GAMES FAMILY DEMAND MODELLING FOR GLASGOW 2014 COMMONWEALTH GAMES

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1 INTRODUCTION

Any major event such as the Commonwealth Games requires the movement of a significant number of people. In addition to spectators and workforce, there is a core requirement to ensure the expedient transportation of the "Games Family"; a group which includes athletes, dignitaries, media, marketing partners, and support / service staff. A key aspect of the transportation planning process is therefore to establish the Games Family demand in terms of vehicle fleet size and flows across the network during any given time period. This then informs the design and control strategies for the Games Route Network (GRN) and the operational requirements for venues.

This paper sets out the need for a Games Family Demand Model (GFDM) and describes the composition and functional specification of a bespoke GFDM developed to inform transportation planning for Glasgow 2014 Commonwealth Games. The paper also identifies the salient challenges in the development of the model, with a particular focus on the challenges of modelling the complicated movements of dignitaries. The paper then summarises key outputs and culminates with conclusions and lessons learned.

2 THE NEED FOR A GAMES FAMILY DEMAND MODEL

2.1 Satisfying a Key Transport Objective for Glasgow 2014

The Glasgow 2014 Commonwealth Games had three key transport objectives, as follows:-

- Deliver safe, secure, reliable and accessible transport for the Games Family;
- Provide fast, frequent, friendly and accessible transport for spectators, and;
- Keep Glasgow moving during the Games.

In order to satisfy the key objective of providing safe and reliable transport for the Games Family Client groups, there is a need to understand and to quantify who, where, when, and how the Games Family is likely to move around the transport network during Glasgow 2014.

2.2 The Challenge

Reflecting the quantum of Games Family members attending at previous Commonwealth Games (Manchester 2002 and Melbourne 2006) the challenge for Glasgow 2014 using a fleet of in the order of 2,300 vehicles, is to predict the transport demand for in excess of 36,500 Games Family members:

- With nine different travel behaviours;
- In excess of 750km of road network;
- With in the order of 150 individual destinations;
- On a network that changes on different Games days (e.g. on Marathon Race day), and;

- Throughout the Games period of 11 days (or 264 hours) at 15 minute intervals.

Put simply, there are lots of people to transport with varying and complicated behaviour/patterns of movement, using many different vehicle types across a road network which varies in its configuration by day of the Games.

2.3 Alternative Modelling Approaches

Reflecting the above challenge, the question was how best to consolidate and process the complicated Games Family data in order to understand the impact of their movements on the road network, specifically the dedicated GRN, and also the arrival patterns at venues.

A number of conventional modelling approaches were considered to address this problem including the creation (or adaption) of a large micro-simulation model using software such as VISSIM or, alternatively, the creation (or adaption) of a large strategic assignment transport model using software such as SATURN or Voyager. The advantages and disadvantages of each of these conventional approaches for the purpose of Games Family demand modelling are summarised on **Table 1**.

A common disadvantage of both options was the limitation in the modelling period. Reflecting the complicated movement patterns / behaviours of the various Games Family client groups across the full GRN network and associated venues, transport hubs and accommodation clusters, a full and unique 24 hour modelling period was required for each day of the Games (including night time servicing / logistics vehicles). It was considered that neither the micro-simulation or strategic assignment tools would be able to process the quantity of data over this extended daily time period to a sufficient resolution and with an acceptable run-time.

Given the above limitations with conventional modelling approaches, there was an obvious requirement to consider alternative solutions. A bespoke Games Family Demand Model was developed for the London 2012 Olympic Games. The modelling techniques adopted in the production of this model have been taken and utilised for Glasgow 2014.

Each Games Family Client group has different functions to perform and therefore create different travel demands. The London model employed a modular approach which predicted travel demand on a client by client basis. The client travel demand was then collated and assigned onto the GRN.

The key advantages of this bespoke approach to Games Family demand modelling are also identified in Table 1. Crucially, the modular approach provides the flexibility to appropriately reflect complicated Games Family behaviours whilst also enabling efficient modelling of the full 24 hour assessment period for each day of the Games.

The Games Family travel demand can then be readily imported as a data layer on top of background traffic in existing strategic and micro-simulation models. In the case of the 2012 Olympics, GFDM outputs were imported into Transport for London's (TfL's) existing wider strategic assignment SATURN model of London ("CORNETO") and also into a series of localised TfL VISSIM micro-simulation and TRANSYT signal network models for the majority of the London GRN.

