City Logistics

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Presentation Overview

- Freight transportation in urban areas
- The City Logistics idea
  - Concepts, models, successes and failures, trends, challenges ...
- Planning City Logistics systems
  - An illustration for two-tiered CL systems
- Perspectives
Freight Transportation in Urban Areas

\[
\text{Min} \left\{ f^T y + c^T x : A y + B x \geq d, \ y \in Z^n_+, \ x \in R^p_+ \right\}
\]
Essential

To most economic and social activities

- No transportation = No human society as we know it
- No logistics = No economy as we know it

Supply the population for work and play
Supply homes, stores, firms, offices, institutions, ...
Support supply chains and industries
Keep cities clean
Maintain and repair
Major source of employment
Disturbing

♣ Major disturbing factor
♣ Significant part of traffic & traffic-related problems
  ♣ Interference with passenger traffic
  ♣ Congestion
  ♣ Parking problems, …
♣ Significant negative impact on the environment
  ♣ Noise, emissions, …
♣ Safety
♣ Poorly used (loaded)
♣ General feeling: Cities are polluted and not safe …
Close to Home

Canada

Cost of congestion for 9 major urban centres:
2.27 to 3.72 billion / year

Montreal

Delay/congestion costs for motor carriers: $53M (1998)

Economic losses due to congestion: $1 billion (2003)

Usage on trucks in on the rise, most are empty of little loaded, emissions increase dramatically
Problem Will Not Go Away

 World-wide urbanization (heavy) trend
  ✤ Large cities → larger & more cities → large

 Urban population versus total population
  ✤ Countries members of OECD
    50% in 1950, 77% in 2000 → 85% in 2020
  ✤ Worldwide: > 50% in 2007: the first time in history

 Accelerating factors
  ✤ E-business, Express courier, JIT/door-to-door,
      Reverse/green logistics, ...

 The current model for the development and management of the urban freight transportation is not sustainable
The “Tradition”

❖ No planning/control methodology
  ❖ “Freight transportation = private activities performed and supplied by private means”
  ❖ Urban (regional) transport planning models target passenger traffic and consider aggregate truck flows only

❖ Usual controls through regulation
  ❖ Limited access hours
  ❖ Restricted access to selected city zones
  ❖ Parking restrictions

❖ Do not work very well ...
The “Tradition” & Research

- Significant Operations Research & Management Science work
  - Urban (regional) passenger transport planning
  - Distribution: Vehicle routing
  - Models, methods, software, successful transfer to practice
- Significant work in other fields
  - Engineering, Urban studies, Public health, …
  - Intelligent Transportation Systems
  - Focus on people in individual or public transport
- Meanwhile, on freight & the city as a system issue:
Beginning of the 1970s

- Studies and research projects on both sides of the Atlantic
- International conferences
- Limited yield and public enthusiasm
- Traffic regulations to avoid heavy truck presence in cities and “limit” impact of truck traffic on car movements
- 1975 – end 1980s: almost nothing
The 1990s and Beyond

- Renewed and steady interest in urban freight transportation issues
- Increased urbanization and traffic
  ⇒ increased traffic-related problems
- “New” public awareness and pressure (the politicians take notice …)
The 1990s and Beyond (2)

- A more holistic view of (freight) transportation
  - From *Intelligent Vehicle-Highway Systems* (IVHS) to *Intelligent Transportation Systems* (ITS)
  - The US-DOT Intermodal Surface Transportation Efficiency Act
  - The European projects: *intermodal* as keyword
- “Many” projects and pilot implementations
- International conferences
- The *City Logistics* concept (“brand”)
- A lot of work to do …
The City Logistics Idea

$$\text{Min}\{f^T y + c^T x : Ay + Bx \geq d, \, y \in \mathbb{Z}_+^n, \, x \in \mathbb{R}_+^p\}$$
Emerging Needs & Objectives

