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IVT - Seminar

Beobachtung des Verkehrsverhaltens mit GPS

Observing travel behaviour using personal GPS trackers

Dienstag, 2. Mai
ETH Hönggerberg, Zürich

Prof. Martin Lee-Gosselin
Planning and Development Research Centre (CRAD)
Université Laval, Québec &
The PROCESSUS Network, Canada

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Thank you - Merci

Sponsors:

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Social Sciences and Humanities Research Council of Canada

Ministère des transports du Québec

Colleagues, especially:

Profs. Amer Shalaby, Sean Doherty & Marius Thériault

Students, especially:

Amy Tsui, Eui-Hwan Chung,
Dominik Papinski & Casey O'Hara

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Outline

1. A brief history of technology-aided travel survey methods lead by Université Laval
2. The evolution of GPS devices for travel survey applications
3. Post-treatment algorithms: current progress with and without processing of GIS data layers
4. An architecture for LAD-aided personal travel surveys
5. Follow-on work of PROCESSUS Network: what can we operationalise now? where are we going?

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1. History of technology-aided travel survey methods at Université Laval

(Since 1973: work on in-depth transport survey methods)

Since 1990: GRIMES/CRAD very involved in survey design for studying processes of behavioural change in activity and travel patterns

1994 -1996: Aspatial electronic vehicle dataloggers used on private vehicles, links to truck telematics projects

1998-2000: Vehicle-based GPS experiments for long periods of observation

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2000: Formation of PROCESSUS Network, headquartered at U. Laval

PROCesses of behaviour underlying Equity and Sustainability in Systems of Urban access and their Simulation

PROcessus Comportementaux Essentiels aux SystèmeS d'accès Urbain durables et équitables et à leur Simulation

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History…2

The PROCESSUS Network:

- *involves 8 Canadian and 8 other institutions in Australia, France, Sweden, Switzerland, the UK and the USA*
- *Funded by a Major Collaborative Research Initiative of the federal social sciences research council (SSHRC), the GEOIDE Network of Centres of Excellence in geomatics and the Québec Ministry of Transport*

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GIS data models to support simulation of land-use and transport: new requirements for temporally and spatially-referenced data for multi-day or multi-week periods

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2002-2005: 2nd GEOIDE/PROCESSUS project:

An integrated GPS/GIS system for collecting spatio-temporal microdata on urban travel

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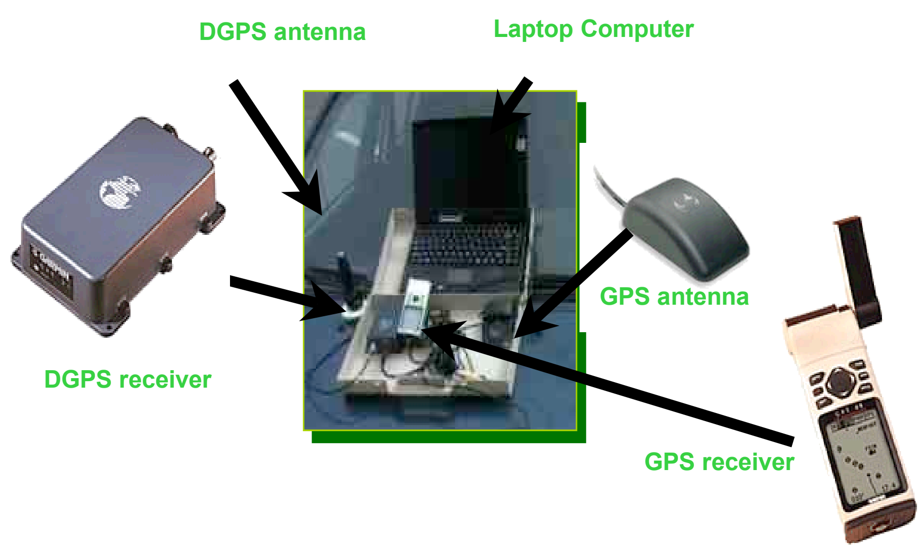
3. The evolution of GPS devices for travel survey applications

Evolution of the use of GPS equipment in research on travel survey methods

Phase I (1999-2000): Initial vehicle-based DGPS experimental platform



Required manual startup, trip-end and shutdown

Evolution of the use of GPS equipment in research on travel survey methods

Phase II (2000-2001): Fully autonomous vehicle-based test platform built by GEOIDE Network Affiliate Specialty Sensor Technologies, St.-Laurent, Québec

- *Data stored only while vehicle is in motion, switched using motion sensor*
- *Up to 4 weeks of data collected*
- *Nothing attached to vehicle except small magnetic antenna*
- *We tested automatic data transmission via a pager network*

Evolution of the use of GPS equipment in research on travel survey methods

Phase III (2001-2002): Tests of a commercialised vehicle-based survey device manufactured by Battelle Memorial Institute, Columbus, Ohio

