The objective of this article is to build a cartographic representation of drive time for freight transport companies from the 13th most important cities in Mozambique.

This model is based on an open source dataset of transport networks (OpenStreetMap, 2016) in Mozambique and the bordering countries. It is simulating, at a fine-grained level, the behaviours of truck drivers by taking in account both, barriers (one-way roads, pedestrian or cycling paths, tracks for agricultural purpose...), and common situations for drivers (border crossing time, turns and U-turns, junctions, local road crossing a regional road...). The model define six classes of roads (from local roads to highways) for more than one million kilometres of roads, with specific average traffic speed empirically deduced from a sample of transit times of a Mozambican freight transport company. This complex network of more than 1 million of road sections is analysed with ArcGIS, in order to build drive time areas (2, 4 and 6 hours), from the city centres of the major urban areas (more than 100000 inhabitants, GeoNames, 2016). The map illustrates the interconnections of these urban areas and the problems of accessibility of their hinterlands in term of land transportation.
! This article is only a short abstract of the original one, in french !


## 1 / Building the roads network

Open Street Map ( www.openstreetmap.org ):

- Botswana (BW) : 78502 roads sections
- Congo Democratic Republic (CD) : 197038 roads sections
- Lesotho (LS) : 79763 roads sections
- Malawi (MW) : 85159 roads sections
- Mozambique : 157368 roads sections
- South-africa (ZA) : 502417 roads sections
- Swaziland (SZ) : 22274 roads sections
- Tanzania (TZ) : 166555 roads sections
- Zambia (ZM) : 53923 roads sections
- Zimbabwe (ZW) : 82 394roads sections

Geofabrik ( http://download.geofabrik.de/africa.html )

## 2 / Building the model



Fig 1 : Modèles dans la géographie des transports

Geography of transport systems, Jean-Paul Rodrigue et al., 3rd édition, 2013 :
Each [level is built] upon the other, implying for instance that the estimation of accessibility cannot be assessed without information about distance and that spatial interactions are derived from accessibility assessments:

- Distance. The most fundamental element of geography in general and transport geography in particular. Distance can be represented in different manners, from a simple Euclidean distance calculation to a complex estimation of a logistical distance that considers all the tasks necessary for the realization of a movement.
- Accessibility. Defined as the measure of the capacity of a location to be reached by, or to reach different locations. Therefore, the capacity and the arrangement of transport infrastructure are key elements in the determination of
accessibility. It is thus based upon the concept of location and distance.
- Spatial Interaction. A realized movement of people, freight or information between an origin and a destination. It is a transport demand / supply relationship expressed over a geographical space.

Routing is a specific category of spatial interaction that considers a given set of origins and destination for which specific (often optimal) routes are found.

- Transportation / Land Use Models. A complex framework trying to assess the numerous relations and feedback effects between transportation and the spatial structure.