👀 Analyze (understand), control, reduce freight vehicle (types &) movements within cities to
✔ Reduce congestion & increase mobility
✔ Reduce emissions & noise
✔ Reduce passenger – freight transport interactions
✔ Improve living conditions
✔ Improve efficiency of movements (mobility)
✔ Reduce empty vehicle-km
✔ Address other environment concerns
✔ Do not penalize city center activities !!
Data Collection

- Significant efforts deployed (Europe, Japan) to survey freight transportation activities and build an understanding of the field and issues
- It also served to justify efforts and mobilize institutions and firms
- Still lagging in North America
  - Little for intercity movements
  - Almost nothing regarding cities!
Move Freight Differently

- Underground automated systems
  - Amsterdam airport
  - Osaka
- Huge investments required
- ...
Modify the Current Practice

Many vehicles dedicated to small (single) numbers of shippers / shipments / consignees ⇒ Many empty vehicles or lightly loaded
Using Proved Strategy in Logistics, Long-haul Transportation, Passenger Transportation, …

Distribution centres

Consolidation (& coordination)
The Fundamental Idea – City Logistics

✍ Stop considering each shipment and company (and vehicle) individually

✍ Rather as components of an integrated logistics system

✍ Consolidation and coordination
  ✿ Coordination of shippers and carriers (& consignees)
  ✿ Consolidation of several shipments of different shippers, carriers, and loads by the same (improved, more energy efficient, “green”) vehicle

✍ Optimize this logistics system
Consolidation Facilities

- Intermodal platforms, freight villages, …
  - Transfer freight between vehicles/modes
  - Storage
  - Sort, consolidate/deconsolidate
  - Additional services (e.g., accounting, legal counsel, …)

- Usually at the outskirts of cities, close to highways
- Sometimes, part of terminals (ports, airports, …)
- Originally not built for City Logistics
The City Distribution Center (CDC)

- (Urban freight consolidation center, …)
- Facility where shipments are consolidated prior to distribution
- An “intermodal platform” with enhanced functionality to provide coordinated and efficient freight movements within the urban zone
Single-Tier Single-CDC City Logistics

City Distribution Center

Customer zone

Urban vehicle
The First Wave

- Single-tier systems, single-CDC mostly
- European pilot implementations, under various business models
- Limited number of shippers and carriers
- Limited usage of ITS technologies
- Very limited usage of decision-support models & methods
Distribution-Licenses Business Model

 alunos

 Initial idea: The Netherlands

 Limited number of licenses (permits) for urban distribution

  - Number of vehicles entering the city & vehicle loads
  - Operating rules: e.g., operate circuits, on-board loading/unloading equipment
  - Distribution advantages (e.g., extended hours)

 Strong local and central government involvement

 Still working

 Limited penetration out of the Netherlands
“City Logistik” Business Model

- Initial idea: Germany
- “Spontaneous” grouping of carriers for coordination and consolidation activities
- Light government involvement (“facilitator”, no particular traffic rules)
- Private initiative ⇒ At same time in the (near) future, the project must prove self-sustainable and profitable (!!)
- Many applications (Germany, Switzerland)
- But … Not financially sustainable in general
- Most stopped/abandoned once EU financing completed
  15 out of 200 still worked by 2002
Public-Service Business Model

- Initial idea: Monaco
- All large vehicles (> 8 tons) forbidden into the city and must deliver to the CDC from where distribution is ensured by unique carrier
- Specialized firm, material, personnel
- Particular characteristics of the Monaco state/municipality
- Still working in Monaco with private carrier now
- It used to be the only one of its kind
- Not any more
Trends: From 2000 on

❖ The field is flourishing
   ❖ New projects and experiments
   ❖ Revisiting “old” ones
   ❖ More countries and cities around the world – U.S. & Canada bit yet really in
❖ O.R. methodology is still lagging
❖ The vision has changed
❖ The CDC still at the core of CL systems, but a broader and more flexible range of functionalities, policies, and business models is contemplated, experimented with, implemented
Number of Projects and Objectives

- Envi+Cong
- Economical
- Environmental
- Congestion

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<th>Period</th>
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Evolution of Infrastructure Financing

[Bar chart showing the evolution of infrastructure financing from 1975-79 to 2005-07.]