Table 1 – Potential Options for Games Family Demand Modelling

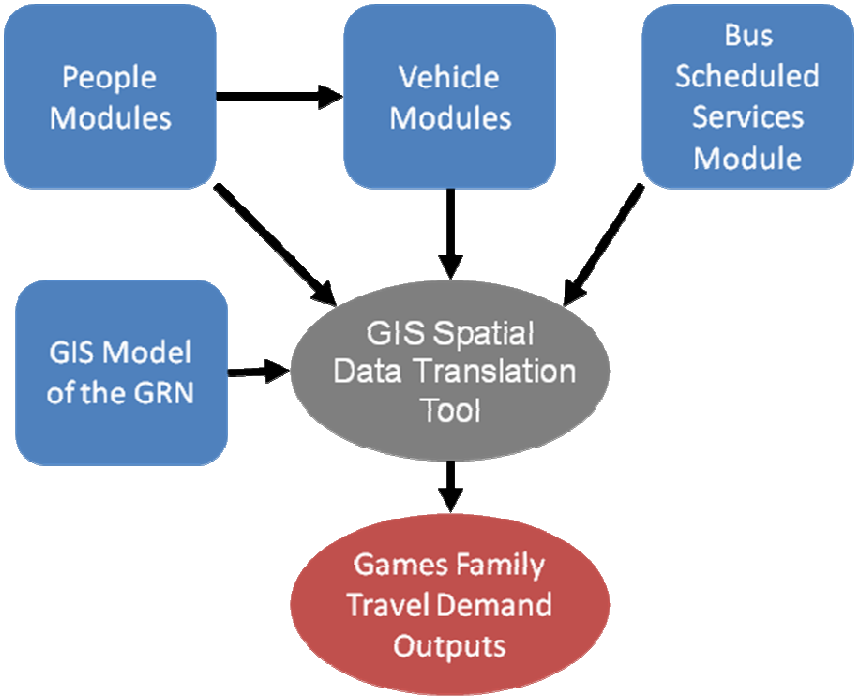
Option	Advantages	Disadvantages
Large **micro-simulation** model (eg VISSIM)	• Visual simulation of network & vehicles • Detailed junction operation • Vehicle/pedestrian interaction – VISSIM	• Time and cost to produce base model • Run time for large network means slow turnaround for outputs • Would need multiple simulation models to represent each day/time period • Limited to peak hours, not 24hr
Large **strategic assignment** transport model (eg SATURN / Voyager)	• Suited to large network with many nodes • Possible to test different scenarios easily • Good at simulating route choice • Provides a wealth of outputs • Existing SATURN model available	• Difficult to replicate complex GF patterns of behaviour / movements during typical Games day period • Limited to peak hours, not 24hr • No dynamic interaction / fixed time slices • Need to extend 'simulation' coding to cover extents of GRN with associated cost and time. • Vehicles are not visualised
Focussed Games Family Demand Model	• Ideal for large input data sets • Modular treatment of different GF behaviours • Illustrates network & routings visually in a transferrable GIS dataset • Transparent outputs • Feedback loop to other models as required (eg to inform SATURN / localised VISSIM)	• Vehicles are not visualised • Requires GIS & programming expertise

3 GFDM COMPOSITION

3.1 Overview

There are a number of component elements to the GFDM, these are shown in simplified diagrammatical form in Figure 1**.**

Figure 1: GFDM Model Composition



- *GIS Model of the GRN*: The Games Route Network defined within GIS, both for road event days and non-road event days;
- *People Modules*: A number of specific people movement modules for different client groups, developed to reflect specific client group behaviours (for example, number of trips per day, arrival/departure profiles). These are populated based on available data and bench marked where possible against previous Games related data;
- *Vehicle Modules*: A number of specific vehicle modules that model vehicle behaviour and generate trips required by the Games Family and also those trips require to provide the service, for example, shift changes;
- *Bus Scheduled Services Module* – A module that generates both in service and out of service trips and associated schedules based on, the level of service requirements required by the Organising Committee and driver shift requirements.
- *GIS Spatial Data Translation Tool* – A module that takes vehicle trip data from the vehicle (and also from specific people) modules and sends the data to the GIS spatial data translation tool for assignment of trips onto the GRN; and
- *Games Family Travel Demand Outputs* - The GIS Spatial Data Translation Tool outputs vehicle link, and junction flow data for designated days and time periods. This data can then be reported and analysed using bespoke spreadsheet tools.

Further detail on each of the key component elements of the GFDM are provided in Sections 3.2 to 3.6.

3.2 GIS Model of the GRN

Central to our modelling approach is a GIS model of the GRN as it exist at each stage of its development during the planning for the Commonwealth Games. Data describing the GRN and its operation is held in data tables within the GIS model. This data may be queried by the GIS Spatial Data Translation Tool in order to correctly assign vehicles in time and space across the GRN network.

The GIS network:

- Models fixed variations of the GRN network so that on certain competition days, sporting events such as the marathon that close sections or sever the GRN can be accounted for.
- Models sections of the public road network used to access the GRN:
- Captures journey times at a sufficiently detailed level for the analysis of predicted flows across the network, through its many junctions. Journey times are calculated from two sources:
  - Link times on core routes between key venues derived from GP from journey time surveys.
  - The remaining unknown link times are derived by assuming average speed over link distance by link type, for example a motorway link will have a much higher average speed than a congested central urban link;
- Defines parts of the network (links) used for loading Games Family into vehicles;
- Defines Games Family bus routes on the network.;
- Defines access routes into each venue and captures vehicle screening areas (VSAs) and the associated security search times for each Games Family client type;
- Defines Games related locations, including competition and training venues, depots, hotel accommodation, transport hubs and associated vehicle staging areas, accommodation drop off/pickup;
- Models banned turns and other movement restrictions at junctions.