Thanks to the

Washington State Department of Transportation

(Loan of 40 units)

- *Data stored in the "black box" based on configuration set with a PDA*
- *Automatic detection of engine operation*
- *Possibility to query driver at trip ends using the PDA*
- *Most of our tests were for seven day periods without trip-end queries*

Evolution of the use of GPS equipment in research on travel survey methods

Phase IV (2003-2005): Software development + pretests using a commercialised "wearable" survey device manufactured by GeoStats, Atlanta

- *Essentially a vehicle logger adapted for person-based surveys*
- *Small shoulder bag with videocamera style battery sled and logger, GPS antenna at top of shoulder strap*
- *Very reliable*

Evolution of the use of GPS equipment in research on travel survey methods

Phase V (2004-2005): Development of a "smart phone" mobile set software development by Doherty, Wilfrid Laurier University:

Sony-Ericsson P900 + TeleText GPS receiver

An external battery sled was built by GeoStats -- very similar in size to the GeoLogger sled

- *Bluetooth or cable communication between phone/PDA and GPS*
- *Battery cycle (continuous): 2-4 hours internal, 36 hours external/sled*
- *Symbian OS-based utility GPSTabs: restarts sometimes needed*
- *GPRS data transmission successfully demonstrated*
- *Prototype Web-based and PDA Prompted Recall completed (paper)*

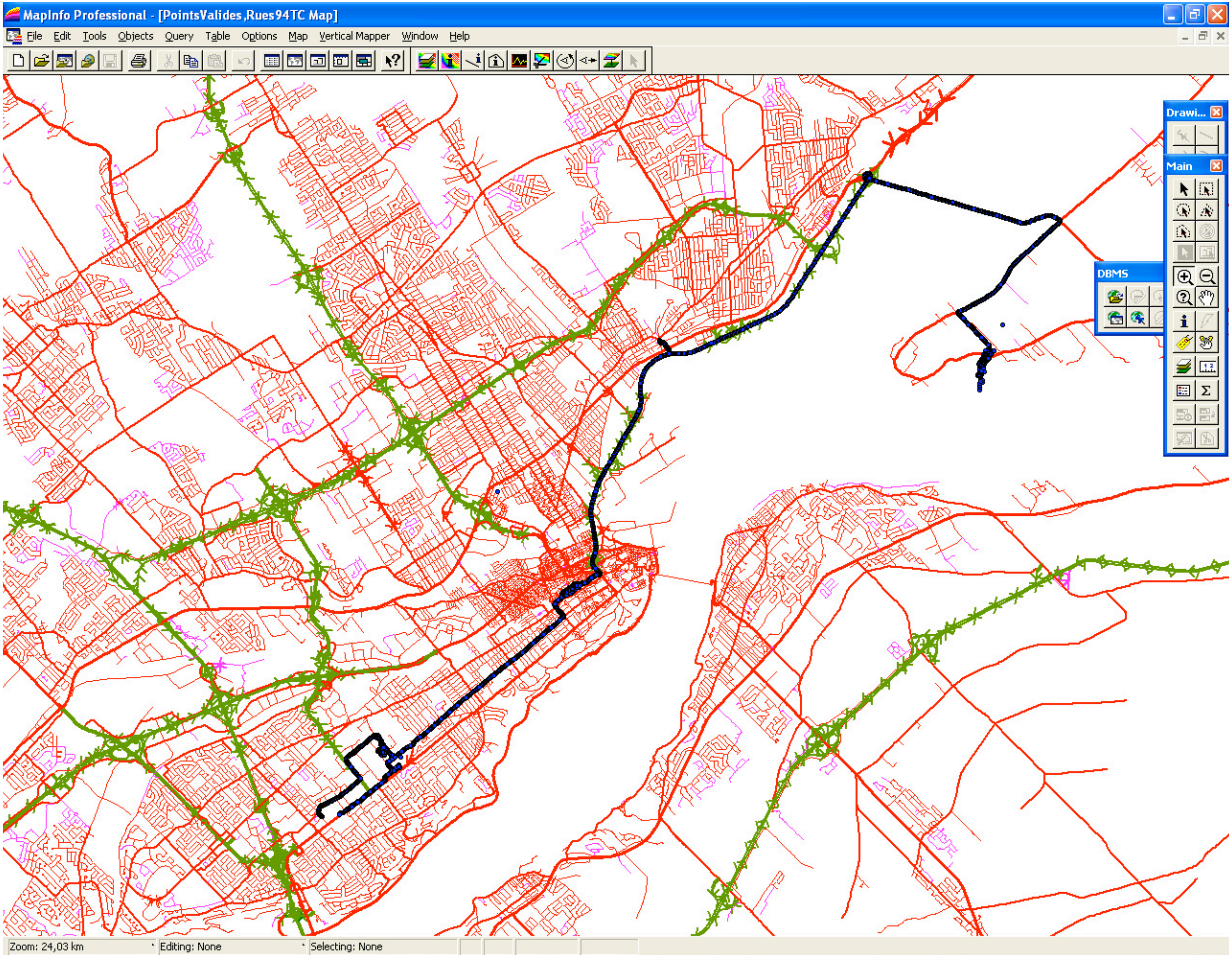
Evolution of the use of GPS equipment in research on travel survey methods