- **75-79**: 2 (Unknown), 3 (Private), 5 (Public)
- **80-84**: 2 (Unknown), 3 (Private), 5 (Public)
- **85-89**: 1 (Unknown), 2 (Private), 5 (Public)
- **90-94**: 1 (Unknown), 2 (Private), 5 (Public)
- **95-99**: 1 (Unknown), 2 (Private), 5 (Public)
- **00-04**: 1 (Unknown), 2 (Private), 5 (Public)
- **05-07**: 1 (Unknown), 2 (Private), 5 (Public)
Evolution of Functionality & Tools
Partnership and Organizational Structures

Many “variants” are tried out
Mix of initial business models
Regulations + “public service” + …
Involvement of public authorities
  Partnerships, infrastructure financing
  Open access of public facilities to private operators
The role of private initiatives is expanding
  Noticeable trend from 2000 on
  Particularly in France and The Netherlands
Private firms use City Logistics concepts and practices
Technology

❖ “Clean” vehicle utilization is growing
❖ Intelligent Transportation Systems
  ✭ From 2000 on
  ✭ Still timid (electronic data exchanges)
  ✭ Growing and acknowledged as success factor
❖ Operations Research & Management Science
  ✭ Very little in practice, not much in research either
  ✭ Routing (dynamic) software in Japan
Single-tier CDC Systems

- “Successful” for small to medium-size cities
  - Unique, compact controlled zone
  - Close to city limits and CDC
  - Public-utility style systems “easy” to implement
- Significantly less successful for large urban areas
Single-Tier City Logistics

City Distribution Center

Customer zone

Urban vehicle
Single-tier CDC Systems & Large Cities

- Large controlled zone(s) far from city limits & CDCs
- High density and diversity of land usage
- Congested, “narrow” streets, little parking space
- Direct CDC → Customer delivery not suitable
  - “Large” vehicles: long distances, difficult tours in the center, difficult to respect customer time windows, poor capacity utilization, but few vehicles
  - “Small” vehicles, better tours and capacity utilization, but many vehicle-km
- More complex structures emerging
City Logistics for Large Cities

Most display a two-tier structure
- Loads consolidated at CDC into “large” vehicles
- Moved to CDC-like facilities “close” to customers
- Transferred to “small” vehicles appropriate for city center
- Delivered to final destinations
Two-Tier City Logistics
City Logistics for Large Cities

- A number of not necessarily integrated sub-systems
- Many have access to some public infrastructure (light rail lines, parking lots, …) even when private initiatives
Example: Chronopost, France

- Single CDC, single satellite facility
- “Green” vehicles in downtown

Source: Chronopost
Example: CityCargo Amsterdam

- Goods delivered at CDCs (1, now, 2 planned)
- Consolidated and loaded into specially-design trams
- Moved on the tram lines to transfer points (sidings)
- Transferred to electric trucks for distribution
  - Crossdock type of transfer

Source: CityCargo
Planning Two-Tiered City Logistics Systems

\[ \text{Min} \left\{ f^T y + c^T x : Ay + Bx \geq d, \ y \in Z^+_n, \ x \in R^+_p \right\} \]
Planning Levels

 makenose

 Strategic

 - System design
 - System evaluation

 Tactical

 - Next-period service network design
  (short-term planning)

 Operational

 - Real-time operation, control, and dispatch of vehicles,
  terminal activities, personnel, … (ITS)

 Politics and policies (public involvement), business
 models, social and working relations, taxation, etc.
Planning & City Logistics

- Relatively much empirical work
- Relatively little formal work and contributions
- Challenges and opportunities for Operations Research and Transportation/Logistics science
Tactical Planning