## 2.1 / Classes of roads networks

| roadstype | fclass | Distance cumulée en km | \% km | Nombre de routes |
| :---: | :---: | :---: | :---: | :---: |
| highway | trunk | 32 305,86 | 2,45 | 6477 |
| highway | primary | 17 124,76 | 1,30 | 2517 |
| highway | secondary | 7217,16 | 0,55 | 934 |
| highway | motorway | 3887,58 | 0,30 | 3000 |
| highway | motorway_link | 1203,88 | 0,09 | 3336 |
| highway | tertiary | 769,96 | 0,06 | 150 |
| highway | unclassified | 199,70 | 0,02 | 40 |
| highway | track | 39,72 | 0,00 | 14 |
| highway | trunk_link | 20,56 | 0,00 | 30 |
| highway | residential | 16,23 | 0,00 | 19 |
| highway | service | 4,91 | 0,00 | 6 |
| highway | track_grade1 | 1,43 | 0,00 | 1 |
| highway | primary_link | 0,46 | 0,00 | 3 |
| highway | living_street | 0,32 | 0,00 | 1 |
| highway | secondary_link | 0,02 | 0,00 | 1 |
| secondary | secondary | 95073,57 | 7,22 | 20798 |
| secondary | primary | 52 886,68 | 4,02 | 12991 |
| secondary | trunk | 3714,15 | 0,28 | 1055 |
| secondary | trunk_link | 307,48 | 0,02 | 894 |
| secondary | primary_link | 283,64 | 0,02 | 1830 |
| secondary | secondary_link | 135,37 | 0,01 | 1200 |
| local | unclassified | 342 480,48 | 26,01 | 265663 |
| local | residential | 197498,16 | 15,00 | 552025 |
| local | tertiary | 181 968,45 | 13,82 | 37945 |
| local | track | 144228,49 | 10,95 | 174820 |
| local | unknown | 90536,28 | 6,88 | 35793 |
| local | track_grade3 | 33035,40 | 2,51 | 11180 |
| local | service | 19 485,83 | 1,48 | 73435 |
| local | track_grade2 | 6001,39 | 0,46 | 2848 |
| local | track_grade1 | 2 119,68 | 0,16 | 1260 |
| local | tertiary_link | 1064,00 | 0,08 | 1068 |
| local | living_street | 731,32 | 0,06 | 2967 |
| non_for_car | path | 62 937,51 | 4,78 | 170539 |
| non_for_car | track_grade4 | 7424,98 | 0,56 | 3047 |
| non_for_car | footway | 5 986,88 | 0,45 | 28987 |
| non_for_car | track_grade5 | 5071,52 | 0,39 | 4932 |
| non_for_car | cycleway | 726,13 | 0,06 | 721 |
| non_for_car | pedestrian | 257,07 | 0,02 | 1224 |
| non_for_car | bridleway | 102,53 | 0,01 | 202 |
| non_for_car | steps | 32,94 | 0,00 | 1439 |
|  |  | 1316882,51 |  | 1425392 |

Tab 1 ; roads type
2.2 Defining roads speed

| roadstype | moyspeed | Total de la distance en km | $\% \mathrm{~km}$ | Nombre de routes |
| :--- | ---: | ---: | ---: | ---: |
| highway | 80 | 7491,09 | 0,61 | 2018 |
| highway | 70 | 49934,79 | 4,05 | 12092 |
| highway | 60 | 4368,47 | 0,35 | 1266 |
| highway | 50 | 19,64 | 0,00 | 29 |
| highway | 40 | 542,70 | 0,04 | 772 |
| highway | 30 | 263,66 | 0,02 | 303 |
| highway | 20 | 164,82 | 0,01 | 45 |
| highway | 10 | 7,38 | 0,00 | 4 |
| secondary | 50 | 105,34 | 0,01 | 25 |
| secondary | 45 | 32,57 | 0,00 | 35 |
| secondary | 40 | 57946,89 | 4,69 | 16299 |
| secondary | 30 | 92981,95 | 7,53 | 22224 |
| secondary | 20 | 1333,24 | 0,11 | 177 |
| secondary | 10 | 0,91 | 0,00 | 8 |
| local | 50 | 2,21 | 0,00 | 1 |
| local | 45 | 14,60 | 0,00 | 30 |
| local | 40 | 2782,20 | 0,23 | 313 |
| local | 30 | 7279,20 | 0,59 | 19358 |
| local | 26 | 2,77 | 0,00 | 28 |
| local | 25 | 0,85 | 0,00 | 19 |
| local | 20 | 184287,42 | 14,93 | 41179 |
| local | 15 | 1,11 | 0,00 | 19 |
| local | 10 | 792607,31 | 64,21 | 1087056 |
| local | 5 | 123171,82 | 2,61 | 11019 |
|  |  | 342,94 |  |  |