3.3 People Modules

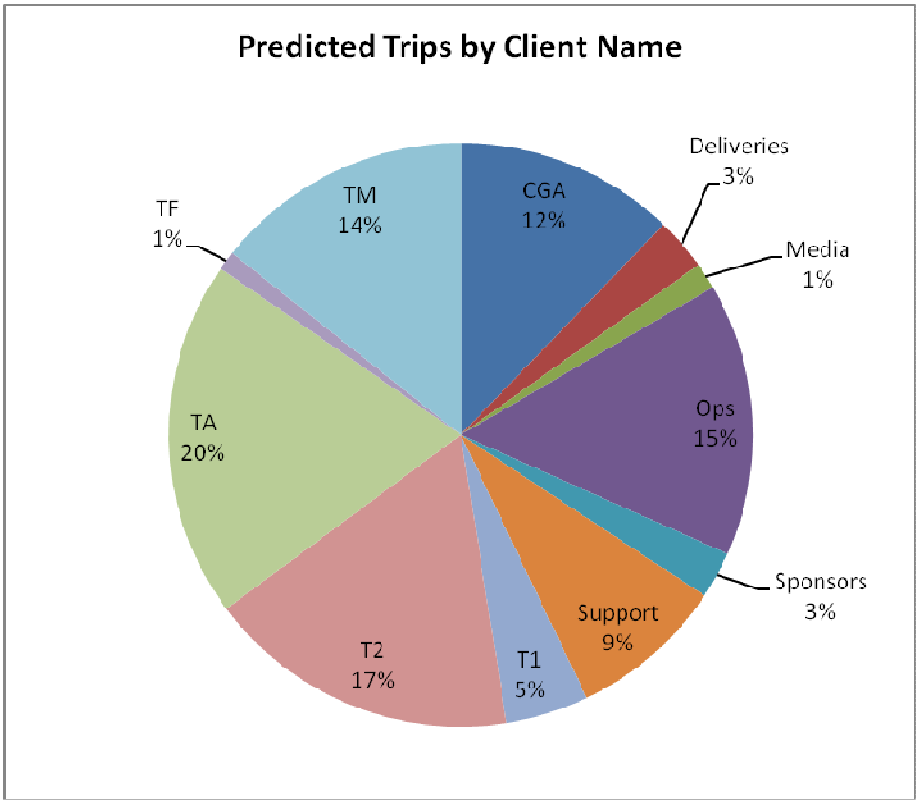
The current objective of the people modules is to model the behaviour of the following client groups that make up the Games Family, during the Commonwealth Games, (for London 2012 Pre and Post Games periods were also modelled):

- T1 Dignitaries – VIPs having access to chauffeur driven transport including, Senior members of the Commonwealth Games Federation (CGF), International Federations (IF) and the Commonwealth Games Association (CGA);
- T2 Dignitaries – Members of CGF, CGA and other Games Family members having T2 privileges. T2 dignitaries are not provided with a personal or shared limousine but with access to a service that behaves in a way similar to that of a taxi;
- Athlete/Officials – Athletes, Technical and Team Officials that travel using dedicated bus services;
- Media – This includes Broadcasters, Written Media, Photographers and Non-Rights Holders using Games vehicles. The majority of the Media client use dedicated bus services. In addition media are able to purchase the use of a vehicle with a venue access pass which enables media to make use of the GRN and access venues.

- Commonwealth Games Association - Commonwealth Games Association members directly involved in athlete development and training travelling using fleet vehicles;
- Support – Emergency and security services
- Operations - Vehicles directly involved in delivering the Games, senior venue staff, organising committee staff, cleaning and waste services etc
- Deliveries – Logistics and deliveries to venues by HGV; and
- Sponsors – Sponsors travel in a variety of vehicles depending on the size of the party and a proportion are permitted to use the GRN.

The proportions of total numbers of trips for each client group for the main competition periods of Commonwealth Games are shown in Figure 2. Over 298,000 Games Family vehicle trips are predicted to take place over the 11 competition days of the Games.

Figure 2: Commonwealth Games Days 1 to 11 Predicted Trips



The People modules model the travel demand created by each client group's behaviour and purpose. Daily travel itineraries are generated for each member of each client group. In order to do this a number of client specific inputs are used to predict travel demand as follows:

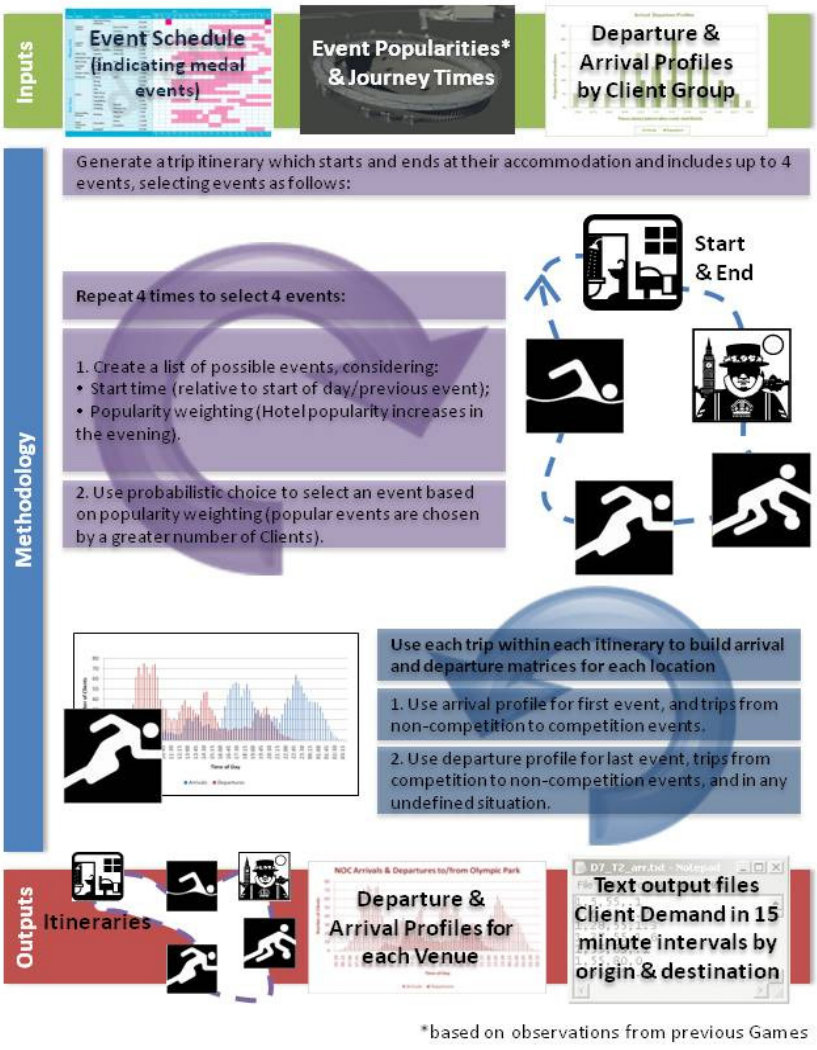
- The capacity at each venue by client group – that is, the maximum number of people who could attend an event at any one time;
- Popularity of an event versus another (e.g. Weightlifting prelim versus Diving final);
- Type of event (prelim, semi final, final) which impact popularity;

