# Design Considerations for SimTRAVEL: A Report of the Discussions at Project Team Meeting on August 15, 2011

The SimTRAVEL project team finished initial runs of the integrated model with dynamic generation of activity-travel patterns. During the process, the project team has identified issues that needed attention before additional model runs are conducted for base scenario and other policy-related scenarios. Following sections describe the various issues/challenges identified through the initial model runs and solutions to address these issues/challenges.

## 1. Operational Overview

Figure 1 shows an operational overview of the integration between OpenAMOS (**Open** source **A**ctivity **Mo**bility **S**imulator) that simulates the activity-travel decisions made by individuals and MALTA (**M**ulti-Resolution **A**ssignment and **L**oading of **T**raffic **A**ctivities) that identifies routes, loads trips on the network and simulates vehicular movement on the network. For every scenario, the integrated model needs to be run multiple times in order to obtain consistency in the inputs and outputs that are generated. The network conditions serve as inputs to OpenAMOS that generates the demand. Also, network conditions are generated as output after routing and simulating trips in MALTA. Therefore, one needs to run the integrated models multiple times until convergence in the network conditions is achieved.

At the start of the simulation for any scenario, peak and off-peak hour link travel times from four-step models are used. In subsequent iterations, link travel times by time of day that are obtained from MALTA are used for simulating the activity-travel choices of individuals. For any iteration *k*, the integrated model proceeds with a minute-by-minute handshaking between OpenAMOS and MALTA. At the end of every minute MALTA provides information about trips that have arrived at their destination and OpenAMOS provides information about trips that need to be loaded on the network in the next one minute time interval. The link travel times from iteration *k-1* serve as an expectation of conditions on the network that the individual uses to make decisions. The link travel times from iteration *k-1* are used to generate origin-destination skim tables by time of day which are then used in OpenAMOS; the link travel times from iteration *k-1* are also used in MALTA to identify paths for trips that need to be simulated. However, the arrival information that is passed from MALTA to OpenAMOS is based on the actual simulation reflecting prevailing network conditions. At the end of iteration *k*, updated link travel times are obtained. Ideally, a second iterative process needs to be run known as the Dynamic User Equilibrium (DUE) wherein the demand that is generated by OpenAMOS is kept constant and MALTA is run iteratively until convergence in the paths identified for origin-destination (O-D) pairs is obtained. Across iterations in DUE, the path set is updated for O-D pairs and the process repeated until the deviation in the paths identified for any origin-destination pair is very minimal. In the initial runs of the integrated model, this second iterative process is being skipped in order to keep the computational overhead to a minimum. After gaining a better understanding of the dynamic nature of the integration between OpenAMOS and MALTA, the second iterative process will be included to analyze and understand the DUE iterative process. Across iterations, averaging procedures are employed to prevent oscillations in the link attributes and to proceed towards convergence faster. It must be noted that separate averaging procedures need not be applied for demand-side (OpenAMOS) and supply-side (MALTA). Only link attributes are averaged across iterations and they feed as input directly in generating paths on supply-side and they are also used in generating origin-destination travel time matrices (skims) which serve as input on the demand-side. At the end of iteration, a demand side convergence criterion and supply side convergence criterion are monitored and the iterative process is stopped when the improvement in both convergence measures is very small. On the demand side, average deviation in aggregate origin-destination demand matrices is used as a measure of convergence and on the supply side the average deviation in travel time matrices is used as a measure of convergence. On the supply side, the average deviation in travel time matrices by time of day will also monitored to identify and characterize any differences in convergence characteristics during congested and uncongested periods.

During the initial runs of the integrated model, some issues were identified and the project team is in the process of resolving them before proceeding to scenario analysis.

**Skims Invariability**

*Problem*: Paths in MALTA are identified using an algorithm called HTDSP (Hierarchical Time-Dependent Shortest Path). HTDSP proceeds by identifying a shortest path across higher aggregations of space called "super zones" (groups of TAZs) and then within a super-zone path is identified at a finer spatial resolution of TAZ. The same HTDSP algorithm is also used to generate travel time skim matrices. After the model run is complete, it was observed that for all O-D pairs where origins belonged to a certain "super zone" *X* and destinations belonged to a certain "super zone" *Y*, the travel time between the TAZs was always the same.