Tab 2 : type of roads and speed

## 2.3 / Turns, jounctions and one way

| Direction | Description | Secondes |
| :---: | :---: | :---: |
| Orientée | De la voie Local à Local Ne traverser aucune voie | 2 |
| Orientée | De la voie Local à Local Traverser la voie Local | 8 |
| Orientée | De la voie Local à Local Traverser la voie Secondaire ou principal | 20 |
| Orientée | De la voie Local à Secondaire | 12 |
| Orientée | De la voie Secondaire à Local | 12 |
| Orientée | De la voie Secondaire à Secondaire Ne traverser aucune voie | 2 |
| Orientée | De la voie Secondaire à Secondaire Traverser la voie Local | 6 |
| Orientée | De la voie Secondaire à Secondaire Traverser la voie Secondaire ou principal | 60 |
| Inversé | De la voie Local à Local | 12 |
| Inversé | De la voie Local à Secondaire | 60 |
| Inversé | De la voie Secondaire à Local | 20 |
| Inversé | De la voie Secondaire à Secondaire | 20 |
| Tournant à droite | De la voie Local à Local | 8 |
| Tournant à droite | De la voie Local à Secondaire | 12 |
| Tournant à droite | De la voie Secondaire à Local | 8 |
| Tournant à droite | De la voie Secondaire à Secondaire | 12 |
| Tournant à gauche | De la voie Local à Local | 8 |
| Tournant à gauche | De la voie Local à Secondaire | 40 |
| Tournant à gauche | De la voie Secondaire à Local | 20 |
| Tournant à gauche Fin $21 \cdot$ tirnc | De la voie Secondaire à Secondaire naltioc ( $\Delta$ rnficl | 32 |


| Direction | Largeur (degrés) |
| :--- | ---: |
| OOrientée | 60 |
| O Inversé | 60 |
| $\diamond$ Tournant à droite | 120 |
| $\bigcirc$ Tournant à gauche | 120 |
|  |  |

Fia 0 の • tirne and annlac

| roadstype | oneway | Nombre de routes |
| :--- | :--- | ---: |
| highway | B | 8124 |
| highway | F | 8403 |
| highway | T | 2 |
| secondary | B | 25104 |
| secondary | F | 13605 |
| secondary | T | 59 |
| local | B | 1138941 |
| local | F | 19632 |
| local | T | 431 |
| Fig 3.1 : one way |  |  |



Fig 3. : example in Maputo ( $B$ in gris, $F$ in'red and $T$ in blue)
$3 /$ Core cities


22061451 inhabitants, GeoNames, 2016

| country | asciiname | population | geonameid | rank |
| :---: | :---: | :---: | :---: | :---: |
| MZ | Maputo | 1191613 | 1040652 | 1 |
| MZ | Matola | 675422 | 1039854 | 2 |
| MZ | Beira | 530604 | 1052373 | 3 |
| MZ | Nampula | 388526 | 1033356 | 4 |
| MZ | Chimoio | 256936 | 1049261 | 5 |
| MZ | Nacala | 224795 | 1035025 | 6 |
| MZ | Quelimane | 188964 | 1028434 | 7 |
| MZ | Tete | 129316 | 1026014 | 8 |
| MZ | Xai-Xai | 127366 | 1024552 | 9 |
| MZ | Maxixe | 119868 | 1039536 | 10 |
| MZ | Ressano Garcia | 110000 | 1028079 | 11 |
| MZ | Lichinga | 109839 | 1043893 | 12 |
| MZ | Pemba | 108737 | 1028918 | 13 |
| MZ | Dondo | 78648 | 1024696 | 14 |
| MZ | Antonio Enes | 74624 | 1052944 | 15 |
| MZ | Inhambane | 73884 | 1045114 | 16 |
| MZ | Cuamba | 73268 | 1047660 | 17 |
| MZ | Montepuez | 72279 | 1037125 | 18 |
| MZ | Chokwe | 63695 | 1048364 | 19 |
| MZ | Chibuto | 59165 | 1049861 | 20 |
| MZ | llha de Mocambique | 54315 | 1037390 | 21 |
| MZ | Mutuali | 30523 | 1088155 | 22 |
| MZ | Mocimboa | 27909 | 1037370 | 23 |
| MZ | Manjacaze | 25541 | 1040938 | 24 |
| MZ | Macia | 23156 | 1024701 | 25 |



Fig 4 - Example bewteen Maputo and Beira-Chimoio (illustration)
4 Validation and main results
see final map (annex 4) or the pdf file.