✎ City Logistics: Consolidation-based system
✎ Tactical planning: Service network design
  ✎ Transportation plan & schedule
  ✎ Select services & departure times
  ✎ Determine demand distribution itineraries
  ✎ (Terminal workloads)
✎ Tactical planning for City Logistics
  ✎ Demand & services change daily, but may be planned (known/forecast)
  ✎ Tomorrow's plan and schedule
✎ The day-before planning problem
Next-Day Planning for Two-Tier City Logistics

❖ For evaluation and short-term planning
  ✤ Access times and routes of urban trucks
  ✤ City-freighter fleet management (utilization)
  ✤ Terminal – CDC, satellite – utilization
  ✤ Demand routing

❖ To best plan / use available resources while
  ✤ Satisfying demand
  ✤ Controlling the presence of vehicles in the city
  ✤ Controlling the impact of vehicles on city traffic
Problem Description

Planning the next period of operations, performed a short time before (“the day before”)

Most demand is known (stochastics later …)

- In-bound traffic (more later …)
- Assumed to be at CDCs
- Volumes and product characteristics (e.g., vehicle type)
- Latest due dates – time windows
Problem Description (2)

- Logistics structure known
  - Satellite location & capacity (operating time window)
  - Satellite assignment to CDCs
  - Customer (customer zone) assignment to satellites
  - City access/egress corridors

- Vehicle fleets given
  - Vehicle characteristics (product-vehicle combinations)
  - Fleet size

- Congestion-based (time dependent) travel times

- Activity times at terminals and customers
Modelling Goals

- Determine the **best global strategy** – in terms of customer demand, system utilization, and city congestion – to distribute flows

- Demand is consolidated in urban trucks ⇒ Determine the **best times & routes** for **urban-truck services** to enter the city and deliver to satellites

- Demand is transferred and consolidated at satellites into city freighters ⇒ Determine the **city-freighter fleet circulation / management: work schedule**

- Determine how **demand is distributed**: The “CDC→truck→satellite→freighter→customer”” best itineraries (**times and routes**) to minimize total system cost
Model Structure

- Two major components
- Urban-truck scheduled service network design
- City-freighter synchronized multiple-tour routing
- linked by
- Demand itineraries
Customers & Satellites

\[ s, \pi_s, \lambda_s, \delta \]

\[ d : p, \text{vol}, e, c, [a, b], \delta(d) \]
Urban-Vehicle Scheduled Services

- Urban-vehicle type
- Route & schedule
  - External platform, departure period
  - Sequence of satellites (corridors)
  - Arrival & departure times at satellites
  - Exit the system or return to an external zone
- The same (route) service at different periods
- Different services leaving the same platform at the same period
- Fixed cost: “nuisance” to enter & circulate in the city (operation)
Urban-Vehicle Services – Schedule Specifics

Decision: Which service to run? (when?)
\[ \rho(r) \in \{1,0\} \]

\[ r: t(r) = t + 1 \]

\[ r': t(r') = t \]
Urban-Vehicle Services – Route Specifics

Decision: Which service to run?

\[ \rho(r) \in \{1,0\} \]

\[ r: t(r) = t; \ \sigma(r) = \{s,s'\} \]

\[ r': t(r') = t; \ \sigma(r) = \{s\} \]
City-Freighter Circulation

- Work during the “day” moving out of satellites to serve customers, back to satellites to pick up freight, …

- Coordination and synchronization
  - At satellites with urban vehicles (no waiting space!!)
  - Customer time windows

- Work assignments (full routes)
  - Sequence of work segments (returns to depots) & work legs (visits to satellites)
  - Associated arrival & departure periods

- Which work assignments \( \varphi(h) \geq 0 \) to operate?
City-Freighter Work Segment

\[ st \]

\[ i \]

\[ j \]

\[ k \]

\[ h \]

\[ i' \]

\[ j' \]

\[ k' \]

\[ h' \]

\[ g't^- \]

\[ g't^+ \]

\[ g't^{++} \]
Demand Distribution

❖ **Itineraries**
❖ From given external platforms to given customers
❖ On what services?
❖ Through which satellites?
❖ On what city-freighter work assignment?
❖ To arrive on time