*Solution*: In the initial runs of the integrated model, a "super zone" comprised of 50 TAZs. This spatial aggregation for super zones may be too coarse to observe variability in travel skims. The project team is currently experimenting with finer aggregations of zones to create "super zones". One of the main reasons for adopting HTDSP algorithm was to gain computational efficiencies when identifying paths. In the current implementation, all the paths are identified on the fly using the HTDSP algorithm and are not determined by mining from a comprehensive dataset of paths. The later approach was not selected because of two reasons namely, a file that enumerates paths for all possible origin-destination pairs is very large and secondly, searching for paths across such a file would comprise a significant computational overhead. The finer aggregations of zones will potentially increase the computational overhead. So in order to offset the computational overhead, the temporal resolution at which link attributes are stored by time of day will be altered. In the initial runs the link attributes by time of day at a resolution of 1 minute were used. However, it may be reasonable to assume that individuals have knowledge of network conditions at a resolution of 5 minutes and they use that to make decisions.

**Path Invariability**

*Problem*: For a given origin-destination pair, the HTDSP algorithm seems to return the same path irrespective of the time period in which the trip was originating or the number of trips for a particular origin-destination pair.

*Solution*: There are two parts to this problem. Firstly, the lack of variability in paths across time periods (e.g. congested versus uncongested periods for a origin-destination pair) and secondly, it is the lack of variability in paths for multiple trips within the same time period. The lack of variability in paths across time periods may be explained by the lack of congestion on the actual path taken by the vehicle even though the trip was pursued during the peak period. The project team is currently mining the outputs that are generated to see if such a problem is observed even when comparing paths that involve links where congestion is observed. The invariability may also be explained by the coarser of aggregation of zones to create "super zones" for use in the HTDSP algorithm. The disaggregation of "super zones" could potentially address the path invariability across time periods issue. The lack of variability in paths within a time period can be explained by the lack of DUE step. For a given origin-destination pair, multiple trips between that pair can take alternate paths only when the DUE step is implemented. The DUE process enumerates and updates path sets across iterations thereby allowing for choosing alternative paths for a given origin-destination pair. In the future when the DUE step is implemented, the lack of path variability across trips within a time period can be overcome.

**Missing Trips**

*Problem*: MALTA is able to identify paths for all trips and load them on the network. However, it fails to complete some trips and as a result the arrival information is never sent back to OpenAMOS to make subsequent activity-travel decisions for that individual(s). While the percentage of these trips is very small, it is important to account for every individual so that full-day activity-travel patterns are generated and also to ensure that all the processes that route and simulate vehicles work as expected.

*Solution*: The project team is currently identifying additional information about the missing trips and trying to replicate the problem. Once the problem is replicated, the project team will explore potential causes for the missing trips.

**OpenAMOS Model Specifications**

*Problem*: As mentioned earlier, the initial SimTRAVEL runs were complete, consistent with the proposed dynamic design. During the initial runs some basic calibration and validation exercises were conducted to check for reasonableness of the activity-travel outputs. The results were very encouraging and OpenAMOS seems to compare favorably with key statistics and distributions observed from the latest wave of the NHTS (National Household Travel Survey, 2008) including, trip frequencies, activity- and trip- start time and end time distributions, and trip purpose distribution. While the model results were satisfactory, the model specifications lacked desired level of sensitivity and the parameter estimates for error terms were rather high.

*Solution*: It is important to have models that are sensitive in order to accurately capture the impacts of policies. The project team is currently looking at enhancing model specifications and also exploring alternative model formulations to enhance sensitivity to a host of socio-economic, demographic, land-use and activity-travel engagement attributes and to reduce the variance of unobserved attributes affecting activity-travel decisions.

**Additional SimTRAVEL Elements**

*Problem*: The individual model systems namely OpenAMOS, and MALTA incorporate all the fundamental elements to run SimTRAVEL for a base year and iterate the model systems through to convergence. However, there are some elements that are missing from the current version of the individual model systems which when implemented can enhance the behavioral richness of SimTRAVEL model system.. Firstly vehicle type allocation to tours and trips, tracking the movement of vehicles and its occupants, and ensuring temporal and spatial consistency. Secondly, incorporate intra-household interactions beyond the ones involving children and adults namely, joint activity-travel engagement involving various combinations of household members. Finally incorporate impact of cost on activity-travel engagement decisions.

Similarly on the MALTA side integrate FAST-TrIPs to account for transit and multimodal trips in addition to trips by auto modes.

*Solution*: On the OpenAMOS side, currently efforts are underway to incorporate all the three elements identified above namely vehicle allocation and tracking, intra-household interactions including adults and children, and pricing component to address sensitivity of OpenAMOS to various pricing policies and scenarios. On the MALTA side, development of FAST-TrIPs is underway.

