM		+	+	+	+	+		+

Source: [Wegener and Fürst, 2004]

*Large scale urban/transport ABMs must be validated for relevant and robust policy applications*

A few example of MATSim validation or sensitivity analysis in the literature: uncertainty [Bienzeisler et al., 2021], sensitivity analysis [Zhuge et al., 2019], discrete choice parameters [Hörl, 2021]

## **Research objective:**

*Provide a modular and open implementation of MATSim generic to any UK urban area and test global sensitivity analysis methods on it*

## *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/> [Axhausen et al., 2016]
- SPENSER model (University of Leeds) for the synthetic population  
<https://github.com/nismod/microsimulation>  
[Spooner et al., 2021]
- QUANT model (CASA, University College London) for spatial interactions to generate home-work plans  
<http://quant.casa.ucl.ac.uk/> [Batty and Milton, 2021]
- 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

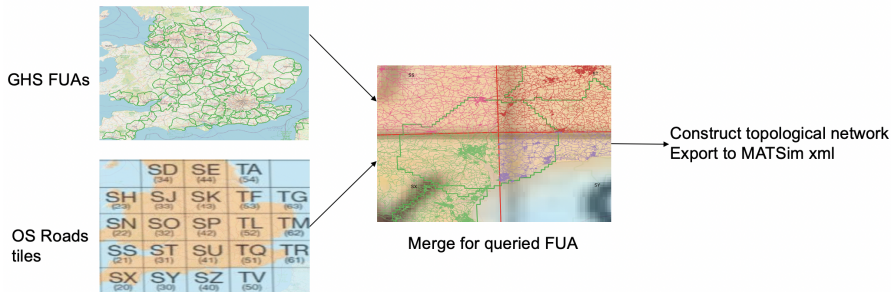
## **Workflow systems for the integration of submodels:**

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

## **Implementation**

- Synthetic SPENSER population distributed at the micro level using OSM buildings
- QUANT model to generate home-work commuting flows, job locations determined by sampling flows
- Network and plans (simple uniform commuting plans) prepared into MATSim xml files and fed into a multimodal MATSim model
- 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

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/>



*Parameter sampled for the sensitivity analysis:*

- Functional Urban Area (spatial context [Raimbault et al., 2019])
- Random seed (influence of stochasticity [Bienzeisler et al., 2021])
- Synthetic population sampling
- Modal choice parameters [Hörl, 2021]: mode constants in scoring function (car, public transport, walking)

Home / Workflows / Workflow Status

## Workflow Status

Key

Iterator

Template

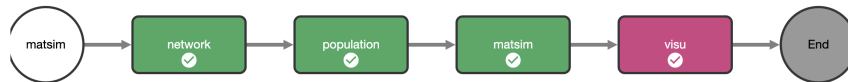
Model

Publisher

Visualisation

Reset position

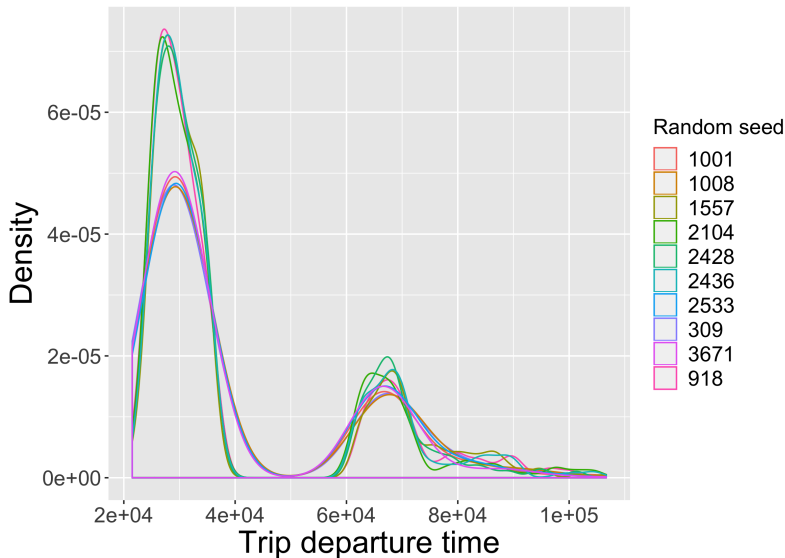
Click and drag on the white area around the Workflow to pan the canvas.