❖ **Which itinerary to use?**
Demand Itineraries

Select itinerary to deliver cargo on time: \( \zeta(m) \geq 0 \)

\[ m: \{ e, r(m), t(m) < t(r), s(m) = s(m) \in \sigma(r(m)), \forall(p(d)), l(h(m)), c(d) \} \]

\[ d: e, c, p, t, [a, b], vol \]
A General Model – Variables

\( \rho(r) = 1 \), if the urban-vehicle service \( r \in \mathcal{R} \) is selected (dispatched), 0, otherwise;
\( \varphi(h) = 1 \), if the work assignment \( h \in \mathcal{H}(\nu) \) is selected (operated), 0, otherwise;
\( \zeta(m) = 1 \), if itinerary \( m \in \mathcal{M}(d) \) of demand \( d \in \mathcal{D} \) is used, 0, otherwise.
A General Model

Minimize \[ \sum_{r \in \mathcal{R}} k(r) \rho(r) + \sum_{h \in \mathcal{H}} k(h) \varphi(h) \] (1)

Subject to \[ \sum_{d \in \mathcal{D}} \sum_{m \in \mathcal{M}(d,r)} \text{vol}(d) \zeta(m) \leq u_r \rho(r) \quad r \in \mathcal{R}, \] (2)

\[ \sum_{d \in \mathcal{D}} \sum_{m \in \mathcal{M}(d,l,h)} \text{vol}(d) \zeta(m) \leq u_l \varphi(h) \quad l \in C_t(w), h \in \mathcal{H}, \] (3)

\[ \sum_{m \in \mathcal{M}(d)} \zeta(m) = 1 \quad d \in \mathcal{D}, \] (4)

\[ \sum_{t=t-\delta(r)+1}^{t} \sum_{r \in \mathcal{R} (s,t^-)} \rho(r) \leq u_s^T \quad s \in \mathcal{S}, \ t = 1, \ldots, T, \] (5)

\[ \sum_{t=t-\delta(r)+1}^{t} \sum_{h \in \mathcal{H} (s,t^-)} \varphi(h) \leq u_s^T \quad s \in \mathcal{S}, \ t = 1, \ldots, T, \] (6)

\[ \sum_{h \in \mathcal{H}(\nu)} \varphi(h) \leq n_\nu \quad \nu \in \mathcal{V}, \] (7)

\[ \rho(r) \in \{0,1\} \quad r \in \mathcal{R}, \] (8)

\[ \varphi(h) \in \{0,1\} \quad h \in \mathcal{H}, \] (9)

\[ \zeta(m) \in \{0,1\} \quad m \in \mathcal{M}(d), \ d \in \mathcal{D}. \] (10)
Problem and Model Structure

❖ Integrated
  ❖ Scheduled urban-vehicle service network design
  ❖ Synchronized city-freighter routing and scheduling problem

❖ 2SS-MDMT-VRPTW: two-echelon, synchronized, scheduled, multi-depot, multiple-tour, heterogeneous VRPTW
  ❖ Complex and large
  ❖ Methodology to be developed for the most part
Hierarchical Decomposition Approach

- Urban-vehicle service network design
- City-freighter allocation & management (circulation)
- Building blocks for more sophisticated methods
Hierarchical Approach – Single Pass (Evaluation)

Customer-to-satellite assignment
Approximate cost of serving each customer from its satellite

Urban-vehicle service design

Selected services
Custer demands at satellite-period

City-Freighter routing

City-freighter work assignments
Hierarchical Approach – Multiple Pass

Customer-to-satellite assignment

Approximate cost of serving each customer from its satellite

Urban-vehicle service design

Selected services

City demands at satellite-period

City-Freighter routing

City-freighter work assignments
City-Freighter Circulation Model

UV service design yields $C_{st}^V$

- Customer demands to be served
- Satellite-period-city-freighter type

Once all customers are served, the city freighter goes

- To a satellite for rendez-vous with urban vehicles and next work leg
- To a “depot” (parking) for end of day or next work segment
City-freighter Possible Movements

