Transportation Logistics

An Introduction to Dynamic VRP

Friday, 07.12.2012 – 8:30 – 10:00

Winterterm 2012/2013

PD Dr. Jörn Schönberger · jsb@uni-bremen.de
Agenda

- A simple example
- Characterization of dynamic VRPs
- Challenges
A VRP with dynamically appearing requests

Who should fulfill this request? V1 or V2?
Overlapping of plan generation and execution

- Static vehicle routing problem

- Dynamic vehicle routing problem
Application areas (1/2)

- **Delivery of petroleum products**
  - Exact „fill up“ quantity is not known
  - En-route shortage of load require additional depot visit

- **Courier Services**
  - Customer requests show up en-route
  - Adjustment of planned routes are necessary
  - Idle periods during waiting for new requests

- **Intermodal services**
  - Coordination of upstream and downstream process parts fails sometimes
  - Re-planning of routes necessary in order to keep transport chain alive
Application areas (2/2)

- Tramp ship operations
  - Tramp ship is rented for a transport from A to B
  - Uncertainty about upstream / downstream rentals
  - Weather conditions delay arrival at B and endangers to in-time availability of a tramp ship for the next assignment

- Taxi-services

- Emergency services

- Robots routing in a production system
What means „dynamic“? (1/2)

- **Evolution of information**
  - static (invariant)
  - dynamic (varying over time)

- **Quality of information**
  - known-deterministic
  - forecast (estimated e.g. travel times in a road segment)
  - probabilistic (described by probability distributions)
  - unknown (no information about this topic is available now)

- **Availability of information**

- **Processing of information**
What means „dynamic“? (2/2)

- **Availability of information**
  - locally available information (e.g. exact heating oil demand at a certain customer location)
  - globally available information (e.g. traffic jams broadcasted by radio)

- **Processing of information**
  - centralized
  - decentralized
1 -Scheduling becomes more important

- Scheduling = consideration of time aspects
  - Determination of arrival, departure, service starting times, etc.
  - Consideration of travel and transfer times
  - Load / unloading times are important

- Simplification: travel times are proportional to distance

- If additional requests are included into planning: updated schedules must be realistic
2 – Unclosed Problem

- Dynamic vehicle routing problems do not cover a well-limited time-period
- The completion time of a request is not known in advance
- A proposed solution of a problem instance will not be realized completely (the probability is quite high!)
- Subject of planning are paths (open routes) instead of closed trips starting and ending at the depot
3 – Future events are uncertain

- Strict distinction between past, present and future
  - Static VRP: no distinction
  - Dynamic VRP: strict distinction due to scheduling (fixing non-future decisions)

- Today, real-time information are quite reliable and should be considered during replanning („present“)

- „Future“-events are uncertain

- Often they cannot be modelled by probability distributions (e.g. taxi service applications, emergency services, …)
4 – Near future events must be considered first

- Static vehicle routing problems: near and far away events are treated in the same way
- Dynamic VRP: near events can be described in more details
- Unexpected intermediately appearing events reduce the benefit of far away events
- Conclusion: near future events must be processed with higher preference than far away events
5 – Continuous update of relevant data

- Addition data being relevant for executing the route generation show up spontaneously
- These data must be included in the update of the routes
- Before these data are given to planning these must be checked for consistency, filtered and aggregated.
- Updates of the routes must be propagated to the drivers immediately.
6 – Replanning must be possible

- Often updated information compromise the value of already made decisions
- Sequencing decisions, assignment decisions as well as subcontracting decisions are affected
- During planning it must be ensured that subsequent plan revisions are still possible
- Customer-orientation and reliability promises make the revision of planning decisions quite challenging
- Negative aspects of re-planning are not penalized
7 – (Re-)Planning tools must answer quickly

- Rapid calculation procedures are unconditionally necessary for an efficient and effective re-planning
- Tools for „What if …“ – analysis should be provided
- Typical planning goals within static VRP like routing cost minimization or request fulfillment times should not be ignored in DVRP-scenarios
- What are good planning goals in DVRPs?
8 – Unlimited right shifting must be prevented

- Delaying of requests („right shifting“) must be possible (no quite short time windows!)
- Sometimes „left shifting“ is possible and beneficial
- „right shifting“ decisions must be controlled over several update cycles in order to prevent infinite delays of request fulfillment
- Well-defined time windows and deadlines are appropriate to prevent infinite right shifting
- Penalization of quite long waiting times
9 – Finding adequate planning goals

- Typical objectives from VRP are not adequate
  - Travel distance minimization
  - Makespan minimization

- Throughput – related indicators are more suitable

- Minimization of average waiting times is also subject of research

- „Moving time window“ – techniques are adequate
  - Consider only events falling in a time window around now
  - Ignore older events and decisions to be realized for the far away future.
10 – Time-constraints must be adjusted

- Hard time windows to be considered in online planning problems will result in quite bad plan quality
- Relaxation of hard time constraints (but penalization!)
- Soft time constraints must be sharpened (e.g. in order to prevent infinite right shifting)
- Conflicting time windows may result in infeasibility of plan update tasks
11 – No short term fleet adaptation possible

- In static VRP a fleet modification sometimes leads to a reduction of costs

- In dynamic VRP a fleet modification is impossible since there is no access to additional transport resources

- An overloading of a transport system results in additional delays, additional detours and so on
12 – Queuing-mechanisms are essential

- In dynamic VRP scenarios a transport system overloading appears if the additional input increases more rapidly than the completed demand.
- A pure adaptation of planning algorithms efficient for static VRPs cannot handle overloading crisis.
- A „holding“ of critical requests that do not fit in the current portfolio contributes to prevent overload.
- Requests in a „holding“ state must be inserted into the executed schedules one after another („queuing“).
Why dynamic VRPs are important

- Efficient vehicle routing becomes more important as markets tend to become increasingly volatile
- Today, real-time decision making has become the „normal“ scenario
- Real-time data processing has become more easier and is a competitive advantage in a pressurized market
- Logistics systems must be able to adapt themselves to ad-hoc material flow challenges
Technological Advances

- Electronic Data Interchange (EDI)
- Positioning systems like GPS or Galileo
- Geographic Information Systems (GIS)
- Intelligent Vehicle – Highway Systems (IVHS)
- Mobile communication systems and mobile Internet
- Traffic information systems
Further challenges

- Protection of once made decisions
  - reliability with respect to announced arrival times etc.
  - Another example: a once made subcontracting decision cannot be revised (because a contract has been already made)

- Different urgencies of requests in a portfolio must be considered

- Anticipation of future system states is necessary
Summary and outlook

- **Summary**
  - Solutions of a VRP-model requires a revision due to uncertain planning data or planning data modifications
  - A one-to-one transfer of static vehicle routing problem formulations to dynamic VRPs is hardly possible
  - Dynamic VRPs become more and more important in reality

- **Outlook**
  - Characterization of generic strategies to manage dynamic VRPs
  - Rolling horizon disposition and dispatching
  - Rule-based approaches vs. model-based approaches
Literature