Phase VI (2006 -): Testing and deployment in a Panel Survey of the StepLogger Model 51

Neve ITS Pty, Adelaide, Australia,
in consultation with Stopher, Univ. Sydney

Latest version:
delivered last week!

- ***Miniaturized combination: GPS logger, accelerometer, GSM modem***
- ***Always ON - power management by accelerometer and/or GPS parameters***
- ***Internal battery: cycle extended to more than one day of typical mobility (now testing)***
- ***GPRS data transmission of GPS trace + equipment "events" including geofencing***
- ***Hi-gain antenna: impressive receptivity from pocket or handbag, as good as or better than shoulder placement of antenna on earlier equipment***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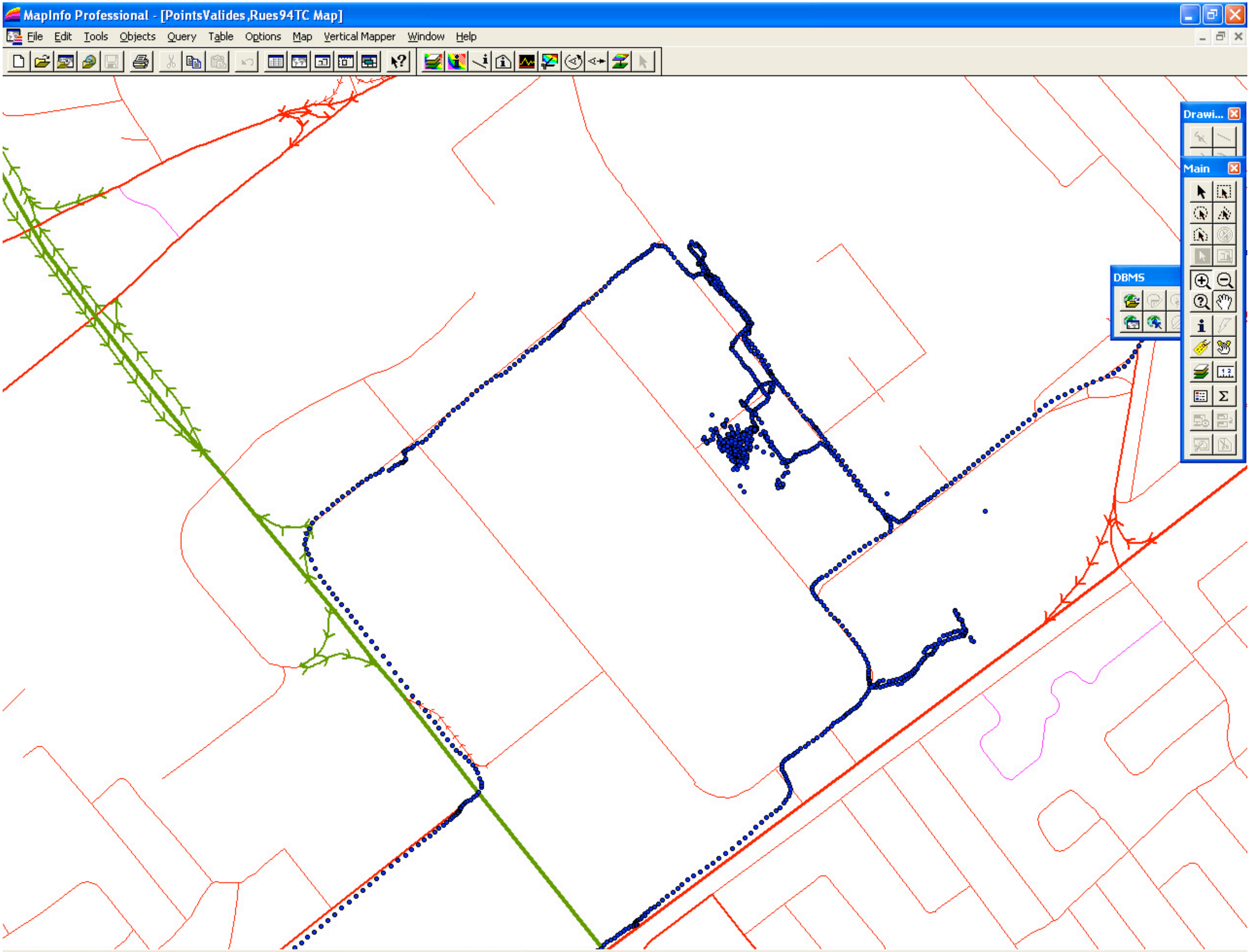
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3. Post-treatment algorithms: current progress with and without processing of GIS data layers