**2. Scenarios**

The research team plans to run and report results for the following five scenarios, namely:

- Base Scenario
- Change in employment density
- Pricing
- Travel demand management strategies (e.g. flex schedules, telecommuting)
- Incident on major freeway

As noted above currently work is underway to revise model specifciations and to integrate the additional modules in OpenAMOS. Once these enhancements are made, the first four scenarios can be operationalized as shown in Figure 1. In order to implement and understand the last scenario (impact of freeway incident on network conditions and activity-travel engagement decisions), the operational overview presented in Figure 1 needs to be modified. In particular the minute-by-minute communication between OpenAMOS and MALTA needs to be modified as shown in Figure 2.

A standard practice to simulate freeway incidents on the network side is to drop the capacity of the freeway section on which the incident occurs for a certain pre-determined time period. Also, in order to simulate freeway incident, the network conditions from calibrated and validated base year run will be used as the expectation of conditions on the network and this is what individuals would use in making activity-travel engagement decisions. Once the incident occurs, the following three options were considered to model the impact of incident on the network and subsequent activity-travel engagement decisions of individuals.

- **No diversion**: In this implementation, it is assumed that people have no knowledge of prevailing conditions on the network and individuals are making decisions about activities and trips in OpenAMOS and routes in MALTA based on base year converged link travel times. As can be seen this assumption of no diversion is unreasonable especially for those trips that require the individuals to pass through the affected section of the freeway. It is safe to assume that people would be aware of the prevailing conditions either by direct visual contact or will have the information passed on to them through some form of Traveler Information System such as local radio, 411 etc. Therefore some sort of diversion in routes is desirable at least for those trips that start after the onset of the accident.
- **Diversion with no en-route rerouting**: In this implementation, after the onset of the incident, the prevailing conditions of the network are used in making routing decisions and subsequent activity-travel engagement decisions. The link travel times in any time period *t* after the onset of the incident is assumed as an expectation of the network conditions for the subsequent time periods. In other words this implementation assumes that the best guess of the network conditions for any future time interval by an individual are the prevailing network conditions. However a limitation of this approach is that it assumes that once people make a choice to engage in an activity, they do not make changes to the path or the activity-travel decisions "en-route". A strong assumption but one that makes the problem computationally tractable.

  Figure 2 provides an operational overview of this implementation. At the end of every minute, MALTA generates origin-destination travel time matrix using HTDSP algorithm assuming that the link travel times for all subsequent time intervals are the same as the prevailing conditions in generating the shortest paths and travel times for O-D pairs. MALTA then passes the travel time matrix reflecting prevailing conditions along with all trips that have arrived at their destination to OpenAMOS to make activity-travel engagement decisions in the subsequent time interval. OpenAMOS then passes back trips that need to be loaded on the network based on the prevailing network conditions. In response to the prevailing congested conditions due to onset of the incident, people may now choose destinations that are closer to engage in activities or may choose locations away from the incident site where the travel times are unaffected by the incident or may just choose to start early to their next fixed activity because it will take longer to get to their fixed activity because of the incident that occurred on the freeway. Once the trips are received by MALTA, routes are identified again using prevailing conditions as the expectation of the network for all subsequent time intervals. MALTA then loads and simulates the trips and the process is repeated until the incident is cleared. Once the incident is cleared, the base year converged network conditions by time of day may again be used to make activity-travel engagement decisions and routing decisions. The flowchart presented in figure 2 provides a very robust framework for modeling incidents. One can also introduce network disruption dissipation phenomenon after the incident is cleared because it will take a little while for the network to go back to base year network conditions after the incident is cleared. This can be achieved by slowly increasing capacity and feeding back prevailing link attributes even after the incident is cleared for some time and then using base year network conditions for the rest of the day.

- **Diversion with en-route rerouting**: This implementation is very similar the previous one except that in here it is assumed that the individual has a choice to make changes to his/her path and also make adjustments to subsequent activity-travel decisions "en-route". While one can envision using the framework presented in Figure 2 to also model diversion with "en-route" rerouting, implementing this becomes rather complex in the dynamic integration proposed in SimTRAVEL wherein activity-travel decisions "emerge" in response to network conditions along a continuous time axis. Also, this implementation would be computationally very prohibitive as it would involve processing and exchanging of network conditions at a temporal resolution of MALTA (i.e. after every 6 seconds).

In this project, the second implementation namely *Diversion with no en-route rerouting* will be adopted to model the impact of freeway incidents on network conditions and subsequent activity-travel engagement decisions. In the proposed framework it should also be straightforward to implement incomplete travel information situation wherein a percentage of drivers or individuals are aware of the incident while others plan and make decisions based on base year network conditions.