- Arrival and departure profiles for each client group;
- Maximum number of trips per day for each client group;
- Event schedule (start and finish times);
- Non competition venues that can be visited by client group;
- The number of clients residing in different accommodation locations;
- Population of each client group; and
- Journey times between each location.

Each client group is modelled separately to reflect each Games Family function and the resulting travel behaviour. Populations and behaviour of the Games Family are based on available data supplied by the Glasgow 2014 Organising Committee and where possible validated against data from the London 2012 or Beijing 2008 Games data. The modules are built in Microsoft Excel using Visual Basic.

Figure 3 provides a flow diagram which provides an indication of how the GFDM 'people' modules operate, summarising inputs, modelling methodology and outputs.

Figure 3: Illustration of GFDM Data Processing Methodology



3.4 Vehicle Modules

In some cases vehicle modules translate person demand into vehicle demand. This approach is necessary for dignitary client groups that have access to fleet vehicles.

The following dignitary groups are modelled:

- **T1** Most important dignitaries, mainly senior members of the Commonwealth Games Federation (CGF), International Federations (IF) and the Commonwealth Games Association (CGA), allocated an individual chauffeur driven vehicle;
- **T2** members of CGF and CGA and other senior people who have access to a dedicated taxi like service.

In the case of the T1 clients the vehicle module is fairly straightforward, simply generating out of service trips between last destination and depots at the start and end of each day.

The T2 service transports groups of clients from one location to another. As a result vehicle movements created by T2 travel demand are particularly complicated to model. A client may wish to travel from their hotel to the Hampden Park Stadium. This would require a T2 vehicle to travel to the hotel to collect the client and then transport the client to the Stadium. The T2 vehicle would then either transport a new set of clients to another destination or return to a vehicle depot. The modelling of T2 vehicles is discussed in detail in Section 4.

3.5 Bus Scheduled Services Module

The bus scheduled services generates bus trips in accordance with the level of service and routes agreed with the Organising Committee, including trips from depots or staging as necessary. It then collects data from the people modules for those clients that use the dedicated bus services and loads the appropriate buses with the appropriate people that require to travel, i.e. it matches a person that requires to travel from a specific origin to a specific destination at a particular time to a bus service that runs between that require origin and destination at the appropriate time for the trip. If there are more people that require to travel on a particular bus route than the bus has capacity to carry and an agreed level of service cannot be met by the people waiting for the next regular bus service, additional buses are despatched to meet the over demand and transport the people to their destination.

Modelling Scheduled Games Family Bus Operations

Currently buses are modelled in a manner similar to private vehicles and are routed through the network on a least cost basis (described in Section 3.6). It is possible when routes become fixed in later stages of the planning process to model buses travelling on designated routes to reflect buses making intermediate stops, travel on bus only links or leaving and then rejoining the GRN.

3.6 Spatial Data Translation Tool

The spatial data translation tool (SDTT) processes the GIS network, bus route information, people and vehicle demand data to allocate journeys onto the network by performing fastest or least cost route analysis.

The analysis of a transport road network to efficiently find the least cost paths (in terms of travel time) between nodes is classically solved by use of an algorithm first proposed by Dijkestra in 1959. However, several factors made application of this algorithm to the GRN particularly challenging, including the following:

- The use of banned turn sequences at junctions;
- The inclusion of *on* and *off* GRN sections to the network, the rule being that the GRN can only be accessed once in a journey. Once the GRN has been exited it cannot be rejoined; and
- The inclusion of client specific time penalties for Vehicle Search Areas (VSA).

The use of banned turn sequences presented a great challenge. The underlying problem is that the basic Dijkestra's algorithm stores a single shortest path sequence from one node to every other node in the network. The introduction of conditionally banned links means that the complete network needs to be re-analysed with the banned link removed in order to find the 'next shortest path'. This requires processing the network an unfeasibly large number of times. To solve the problem, the preferred route has been flagged using an indicator in the GIS network, where route alternatives exist.

Another difficulty is the detail of the GIS representation of the network. The level of network detail that it is required to model movement around venues and junctions; the network includes 509 nodes and 925 links, and this has implications in terms of processing times.

4 FOCUS ON MODELLING DIGNITARIES (T2)

4.1 Summary of Modelling Approach

The T2 dignitary client group formed an important part of the Games Family, being composed of members of the Commonwealth Games Federation (CGF) and Commonwealth Games Association and some Marketing Partners (sponsors).