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2000-2002: 1st GEOIDE/ PROCESSUS project GIS data models

- Established many aspects of the needed GIS platforms for Integrated Land-Use, Transport and Environment (ILUTE) models
- Data needs examined for the microsimulation of daily travel
- GPS work focused on extending the period of observation of travel surveys - so on solving data storage, data transmission and power management issues
- Concluded that to shift from vehicle-based to person-based GPS in real travel survey applications:
  - a large software effort was required
  - mobile equipment available at that point (2002) was too immature, but that mobile computing and telephony developments would soon help

2002-2005: 2nd GEOIDE project: An integrated GPS/GIS system for collecting spatio-temporal microdata on urban travel

Three multi-university sub-teams, led by:

1. *Wilfrid Laurier University (Sean Doherty)*
   - Mobile data collection/processing package based on a smart phone
   - Prompted recall interfaces and methods development + test, Web or PDA based
   - Link to activity scheduling surveys -- and also to scheduling aids
2. *Université Laval (Marius Thériault)*
   - GPS error and reception problem classification (empirical work)
   - Pre-processing filtering of GPS traces
   - Initial detection of stops and travel mode transfers
3. *University of Toronto (Amer Shalaby)*
   - GIS-independent software to identify stops, trip segments and modes
   - Link-matching to enhance mode detection using GIS data layers
   - Experimentation with other modelling techniques to enhance mode detection

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The following 16 slides are copied from the 2006 Transportation Research Board presentation by Amer Shalaby of the paper:

An Enhanced System for Link and Mode Identifications for GPS-Based Personal Travel Surveys

S. Y. A. Tsui and A.S. Shalaby

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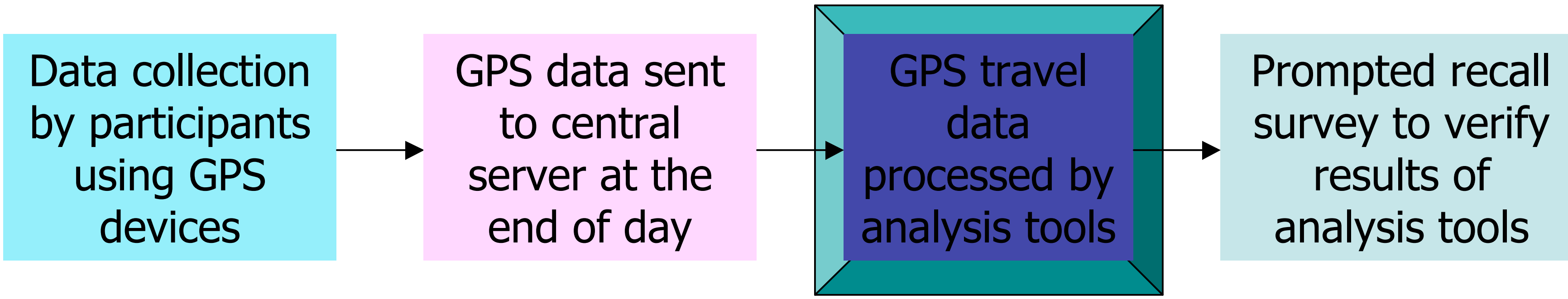
Toronto-Laval sub-teams: objectives