Time windows
Service times

Arrive on time !!
City-freighter Time Constraints

\[ \omega(t) = t - \delta(t) \]

\[ \omega(s) = t - \delta(v) \]

\[ \omega(i) = \omega(s) - \delta_{is} \]

\[ \omega(i) + \delta(i) \]

\[ \omega(k) = t + \delta_{sk} \]
Modelling Approaches

ashboard Fleet Management Model

SS-MDMT-VRPTW, synchronized, scheduled, multi-depot, multiple-tour, heterogeneous vehicle routing problem with (tight and strict) time windows

Decomposition: Relaxing synchronization

Many VRPTW problems solved independently

Each satellite and period

Min-cost network flow problem for each city freighter type

Move city freighters between loading activities at (satellite, period) rendez-vous points (and, eventually, depots)
Issues (Beyond Working on the Algorithms 😊)

❖ Uncertainty & planning
  ❁ What? Why? How?

❖ Intra-city demand
  ❁ To what extend may the same CL system efficiently serve both in-bound (e2c) and intra-city (c2c) demand?

❖ Intuitively, it depends upon
  ❁ Number of c2c requests and associated volumes
  ❁ Uncertainty of both types of demand

❖ Need for deterministic & stochastic tactical models
  ❁ Operating policies / Planning models and tools

❖ To be validated/studied through simulation
Intra-City Demand: Management Policies

How to manage intra-city, customer-to-customer (c2c), demand?

เทร Forget it, do not consider it part of the system (!!)
เทร Separate, dedicated fleet
เทร Integrate c2c and e2c traffic into the same system

เทร Share resources

How to integrate? What operating policies?
Integrating Intra-City Demand

- Indirect impact on 1\(^{st}\) tier – urban vehicle services to satellites – through the space one might want to allow on city freighters out of satellites

- Direct impact on the 2\(^{nd}\) tier, the city freighter routes providing distribution services

- Mixing e2c and c2c traffic must account for LIFO loading/unloading policies
  - No possibility to “re-arrange” loads en route
Possible Operations at Satellites

- Pass through with previously picked up loads
- Re-classify
- Re-classify and transfer
- Not in this phase
Leg & Work Segment for e2c Movements

Diagram showing the segments and points labeled with 'gt-', 'st', 'i', 'j', 'k', 'f', 's', 't+', 'a', 'b', 'c', 'd', and 'g't++.
Possible Operations for e2c Movements
Limitations on Movements

- No intermediate **warehousing**
- No time or space to rearrange vehicle loads during pickup or delivery services at customers: **LIFO policy**

**LIFO Violated!**
Need to rearrange loads in vehicle
LIFO Requirements

\[ s_t \quad i \quad k \quad c_1 \quad c_2 \quad c_1 \quad c_2 \quad m \quad j \quad s_{t+} \]
Pseudo Backhaul

- e2c customers are always served first
- Then vehicles switch to pickup & delivery with LIFO phase to serve c2c
Pseudo Backhaul (2)

Possible legs of *only* pickup and delivery phase → Possible work segment with *only* pickup and delivery!
A General Model – (Same) Variables

\( \rho(r) = 1, \) if the urban-vehicle service \( r \in R \) is selected (dispatched), 0, otherwise;

\( \varphi(h) = 1, \) if the work assignment \( h \in H(\nu) \) is selected (operated), 0, otherwise;

\( \zeta(m) = 1, \) if itinerary \( m \in M(d) \) of demand \( d \in D \) is used, 0, otherwise.
A General Model

Minimize \( \sum_{r \in \mathcal{R}} k(r) \rho(r) + \sum_{h \in \mathcal{H}} k(h) \varphi(h) \)  \hspace{1cm} (1)

