A MICROSCOPIC TRAFFIC SIMULATION BASED DECISION SUPPORT SYSTEM FOR REAL-TIME FLEET MANAGEMENT

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SYSTEM OBJECTIVES

• To provide a methodological framework for the
  – Design,
  – Analysis and
  – Evaluation of City Logistics applications
• Suitable for Real-Time Fleet Management
• Implement the framework in a software
  environment accounting for:
  – Modeling tools
  – Algorithmic tools
• To provide an ad hoc algorithmic development
LOGISTICS and CITY LOGISTICS

• LOGISTICS “…part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customer requirements”

  Council of Logistics Management (2001)

• CITY LOGISTICS “The process of totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, traffic congestion and energy consumption within the framework of a market economy”

  Taniguchi et al. (2001)
KEY CHARACTERISTICS OF CITY LOGISTICS

TWO WAY INTERACTION

City Logistics activities have an impact on traffic congestion
⇒ need to include effect of city logistics deliveries and commercial activities in simulation models of urban traffic

City Logistics activities are impacted by traffic congestion
⇒ must consider time-varying traffic congestion and operational constraints in routing and logistics optimization models
SPECIFICITIES OF CITY LOGISTICS APPLICATIONS

• Fleet management in urban areas has to explicitly account for the dynamics of traffic conditions leading to congestions and variability in travel times severely affecting the distribution of goods and the provision of services.

• An efficient management should be based on decisions accounting for all factors conditioning the problem:
  • Customers’ demands and service conditions (time windows, service times and others)
  • Fleet operational conditions (vehicles’ availability and status, vehicle’s positions, etc.) and
  • Traffic conditions.
DESIGN AND EVALUATION
CRITERIA AND METHODOLOGY

- To be quantitative must be based on suitable models for each design and evaluation purpose:
  - location of logistic centres
  - routing and scheduling vehicles...
- Vehicle Routing and Scheduling provide the core techniques for modelling City Logistics, two cases of particular interest are:
  - When customers specify a time-window to be visited by the pick-up/delivery trucks
  - When the vehicle routing and scheduling has to be dynamic based on real time information.
- Accounting for information changes whilst vehicles are distributing goods, and sequential updating of routes should occur.
  - Need of models to emulate dynamic traffic conditions
- IMPLEMENTED AS A DECISION SUPPORT SYSTEM ON A GIS AS GRAPHIC USER INTERFACE
DECISION SUPPORT SYSTEM FOR CITY LOGISTICS APPLICATIONS

Taniguchi’s Modeling Framework

Models for Vehicle Routing and Scheduling:
- CVRP
- VRPTW
- PDVRPTW
- VRPB
- Dial-a-ride
- Others

Optimal Routing and Scheduling

Average Travel Time on Each Link

Dynamic Traffic Simulation Model
IMPLEMENTATION OF TANIGUCHI’S MODELING APPROACH IN AIMSUN
INFORMATION PROVIDED BY MICROSCOPIC TRAFFIC SIMULATION

- Time Dependent Link Travel Times
- Vehicle’s Paths
- Time dependent shortest path tree from all origins to one destination
- Emulation of the monitoring of an equipped vehicle in microscopic traffic simulation (AVL)
- Estimates of environmental impacts
- AND
- Ability to reproduce recorded scenarios ⇒ Off-line design, testing and evaluation of management strategies
INITIAL DEMAND AND FLEET ESPECIFICATIONS

ROUTING AND SCHEDULING MODULE

INITIAL OPERATIONAL PLAN

REAL-TIME INFORMATION
- New demands
- Unsatisfied demands
- Traffic conditions
- Fleet availability

DYNAMIC ROUTER AND SCHEDULER

DYNAMIC OPERATIONAL PLAN

CONCEPTUAL SCHEME FOR THE EVALUATION OF REAL-TIME FLEET MANAGEMENT SYSTEMS (Regan, Jaillet, Mahmassani)
REAL TIME FLEET MANAGEMENT IN PRACTICE

- Global Positioning System (GPS)
- GPS device pickups signal from satellites
- GPS device calculates position
- Establish communication with network
- Vehicle Data is sent to Fleet Management Center.
- Fleet Manager updates routes and returns them to vehicle.