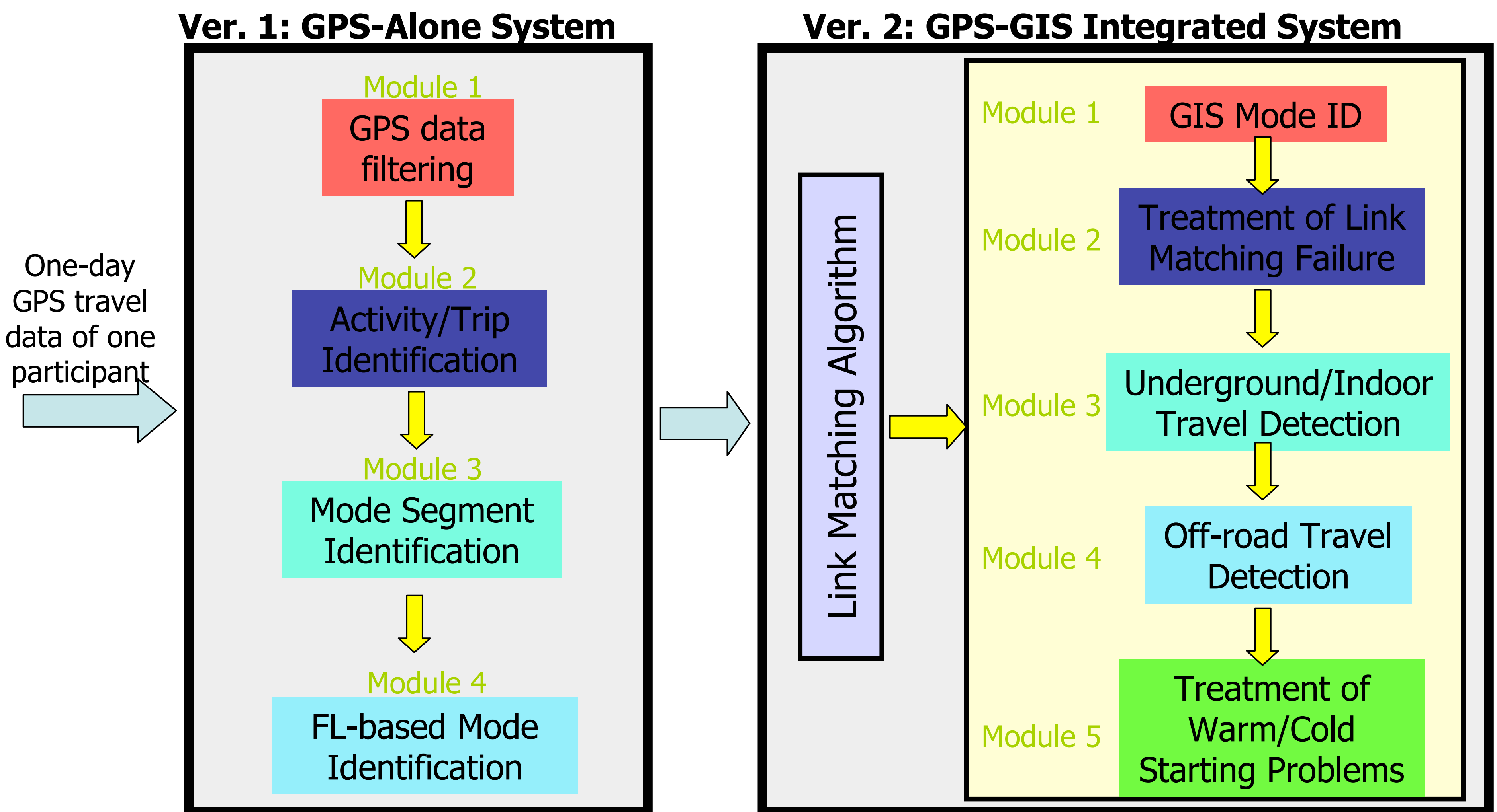
- Develop an interactive analysis system for link and mode identifications of GPS-based survey data
  - Develop a Fuzzy Logic based mode identification algorithm
  - Integrate a recently developed link identification algorithm [Chung, U of T 2003] into the new system
  - Test the system with real GPS data collected in Toronto