Subject to \( \sum_{d \in D^{=d}} \sum_{m \in \mathcal{M}(d,r)} \text{vol}(d) \zeta(m) \leq u_r \rho(r) \quad r \in \mathcal{R}, \) \hspace{1cm} (2)

\( \sum_{d \in D^{=d}} \sum_{m \in \mathcal{M}(d,l,h)} \text{vol}(d) \zeta(m) \leq u_l \varphi(h) \quad l \in C_l(w), h \in \mathcal{H}, \) \hspace{1cm} (3)

\( \sum_{d \in D^{=d}} \sum_{m \in \mathcal{M}(d,l,h)} \text{vol}(d) \zeta(m) \alpha_{ij}(m) \leq u_l \varphi(h) \quad l \in C_l(w), (i, j) \in l^{=d}, h \in \mathcal{H}, \) \hspace{1cm} (4)

\( \sum_{m \in \mathcal{M}(d)} \zeta(m) = 1 \quad d \in D, \) \hspace{1cm} (5)

\( \sum_{t = t_0 - \delta(t) + 1}^{t} \sum_{r \in \mathcal{R}(s,t)} \rho(r) \leq u_s^T \quad s \in S, t = 1, \ldots, T, \) \hspace{1cm} (6)

\( \sum_{t = t_0 - \delta(t) + 1}^{t} \sum_{h \in \mathcal{H}(s,t)} \varphi(h) \leq u_s^Y \quad s \in S, t = 1, \ldots, T, \) \hspace{1cm} (7)

\( \sum_{h \in \mathcal{H}(\nu)} \varphi(h) \leq n_\nu \quad \nu \in \mathcal{V}, \) \hspace{1cm} (8)

\( \rho(r) \in \{0, 1\} \quad r \in \mathcal{R}, \) \hspace{1cm} (9)

\( \varphi(h) \in \{0, 1\} \quad h \in \mathcal{H}, \) \hspace{1cm} (10)

\( \zeta(m) \in \{0, 1\} \quad m \in \mathcal{M}(d), d \in D. \) \hspace{1cm} (11)
Formulations

❖ The general planning model – all activities
❖ A restriction through approximation of satellite-to-customer delivery time/cost
❖ Particular models for each level assuming the activities at the “other” level are fixed
❖ Interesting (!!) algorithmic challenges
Uncertainty & Two-Tier City Logistics

❖ Time
❖ Work at facilities & service at customers
❖ Movements through the city

❖ Demand
❖ Volume
❖ No show (volume = 0)
❖ Unexpected
Demand Uncertainty & Two-Tier City Logistics

- A significant part of e2c demand is known in advance
  - Driven by known customer orders
  - The “day-before” planning problem

+ City Logistics objectives

⇒ It makes sense to plan !!

- Uncertainty in demand → a robust & flexible plan ≠ total reoptimization

- Our choice: Recourse formulations
E2C Demand Uncertainty

- Delivery of known orders
  - Volume, product & vehicle requirements, time of availability, customer attributes – time window
- Most at CDC, or cancelled (postponed) at planning time (the “day-before”)
- Others: en-route ⇒
  - Planned arrival time & Uncertain arrival on time
- Unexpected demand
  - Left for the next day
  - (Depends on operation policy/model)
C2C Demand Uncertainty

Customer-to-customer intra-city movements without intermediate warehousing

- Some known in advance (the “day-before”)
- Some requests arrive “later” ⇒

Uncertainty on

- Origin & destination
- Volume
- Time: Availability (origin) & Window (destination)

These must be soft !!!