The group comprised of over 1,800 clients and 350 vehicles. T2 travel demand was expected to contribute up to 20% of total vehicular movements, the highest proportion in the GFDM.

The approach taken in T2 modelling was the development of a multi-purpose tool that could be re-used for the simulation of taxis, buses and other fleet based services.

4.2 Overview of the Modelling Tool

In instances where a client group uses a dedicated transport system, for example a dignitary using a dedicated car or a logistics delivery using a HGV, it is relatively straightforward to translate people movements directly into vehicular movements.

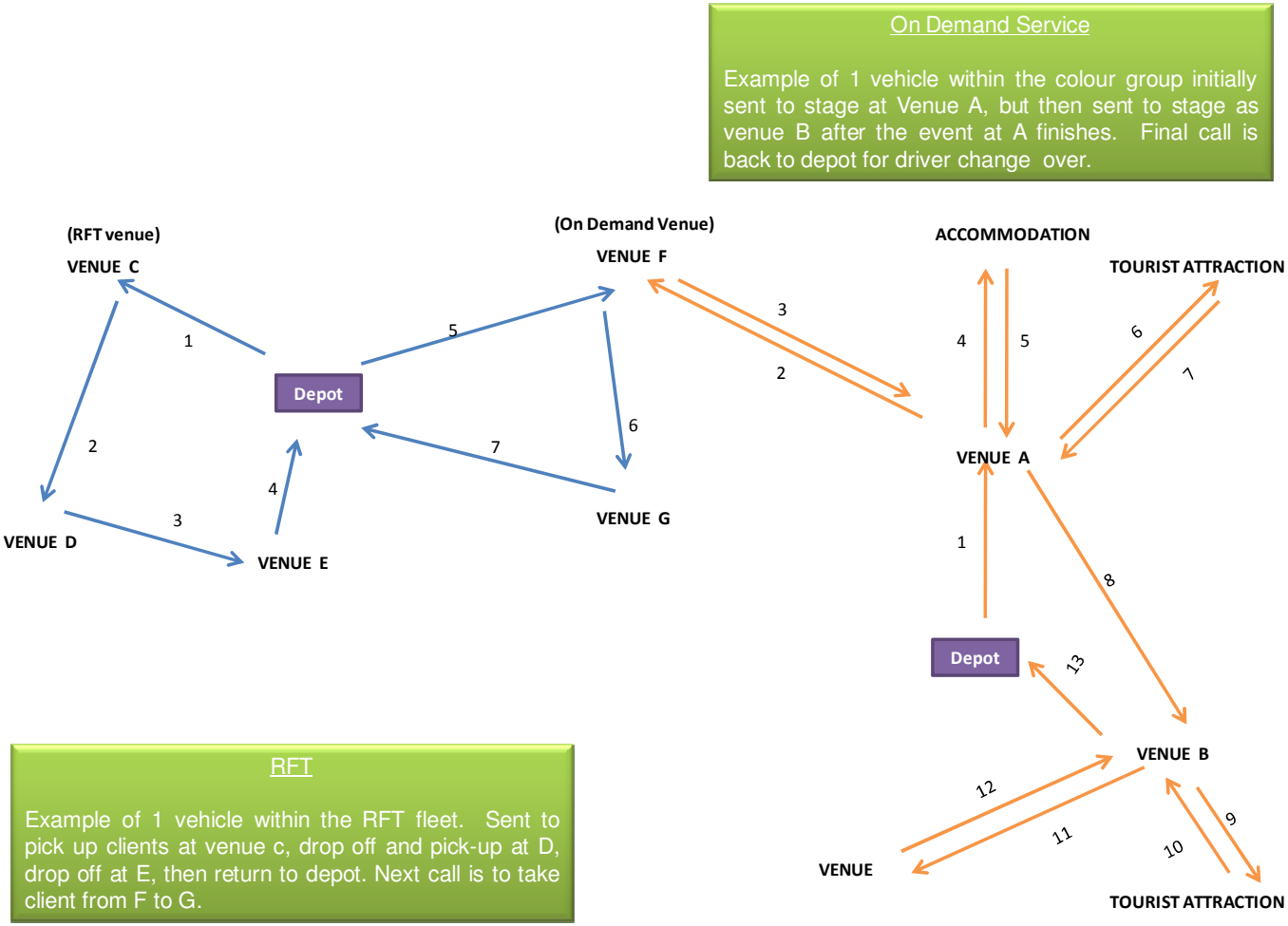
This is not the case in instances where a client group does not have access to a dedicated vehicle. The T2 client group have access to a fleet of vehicles that operate more like a traditional taxi service. A much more complex approach is required because many variables affect the movements of vehicles for this group, including:

- Fleet size (potentially across multiple depot locations);
- Driver shift patterns;
- Type of service ('on-demand' service or 'request for transport' (RFT), that is pre-booked);
- Travel times between picking up and setting down locations; and
- Staging area and load zone capacities.

Figure illustrates the various vehicular movements of the T2 clients.

A review of commercial applicable modelling tools undertaken during the development of the Games T2 model concluded that it would be difficult to model T2 behaviour without a great deal of customisation. A bespoke modelling tool was therefore developed that implements the necessary simulation algorithms using a combination of Excel and VBA modules. The vehicular flow outputs of the T2 tool (and those from other GFDM components) can inform conventional transport models used to assess the operation of the network including VISSIM, SATURN and TRANSYT.

Figure 4: Simplified Diagram of T2 Movements



4.3 T2 taxi simulation algorithm

The simulation operates using 288 discrete time steps of five minute intervals representing a 'day' that starts at 4am and ends 24 hours later. This timeframe allows for late night vehicle movements to be 'carried over' to the next day, ensuring that vehicles complete trips and return to depots.