Tools

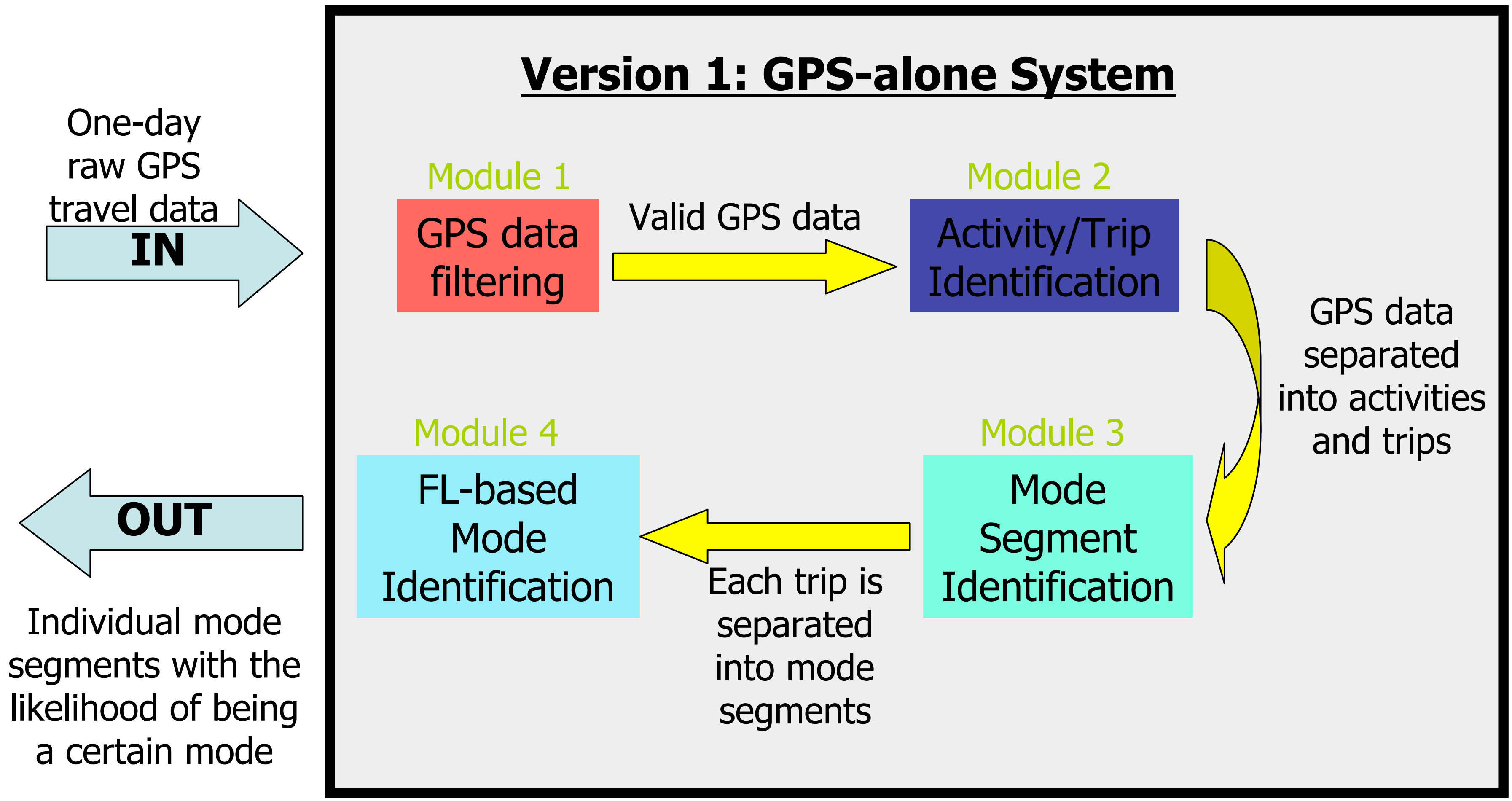
- Hardware:
  - GeoStats Wearable Geologger
- Software:
  - Visual Basic 6.0
  - ArcGIS: ArcMap, ArcObject
  - NEFCLASS-J: neuro-fuzzy classifying software

[GeoStats, 2003]

System Structure



Version 1 – Flow Chart



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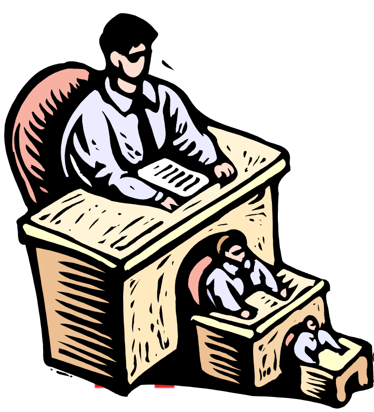
Module 1: Data Filtering

- Rule-based
- Data filters provided by Laval University
- Additional filters for enhancement:
  - Low no. of Satellites (<= 3)
  - High HDOP (> 5)
  - Sudden jump points [Chung and Shalaby, 2005]



Module 2: Activity Identification

During Activity: → **Activity Type:**

- Activity
  - No Signal Loss
    - Outdoor Activity*:
      - Zero-speed GPS traces > 120 sec
  - Signal Loss
    - Short-Duration Indoor Activity:
      - 600 sec > Dwell time > 120 sec
      - GapDist# < 50 m
    - Underground/Indoor Activity:
      - Dwell time > 120 sec
      - GapDist# > 500 m
    - Long-Duration Indoor Activity:
      - Dwell time > 600 sec
      - 500m > GapDist# > 50 m

* Leave GPS device outdoor during other activity

GapDist: distance travelled between last GPS point before signal loss and first GPS point after signal loss