Schell,oms

```
1 val popSample = Val[Double]; val seed = Val[Double]; val fuaIn = Val[Double]; val utilityWalk = Val[Double]; val utilityCar = Val[Double]; val utilityT = Val[Double];
2 val fuaName = Val[String]; val fuaFile = Val[File]
3 val iterations = Val[Int]; val threads = Val[Int]
4 val dataDir = Val[File]; val netDir = Val[File]
5 val planFile = Val[File]; val networkFile = Val[File]; val transitScheduleFile = Val[File]; val transitVehiclesFile = Val[File]
6 val outputDir = Val[File]
7 val carShare = Val[Double]; val bikeShare = Val[Double]; val walkShare = Val[Double]; val avgFrigDistance = Val[Double]; val avgScore = Val[Double]
8
9 val setPUP = ScalaTask(
10 ---
11 val potPUP = fuaFile.content.split("\n").toList
12 val fuaName = potPUP.filter(_.startsWith("fua-")).toList
13 ---
14 )
15 set {
16 (inputs, outputs) => (popSample, seed, utilityWalk, utilityCar, utilityT),
17 inputs => (fuaIn, fuaFile),
18 outputs => (fuaName),
19 fuaFile => workDirectory / "fuaName.txt"
20 }
21
22 val popCommand = "ls /data/LAD/export SHF_OPTS@\"'-ResIG@\"'sbc \\project spatialData; fuaMain org.openmoles.spatialData.application.MainBusMain --synthPop --popMode=detailed --jobMode=sample --planMode=default --sample=${popSample} --fuaName=${fuaName}"
23 "--fuaFile=${dataDir}/fua_${seed}_${fuaName}_${iterations}_k_v1.g_MoJas.gpx --ladFile=${dataDir}/LAD/LAD_MSH4.shp --netFile=${dataDir}/OSM/OSM311_MSH4.shp --networkFile=${dataDir}/England/EnglandDefault/EnglandDefault_MSH4.shp --SPNSRDir=${dataDir}/SPNSR/England, /data/SPNSR/Scotland, /data/SPNSR/
24 "--OSMIDirectory=${dataDir}/OSM/OSM311, /data/OSM/OSM311_MSH4.shp --OSMFile=${dataDir}/OSM/OSM311_MSH4.shp --OSMFile=${dataDir}/OSM/OSM311_MSH4.shp --OSMFile=${dataDir}/OSM/OSM311_MSH4.shp"
25
26 val population = ContainerTask(
27 image = workDirectory / "images" / "main-population-1.0-3a32a7b0f.tar.gz",
28 command = popCommand,
29 workDirectory = "/root/spatialData/Library",
30 containerSystem = Singularity(),
31 execOnNetwork = false
32 )
33 set {
34 (inputs, outputs) => (fuaName, popSample, seed, utilityWalk, utilityCar, utilityT),
35 inputFiles => (dataDir, "/data"),
36 outputFiles => ("Files_${fuaName}.xml", planFile),
37 dataDir => workDirectory / "travata"
38 }
39
40 val readFiles = ScalaTask{
41 val networkFile = newDir / (fuaName + ".xml.gz")
42 val transitScheduleFile = newDir / (fuaName + "_transit_schedule.xml.gz")
43 val transitVehiclesFile = newDir / (fuaName + "_transit_vehicles.xml.gz")
44 ---
45 }
46 set {
47 (inputs, outputs) => (fuaName, popSample, seed, utilityWalk, utilityCar, utilityT, planFile),
48 inputs => (networkFile, transitScheduleFile, transitVehiclesFile),
49 outputs => (networkFile, transitScheduleFile, transitVehiclesFile),
50 }
51 newDir => workDirectory / "Network" / "runtime"
52 }
```

FUA: Taunton



*Method based on the estimation of conditional relative variances*  
[Saltelli et al., 2010]

## **First order index**

$$S_i = \frac{\text{Var} [E_{\mathbf{X}_{\sim i}} (Y|X_i)]}{\text{Var} [Y]}$$

is the expected relative variance reduction if  $X_i$  would be fixed

## **Total effect index**

$$ST_i = \frac{E_{\mathbf{X}_{\sim i}} [\text{Var} (Y|\mathbf{X}_{\sim i})]}{\text{Var} [Y]}$$

is the expected relative variance if all factors but  $X_i$  are fixed (includes interaction effects)

output	$\beta_W$	$\beta_{PT}$	$\beta_C$	S	FUA	$p$
carShare	0.023	0.0058	0.0079	3.94	0.165	0.379
ptShare	0.0081	0.0074	0.0030	2.164	0.04	0.0169
walkShare	0.0059	0.0017	0.0074	0.834	0.16	0.082
avgTripDistance	0.11	0.19	0.087	0.04	1.51	0.049
avgScore	0.43	0.0003	0.0039	0.057	0.0085	0.0073

*Total order Saltelli indices obtained with  $\simeq 50$  model runs*

## **MATSim sensitivity analysis**

→ Preliminary results, but suggest a strong influence of stochasticity, context and parameters

## **Large scale open, reproducible and validated models?**

→ Still a long way to go: a lot of tuning even with containers; issue of infrastructure (memory vs CPUs)

## **Role of visualisation**

→ Some models are intrinsically interactive/visual (cf QUANT): compatible with workflow systems / integration? (change in model function)

## **Future developments**

→ dynamical strong coupling of models (SPENSER/QUANT); applications to policies

- Open, reproducible and validated urban models as elementary bricks towards larger integrated models
- Workflow systems provide model construction and exploration/validation
- A preliminary global sensitivity analysis of multimodal MATSim for a generic implementation on UK FUAs

## Open repositories




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




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




## Acknowledgements




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