The main input to the T2 simulation algorithm is the passenger demand generated by the people movement demand model module. The input file data includes the:

- trip origin;
- trip destination;
- departure time; and
- number of people travelling from the origin to the destination in the time step.

Each individual vehicle that makes up the T2 fleet is assigned:

- A unique ID number; and
- A 'home' depot.

It is currently envisaged that 3 key fleet depots will operate in the Glasgow area during the 2014 Commonwealth Games with a further depot for Media Client vehicles, namely the:

- Duke Street Depot;
- Polmadie Bus Depot; and
- A Media Transport Depot at the SECC.

The total number of vehicles operating in the fleet is likely to be in the order of 350 - T2 vehicle occupancy is three per vehicle. A percentage of the available fleet at each depot, is reserved for RFT (pre-booked) travel, the remaining vehicles are used for on-demand services, similar to taxis collecting passengers from a taxi rank.

Both person and vehicular queuing at pickup locations is modelled by the simulation software. During the simulation, the on-demand vehicles are placed in pick up locations at each venue waiting to collect clients.

At the initial time step of the simulation:

- All the vehicles are placed at their home depots;
- The people movement demand model module output file is scanned for departure requests from venues that are only serviced by RFT vehicles;
- Trips from RFT only origins are, if possible, serviced by cars reserved for RFT behaviour; and
- All cars are scheduled in chronological order and an iterative process chains trips so that RFT requests are serviced by vehicles sent from locations nearest to the requesting venue.

At each subsequent time step of the simulation:

- On demand clients (and any unmet RFT demand) are queued at the venues, and wait to be picked up by the fleet;
- In transit vehicles arriving in the current time step are added to vehicle queues at destination venues;
- Vehicles available in the simulation may vary depending on driver shift patterns. The simulation:
  - Brings vehicles of drivers that are at end of shift back to the depot;
  - Releases additional vehicles from the depot if additional drivers are available; or
  - Brings vehicles back to the depot and then removes them from the simulation if fewer drivers are on shift.
- All vehicles in venue queues are monitored. If a shift changeover trip is due (based on the calculated arrival time for the vehicle at its depot being equal to or later than its shift change time), a trip is scheduled that sends the vehicle back to its depot, and that vehicle is removed from the venue queue;
- Clients are removed from the origin queues and allocated to the next available vehicle, with a trip being scheduled to take the client(s) to their destinations. If the trip origin is an accommodation or training venue and demand still exists then a return trip is also scheduled.
- Out of service trips are scheduled to move spare vehicles from venues with no demand.

Movement of the on-demand fleet uses a look-ahead algorithm to approximate the task of the fleet managers sending vehicles to pre-empt future demand, for example to service demand at the end of a competition session. The process selects vehicles in the fleet depot or at other venues if no future client demand is expected. Vehicles are sent from 'nearest' venues in order of predicted travel time, the algorithm thus seeks to limit out of service journey times and client wait times.

4.4 Modelling Staging Behaviours

The simulation process is further complicated because there can be limited vehicle staging/waiting capacity at several locations. To reflect these restrictions the simulation includes designated staging areas away from the main venue load zones where vehicles wait prior to making their next trip. The waiting vehicles are sent from the designated staging areas to the corresponding venue load zone to arrive in time to collect their client, such that client waiting is minimised.

Venue staging areas typically also have a limited vehicle capacity and so vehicles are sent to staging to match future demand, but are limited to the maximum available vehicle staging capacity.

4.5 Predicted Network Journey Times

Central to operation of the T2 simulation is a "table" or "grid" of venue to venue travel times, estimated using a least cost path analysis of trips across the GRN.

During development of the GRN it is likely that it will be necessary to modify the routings and trip origins and destinations included in the spatial GIS network. This necessitates the employment of an iterative approach to the modelling. Journey times for each subsequent run are derived from the previous network version; where necessary missing times are in-filled with times derived from average speeds and crow fly distances. A second iteration of the process using shortest route times based on the revised network results in further refinement.

4.6 Reuse of the Software and Conclusions

Significant effort has gone into developing T2 vehicle software module. It has been designed so that it can be applied to applications other than the T2 fleet simulation. For example, within the GFDM the module could also be used for modelling arrival and departure coach services to transport Games Family members from transport hubs such as Glasgow Airport to accommodations. In this case a separate module uses flight departure data to estimate persons departing at airport terminals, grouped according to likely flight departure profiles. This demand file is fed into the T2 software to schedule coach services. The software simulates out of service trips for coaches leaving fleet depots, and returning to accommodations for further pickups.

The following output information can be produced using the module:

- Predicted numbers of persons queuing at venues/staging areas;
- Predicted fleet utilisation; and
- Total predicted vehicle kilometres travelled.

The software can be used for:

- Scenario testing of fleet size;
- Scenario testing of number and location of depots; and
- Assessment of fuel cost and environmental impact.

5 KEY OUTPUTS

5.1 Key Outputs

The outputs generated by the GFDM and key benefits they provide to the Games planning process include:

- *Provision of link and junction data* - Link flows, turning movements and journey times at 15 minute intervals for each day of the Games by client group, available as either vehicles or pcus (passenger car units). This data has potential to inform network, venue, traffic and people management strategies, as well as strategic and localised transport modelling;
- *Database querying* – The GFDM GIS database can be interrogated to extract a variety of information, for example vehicle kilometres to inform fleet operational costs;
- *"What if" scenario testing* - The GFDM can be used to test and quantity the impact of a range of potential scenarios. For example, what happens if an incident or a Games related event results in the closure of a particular GRN link for a particular day and time period;

Examples of junction and link outputs for the Glasgow 2014 GRN as derived from the GFDM and transposed into user-friendly spreadsheet tools with control panels are provided in Figure 5 and Figure 6 respectively.