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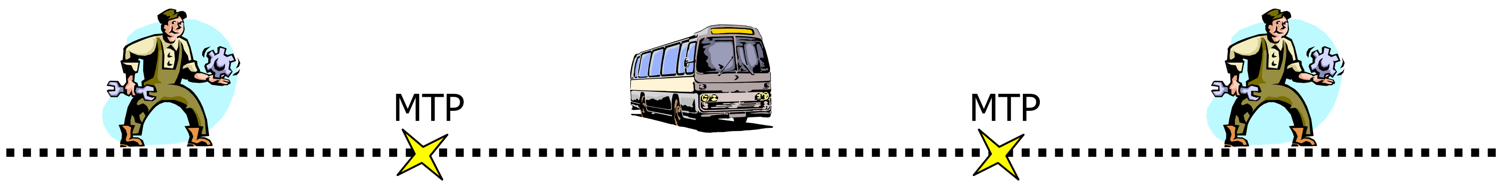
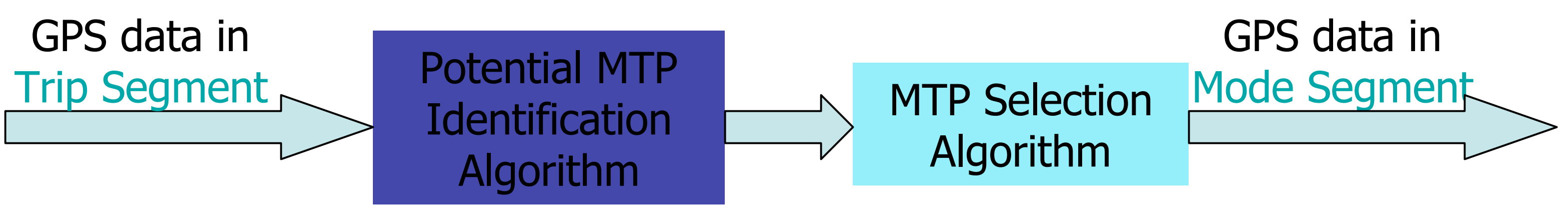
Module 3:
Mode Segment Identification

- Any trip typically involves more than on travel mode



- Divide a trip into mode segments such that each segment consists of GPS points for one mode only
- Separate mode segments by points called "Mode Transfer Point" (MTP)



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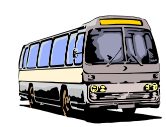
Module 4: Fuzzy Logic Mode Identification

- Fuzzy variables:
  - 95th percentile speed
  - Average speed
  - Median acceleration
  - Data quality (Total Valid Records / Total Records)

- Membership functions:
  - Triangular membership functions
  - Parameters found by neuro-fuzzy logic software NEFCLASS

- Fuzzy inference system:
  - 17 decision rules
  - Max-min inference method



- Mode classifications: walk, cycle, bus, auto

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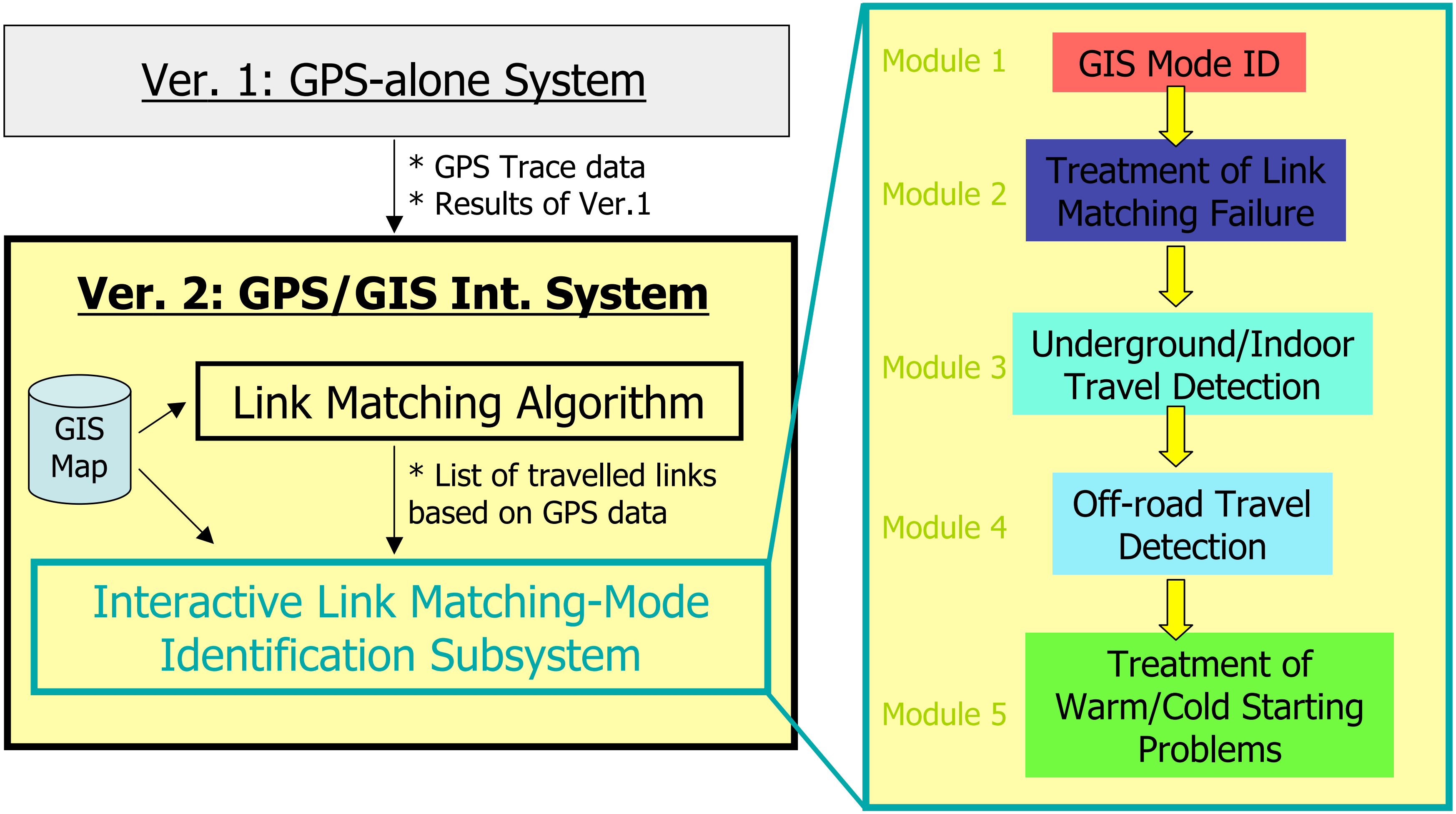
Version 2 GPS/GIS Integrated System