## 5 / Discussion

Annex 1 / Geofabrik OSM Standard, OpenStreetMap Data in Layered GIS Format (Version 0.6.7)

All kinds of roads from motorways to gravel tracks as well as cycleways, footpaths, etc.
Additional attributes:

| Attribute | PostGIS Type | Description | OSM Tags |
| :---: | :---: | :---: | :---: |
| ref | VARCHAR(20) | Reference number of this road ('A 5', 'L 605', ...) | ref=* |
| oneway | BOOLEAN | Is this a oneway road? | oneway $=*$ |
| maxspeed | SMALLINT | Max allowed speed in $\mathrm{km} / \mathrm{h}$ | maxspeed=* |
| layer | SMALLINT | Relative layering of roads ( $-5, \ldots, 0, \ldots, 5$ ) | layer=* |
| bridge | BOOLEAN | Is this road on a bridge? | bridge=* |
| tunnel | BOOLEAN | Is this road in a tunnel? | tunnel=* |

Roads of type 5111 (motorway) and 5112 (trunk) are always oneway.

The following feature classes exist in this layer:

| code | layer | fclass | Description | OSM Tags |
| :---: | :---: | :---: | :---: | :---: |
| 511x | roads |  | Major roads |  |
| 5111 | roads | motorway | Motorway/freeway | highway=motorway |
| 5112 | roads | trunk | Important roads, typically divided | highway=trunk |
| 5113 | roads | primary | Primary roads, typically national. | highway=primary |
| 5114 | roads | secondary | Secondary roads, typically regional. | highway=secondary |
| 5115 | roads | tertiary | Tertiary roads, typically local. | highway=tertiary |
| 512x | roads |  | Minor Roads |  |
| 5121 | roads | unclassified | Smaller local roads | highway=unclassified |
| 5122 | roads | residential | Roads in residential areas | highway=residential |
| 5123 | roads | living_street | Streets where pedestrians have priority over cars | highway=living_street |
| 5124 | roads | pedestrian | Pedestrian only streets | highway=pedestrian |
| 513x | roads |  | Highway links (sliproads/ramps) |  |
| 5131 | roads | motorway_link | Roads that connect from one road to another | highway=motorway_link |
| 5132 | roads | trunk_link | of the same of lower category. | highway=trunk_link |
| 5133 | roads | primary_link |  | highway=primary_link |
| 5134 | roads | secondary_link |  | highway=secondary_link |
| 514x | roads |  | Very small roads |  |
| 5141 | roads | service | Service roads for access to buildings, parking lots, etc. | highway=service |
| 5142 | roads | track | For agricultural use, in forests, etc. Often gravel roads. | highway=track without tracktype specification |
| 5143 | roads | track_grade1 | Tracks can be assigned a "tracktype" from 1 (asphalt or heavily compacted) to 5 (hardly visible). A detailed description is here: http://wiki.openstreetmap.org/wiki/Tracktyp e | ... with tracktype=grade1 |
| 5144 | roads | track_grade2 |  | ... with tracktype=grade2 |
| 5145 | roads | track_grade3 |  | ... with tracktype=grade3 |
| 5146 | roads | track_grade4 |  | ... with tracktype=grade 4 |
| 5147 | roads | track_grade5 |  | ... with tracktype=grade5 |
| 515x | roads |  | Paths unsuitable for cars |  |
| 5151 | roads | bridleway | Paths for horse riding | highway=bridleway or highway=path with horse=designated |
| 5152 | roads | cycleway | Paths for cycling | highway=cycleway or highway=path with cycle $=$ designated |
| 5153 | roads | footway | Footpaths | highway=footway or highway=path with foot=designated |
| 5154 | roads | path | Unspecified paths | highway=path without cycle/foot/horse=designate d |
| 5155 | roads | steps | Flights of steps on footpaths | highway=steps |
|  |  |  | Unknown |  |
| 5199 | roads | unknown | Unknown type of road or path | highway=road |

Note: For large excerpts where the roads data becomes too large to fit all roads in one shape file, we will split the roads layer in six: "major" (codes 5110-5119), "minor" (codes 5120-5129), "link" (codes 5130-5139), "small" (codes 5140-5149), "paths" (codes 5150-5159) and "other" (all others).

## Annex 2 / Map of roads for « highway » and « secondary » classes



Annex 4 / Map of roads for « local » classe


## Annex 4 / Download the final map (v15)



Annex 5 / Resources and scripts used with ArcGis 10.2 (Network Analysis)
123456789 ' pre logic VBScript roadstype (text): building roadds types

123456789 'pre logic VBScript roadstlass (entier court): building roads classes


123456789 \# Ditance for each road séctebrainklmi) (djsthねm) =