## 3. Computational Challenges

As with any microsimulation model system computational overhead is always a concern. This becomes an even bigger challenge in the context of integrated model link SimTRAVEL that aims to integrate microsimulation model systems of land use, travel demand and dynamic traffic assignment in a seamless fashion.

### Runtime Profile

*Problem*: Each iteration of SimTRAVEL takes anywhere from 24-30 hours; the variability in runtimes is attributed to the specs of the machine running SimTRAVEL. Following are results from a profiling exercise aimed at identifying specific components within individual model systems that contribute the most to the runtimes.

| Model System: Component description | Total Time |
|---|---|
| OpenAMOS: Activity-travel demand generation | 12.89 hrs |
| MALTA: HTDSP for identifying paths | 6.69 hrs |
| MALTA: Update speed and density | 3.13 hrs |
| MALTA: Update vehicle positions | 1.69 hrs |

*Solution*: It can be seen that OpenAMOS does add some significant overhead. However, given the nature of the processes involved in the dynamic generation of activity-travel engagement decisions, the amount of computational overhead associated with OpenAMOS may not be unreasonable. The project team continues to explore enhancements to reduce the computational times on the demand side. On the MALTA end, the identification of paths contributes the highest towards the computation overhead followed by the actual simulation of vehicles and their movement. The project team is exploring options to parallelize the identification of paths and also the simulation of vehicles in order to gain further efficiencies in run times.