Figure 5: Junction Output Tool

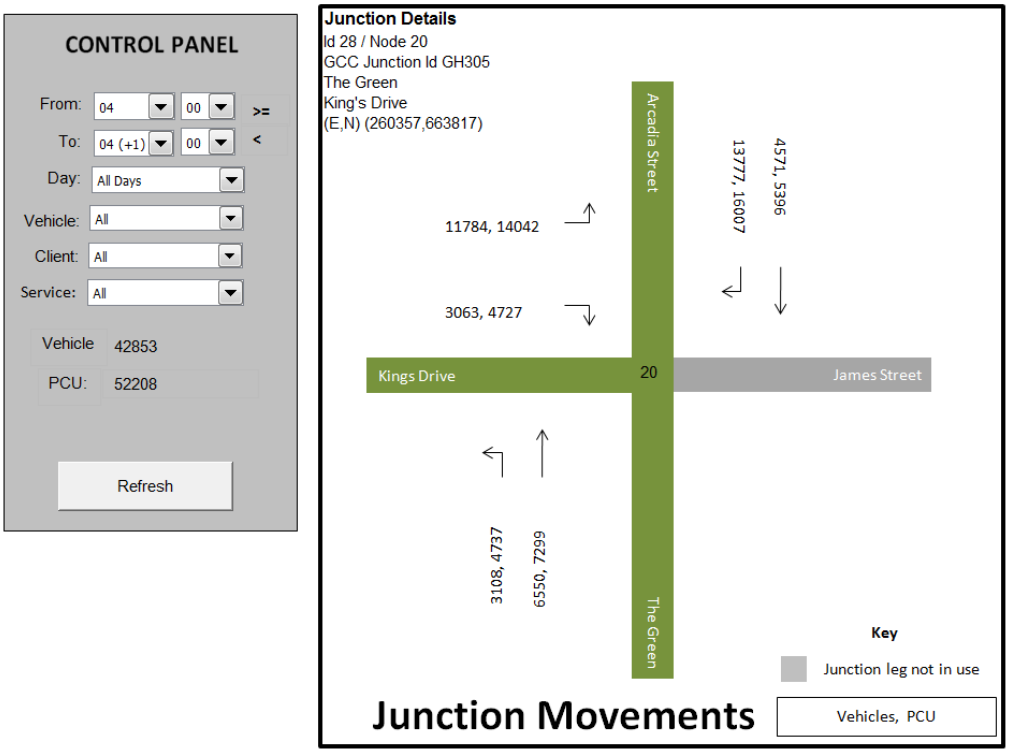
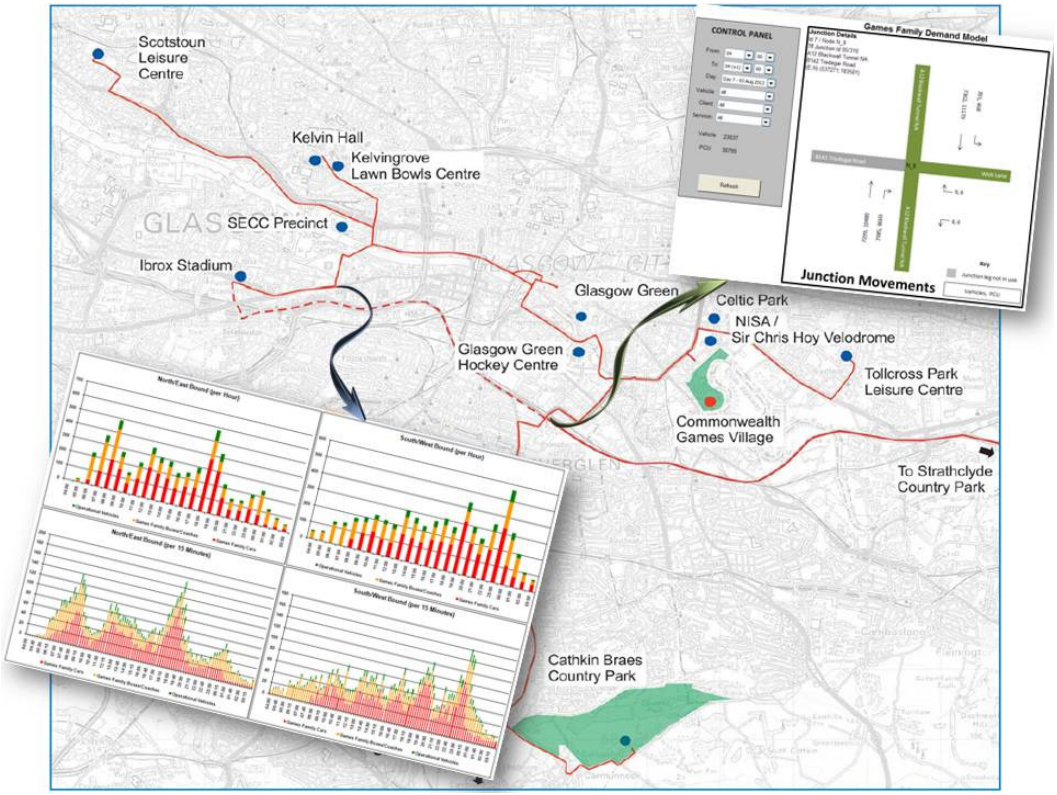


Figure 6: Link Output Tool



5.2 Benefits to Glasgow 2014

In the run up to the Games, Glasgow 2014 and stakeholders are required to assess the GRN design proposals and determine their feasibility in terms of capacity. This assessment relies on an understanding the potential worst case flows throughout the Games period, in particular during the AM and PM peak periods, when background traffic is at its greatest. A prediction of Games Family traffic flows is therefore required to test the proposed design of the GRN and inform alternative solutions if initial designs do not meet forecast demand.