GPS Satellites

Vehicle Position

Vehicle Data

Updated Route

Vehicle

Cell Tower

Updated Route

Vehicle Data

Updated Route

Fleet Management Center
DYNAMIC VEHICLE REROUTING
IN A REAL-TIME FLEET MANAGEMENT SYSTEM

- Compute an initial vehicle scheduling
  - Link costs $c_{ij}$ ~ link travel times $t_{ij}$
- Run the simulation
  - Track vehicles along the scheduled routes
- Real time customers demand
  - New customer calls at time $t$
- Inputs to the decision support system
  - Positions of each vehicle at time $t$
  - Identification of vehicle candidates
  - Identification of new time dependent routes
    - Link travel times, current and forecasted provided by the simulation
- Decision
  - Consider diversions versus non diversion policies
  - Assign the new customer to vehicle $k$
  - Compute new route
MICROSCOPIC SIMULATION AND CITY LOGISTICS

• Vehicle Tracking by simulation emulates the information provided in real-time by equipped vehicles (i.e. GPS) that can be used to enhance the performance of the fleet management decisions.

• In the dynamic case we assume that a fraction of the demand is known in advance

• Dispatchers must have the capability to react to events occurring in real time

• Considering diversions and insertions in Real-Time Dispatching accounting for
  – Time dependent travel times depending on traffic conditions and on the time \( t \) at which the new request occurs
  – Expected travel times and time dependent routes provided by simulation
INFORMATION PROVIDED BY MICROSCOPIC SIMULATION: Time Dependent Link Travel Times
INFORMATION PROVIDED BY MICROSCOPIC SIMULATION: Tracking fleet vehicles
GENERAL DYNAMIC ROUTER AND SCHEDULER

• Definition: Set of tools that provides on-line solution to a real-time vehicle routing problem.
• Tools might be exact algorithms, heuristics or hybrid approaches.
• AIMSUN NG, the underlying microscopic traffic simulation software.
• Random events considered that might modify routing plan:

  1. Arrival of new requests.
  2. Cancelation of requests.
  3. Changes in time windows bounds.
  4. Breakdown of vehicle.
  5. Changes in demand.

  6. Arrival of a vehicle to a destination.
  7. Changes in travel time.
  8. Delays in delivery start times.
  9. Delays in arrival times.

  **External Events**: do *not* depend on traffic conditions.

  **Internal Events**: do *depend* on traffic conditions.
NEW ROUTING PLAN

DYNAMIC ROUTER AND SCHEDULER

TABU SEARCH

INTERNAL EVENTS

DYNAMIC MONITORING

SOLVING STRATEGIES

Reactive Strategies
- One-by-one
- Pooling

Preventive Strategies
- Vehicle Relocation

Waiting Strategies
- Drive-First
- Wait-First
- Combined

EXTERNAL EVENTS

INTERNAL EVENTS

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Reunió de OPTIMOS
DYNAMIC ROUTER AND SCHEDULER (I)

- The heuristic used in the DRS is derived from the basic insertion heuristic proposed in Campbell and Savelsbergh (2004)
- Every unrouted customer is evaluated at every insertion point.
- The evaluation of this movement, consist in checking the feasibility and profitability of every insertion, which is the negative of the amount of additional travel time added to the route.
- The customer with a feasible insertion having the maximum profitability is then selected and inserted in the route.
- This heuristic has been adapted for
  - The Dynamic Vehicle Routing Problem with Time Windows (DVRPTW) and
  - The Dynamic Pickup and Delivery Vehicle Routing Problem with Time Windows (DPDVRPTW).
DYNAMIC ROUTER AND SCHEDULER (II)

- When a new call is received, the system must decide where to insert the new customer.
- Let’s assume that a new customer \( w \) arrives at time \( t > 0 \).
- When this happens, vehicles of the fleet can be in one of the three \( status \):
  - In service at some customer \( i \) (SER).
  - Moving to the next planned customer on the route or waiting at the customer location to start service within the time window. (MOV).
  - Idle at the Depot, without a previously assigned route (IDL).
- This status determines when a vehicle should be diverted from its current route, be assigned to a new one if is idle or keep the planned trip.
- Whenever a new customer arrives, the status of a vehicle must be known to compute travel times for this new customer.
- If the vehicle has a MOV status, the travel time is computed from the current position of the vehicle to the location of the new customer.
- If the vehicle is in IDL status, the travel time is just the travel time from the depot to the new customer \( w \).
- If the vehicle is in SER status, the amount of time needed to arrive to the customer \( w \) is the remaining service time at the current customer plus the travel time between the current customer and the new customer \( w \).
DYNAMIC INSERTION HEURISTIC FOR NEW CUSTOMERS

1. New customer request.
2. Check status of vehicles.
3. Routes recalculation (least cost insertion).
4. Execute new plan.

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