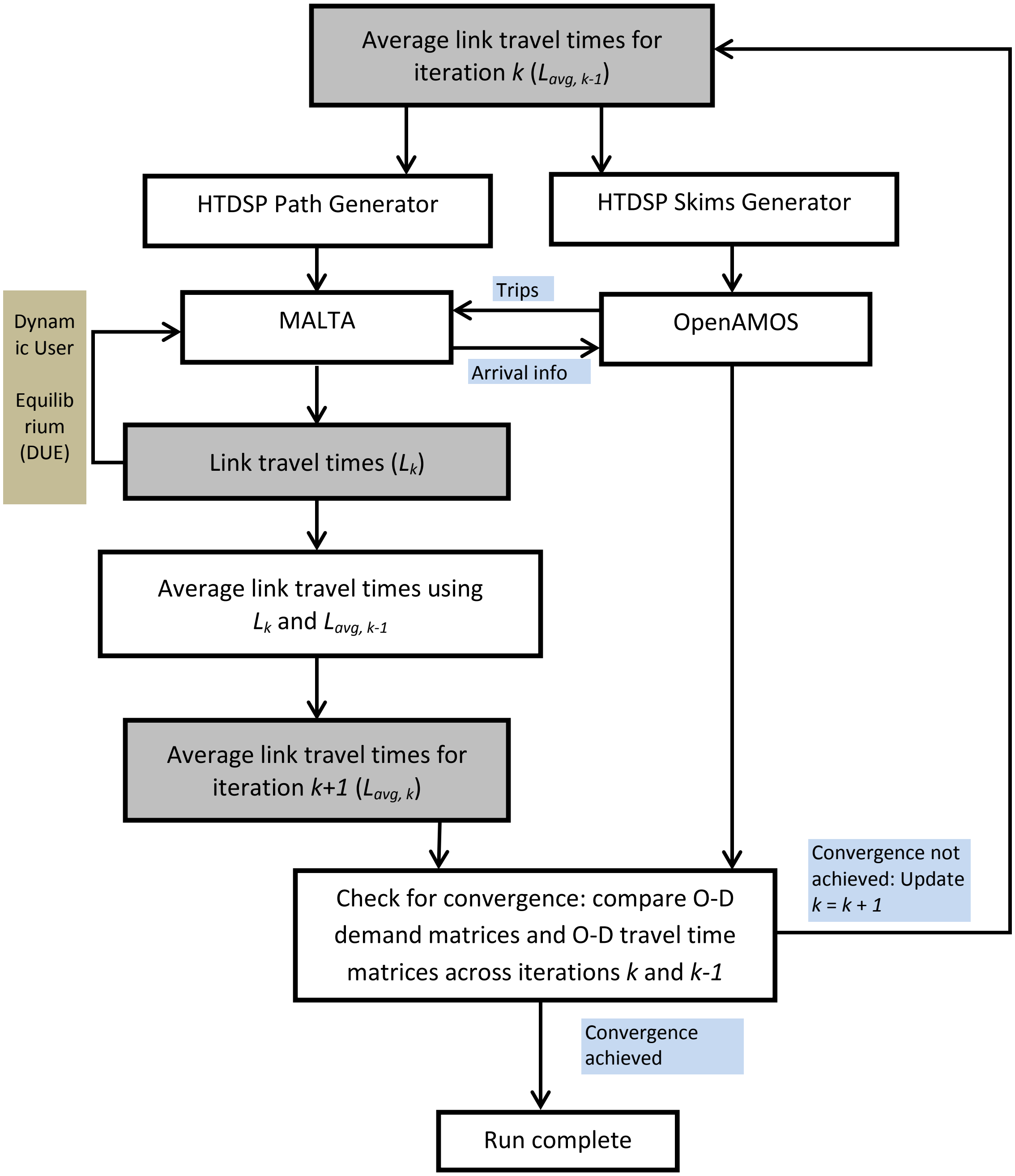


Figure 1: Operational overview of the integration between MALTA and OpenAMOS

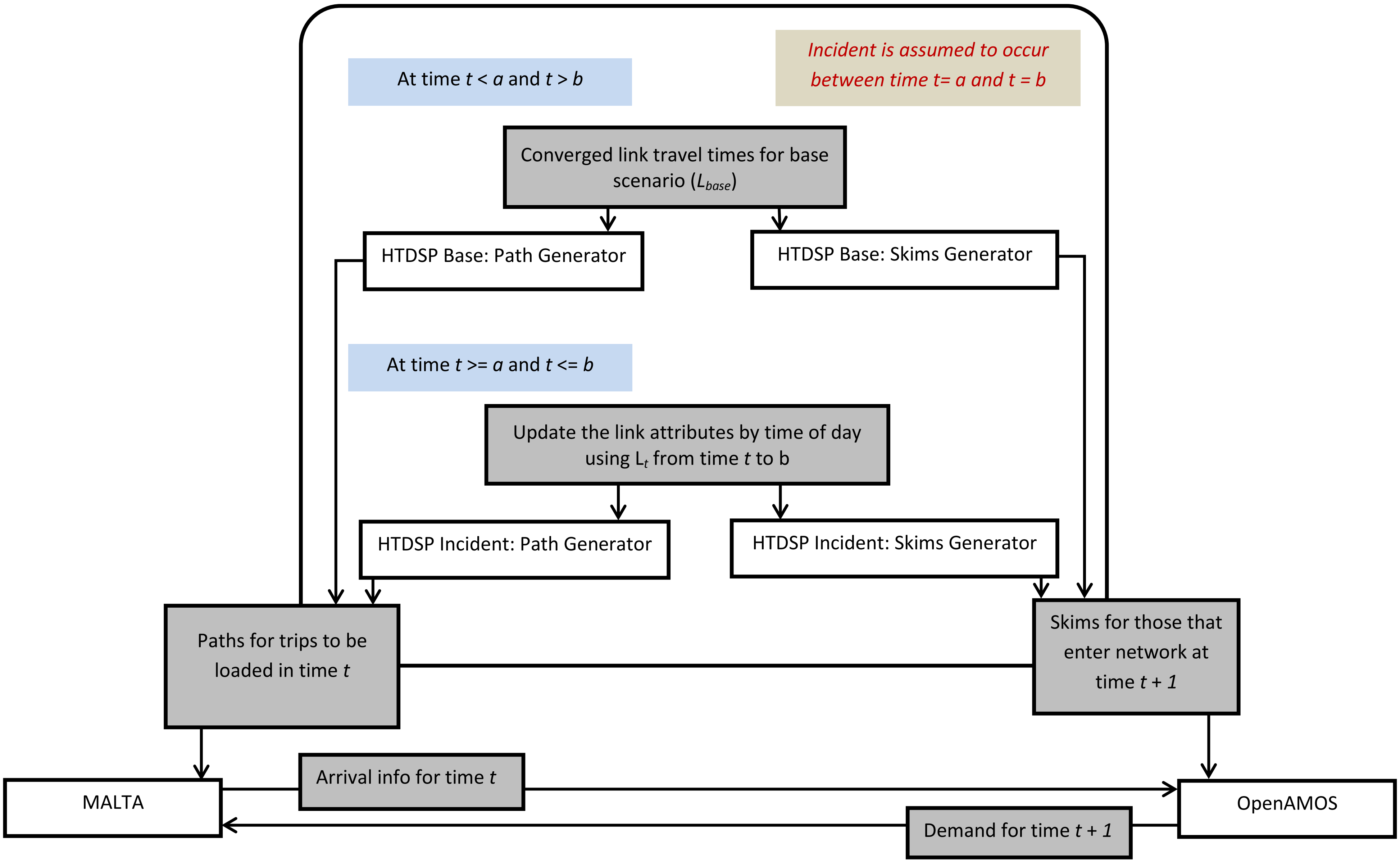


Figure 2: Flowchart showing the integration to model incident response