Specifically, outputs from the GFDM can assist the following tasks to assess the GRN design:

- Development of Signal Strategies on an Hour-by-Hour Basis;
- UTC-VISSIM Testing; and
- Event Timetabling and Alternative Routes for Games Family traffic.

6 CONCLUSIONS, FUTURE APPLICATIONS AND LESSONS LEARNED

This paper has provided an overview of the modelling approach taken by AECOM to predict Games Family travel demand for Glasgow 2014 and London 2012. Key lessons learned, conclusions and future applications are provided below.

6.1 Lessons Learned from the London 2012 model

The lessons learned from providing Games Family Demand predictions for London 2012 have proven invaluable in the preparation of demand predictions for Glasgow 2014. Nevertheless Commonwealth Games are not Olympic Games and lessons learned can only be applied in context.

The Glasgow 2014 GFDM may undergo further development, primarily in the form of updated, more accurate, data. A full evaluation of lessons learned will not be possible until after the 2014 Commonwealth Games.

Comparisons of predicted and observed data for London 2012 were undertaken. This work indicated that the model, (providing worst case predictions of vehicle flows on the GRN during the 16 day main Games period) predicted flows that were generally higher than those that were observed. Anecdotal evidence can be gathered to explain why this was the case:

- Surveys confirming higher than expected use of public transport by the Games Family;
- Variable use of the chauffeur driven vehicles supplied for dignitaries;
- Games Family vehicles deviating from the dedicated Games lanes because quieter than expected roads in Central London facilitated faster alternative routes;
- Trip end surveys undertaken at the two main entrances into the Olympic Park suggest a better fit to predicted levels. This may confirm the theory that vehicles were deviating from the ORN, but arriving at venues in the quantum expected;
- Media client group used established studios outside of the Olympic Park, whilst consuming broadcast feeds from within the Park, and so did not require frequent travel to the Park.

The main lessons learned were:

- *Data dependency* - The modelling process and associated data outputs are only as good as the data informing it. In the case of planning an event as significant, as large and as complex as Olympic Games, the production and timely release of required data needs to be a key requirement for all parties involved in various aspects of the transportation planning process.

- *Sensitivity testing* – The primary aim of the Games Family demand model was to develop a "worst case" data set so that TfL and LOCOG could plan for this eventuality; that is to assume all Games Family use the full dedicated vehicle fleet available, make the expected number of trips, and make full use of ORN. However, anecdotal evidence from London 2012 suggests that that not all expected trips were made by the Games Family; that not all of the dedicated vehicles were used with some opting for existing public transport; and that because background traffic levels were lower, some opted to use alternative and more direct routes than the prescribed ORN. A key lesson learned is therefore that it would be advantageous to incorporate a 'public transport use' and 'alternative routing' sensitivity testing facility within the Games Family demand model. This would make it possible to undertake a range of sensitivity tests in order to develop a range of Games Family demand flows from which the "most likely" data sets could then be selected and exported into the wider strategic and localised assessment tools.

- *Exporting data to other modelling tools* – A key advantage of the Games Family demand modelling approach adopted for London 2012 was that the aggregated data sets of link flows and junction turning count volumes could then be exported into other modelling tools, be that upwards to wider strategic assignment models, or downwards to more localised junction modelling tools. A lesson learned is that, as with any transfer of data between models of different scales, caution needs to be applied when exporting to more detailed localised models, in particular micro-simulation models whereby it is possible to disaggregate the imported data and to visualise the routing behaviour of each individual Games Family vehicle through individual junctions. Given the above, there is a requirement for a robust checking process to smooth out any localised individual vehicle routing errors when importing Games Family demand data into micro-simulation process. This smoothing / data transition process was successfully achieved for London 2012.

6.2 Conclusions and possible future applications

Early application of the Games Family modelling process and the associated determination of expected Games Family vehicular flows has significant potential to support a value engineering approach to transport planning for major sporting events. Specific opportunities for applications of the Glasgow 2014 GFDM include:

- The GFDM offers information to inform models used in designing the transport infrastructure for the Glasgow 2014 Games. The outputs from the various GFDM tools could enable modelling the impact of Games Family traffic on the operation of the GRN and venues using the SATURN, TRANSYT and VISSIM as well as venue pedestrian models;

- The model provides worst case predictions of stress on the various network components resulting from Games Family trips, thereby informing Glasgow 2014's and Glasgow City Council's traffic management strategies;

- Detailed analysis, e.g. size/occupancy forecasting, stress analysis to inform design specification of Games related transportation infrastructure such as the GRN, vehicle load zones and Vehicle Screening Areas (VSAs), Depots (Size / Occupancy analysis), Load Zones, Staging Areas, Parking; and

- Sensitivity Testing to test the impact of a range of issues such as fleet size; competition schedule variations, driver shift change patterns.

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