(product & vehicle requirements)
Information Process

❖ New information arrives
   ❖ Between planning time & the beginning of operations
   ❖ During operations

❖ Our model
   ❖ All uncertain information becomes known “at” starting time of operations
   ❖ The plan is then adjusted
   ⇔ Two decision stages

❖ In practice: demand still uncertain at starting time will be served the next day (operational policies might serve some if capacity is available without disturbing service)
Modelling Framework

Minimize \( f(x) + \mathbb{E}_{\xi} (Q(x, \xi(w))) \)

Subject to \( x \in X, \ w \in \Omega \)

- First-stage decisions: the a priori plan \( x \)
- \( \xi(w) \) : Realization of demand for \( w \in \Omega \)
- \( Q(x, \xi(w)) \) : Cost of operating using the a priori plan for demand \( \xi(w) \) given a recourse policy
Approach

- Build a *plan* based on *some information*
- Once the uncertain data is resolved
  - Keep *part/most* of the plan
  - Adjust using a *recourse policy*
First Stage

Information considered

- All & only known information
- Known information + approximation of uncertain data

Defining an a priori plan

- Tactical model with routing
- Aggregated service network design model with approximate routing costs
2nd Stage Recourse Policies

- Separate (city freighter) fleet for the late demand (or even for all c2c demand)
  - Not a stochastic problem!
  - But provides a benchmark
  - It does generate new operating policies and models, e.g., more complex pickup and delivery activities

- The following models
  - Increased latitude in the recourse actions
2nd Stage Residual-Capacity Recourse

- Use tactical model with routing at 1st stage
- Keep
  - Selected first-tier services (routes and schedules)
  - Selected city-freighter work days ("routes")
- New demand may be split on these services and routes
- Provide extra city freighters with high cost for the new demand that cannot be moved by the regular vehicles
- Optimize the distribution of the new demand
- Similar issues with the separate-fleet case
2nd Stage Full-Routing Recourse

- Use service network design model with approximated routing costs at 1st stage
- Keep the selected first-tier services (routes and schedules)
- New demand may be split on these services
- Provide extra city freighters with high cost for the extra demand that cannot be moved by the regular vehicles

Optimize the routing
2nd Stage Restricted Time-Shift Recourse

- Use service network design model with approximated routing costs at 1st stage
- Keep
  - Selected first-tier services (routes and schedules)
  - The demand itineraries & sets of customer demands to be served from each (satellite, period) point
- Identify satellite opportunity windows and urban-vehicle compatible services
Output of Service Network Design

Customer time windows

d(i)

d(j)

d(k)

\[ C_{st} \]

et’

st
Opportunity Windows and Compatible Services

Select among possible occurrences of the service

Satellite, time opportunity window

Customer time windows

$[a(st), b(st)]$

$[a(i), b(i)]$

$[a(j), b(j)]$

$[a(k), b(k)]$

$C_{st}$
2nd Stage Restricted Time-Shift Recourse (2)

- Use aggregated service network design model at 1st stage
- Keep
  - Selected first-tier services (routes and schedules)
  - The demand itineraries & sets of customer demands to be served from each (satellite, period) point
- Identify satellite opportunity windows and urban-vehicle compatible services
- Provide extra city freighters with high cost for the extra demand that cannot be moved by the regular vehicles
- Solve the tactical model with routing on restricted case
And now ...

▪ Solving the deterministic models
▪ Addressing the stochastic formulations
   - Scenarios and decomposition schemes
▪ There are common structures to most cases
Perspectives

\[ \text{Min} \{ f^T y + c^T x : A y + B x \geq d, \ y \in \mathbb{Z}_+^n, \ x \in \mathbb{R}_+^p \} \]
General Perspectives

❖ The issue of freight transportation in urban areas is here to stay and grow
❖ What systems and business models for North America?
❖ For very large cities?
❖ City Logistics and logistics chains?
❖ What freight transportation systems for the future?
❖ Many challenges and opportunities for Operations Research & Management Science
   ↗ Very few contributions yet
   ↗ A field worthy of exploration and “open”
A Few Sources for Information

➦ Best Urban Freight Solutions
  ✿ www.bestufs.net
  ✿ Conferences and workshops
  ✿ Best practice handbook

➦ www.transports-marchandises-en-ville.org

➦ City Logistics Institute www.citylogistics.org
  ✿ International conferences
  ✿ Proceedings & books

➦ The European projects, US-DOT, VERTIS web sites
  ✿ www.google.com, us 😊