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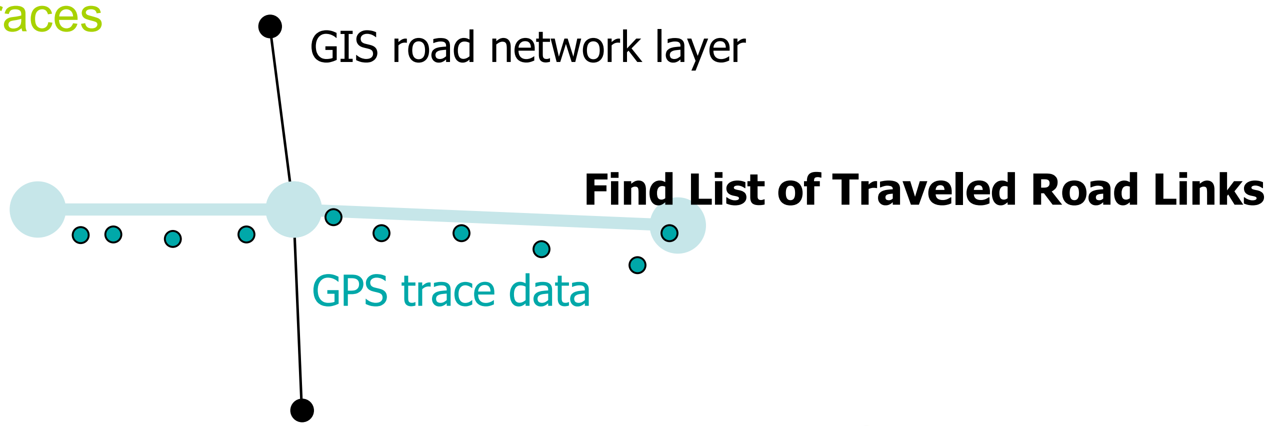
Version 2 Link Matching Algorithm

- Developed by Chung and Shalaby (2005)
- Link Matching Process:
  - Microscopic level
  - Finds link w/ closest azimuth, distance to GPS points
- Post-Processing Process:
  - Macroscopic level
  - Eliminates mismatching of links that do not follow flow of GPS traces



Module 1: GIS Mode Identification

- Inputs:
  - Results of Ver 1 & Link Matching Algorithm
  - GIS topology info (transit routes)
- Differentiate transit modes from others based on availability of surface transit routes
- Mode assignments:

Membership > 0.4			DQ < 0.7	Route is found		No Route is found	
Cycle	Bus	Auto		Mode1	Mode2	Mode1	Mode2
No	Yes	No	--	B/SC	--	A	--
No	Yes	Yes	--	B	A	A	--
Yes	Yes	No	--	B/SC	C	C	--
Yes	No	No	Yes	B/SC	C	C	--

- Other mode segments: top 2 travel modes with highest membership value assigned in FL mode ID in Version 1

Module 2: Treatment of Link Matching Failure

- Goal: fill a gap between GPS points ➔ find set of matching links connecting start and end of gap
- Route-based treatment
  - For segments with transit route found
  - Select links along selected transit route
- Link-based treatment
  - Scenario 1: Poor GPS data
    - For segments without any matched links
    - GPS traces divided into segments with same heading
    - Find link with closest orientation as heading
  - Scenario 2: General
    - 6 cases available for finding matched links

Module 3: Underground/Indoors Travel Detection

- For segments categorized as undergrd/indoor activity in Ver. 1
- Detect underground/indoor travel routes, e.g. TTC subway
- Methodology:
  - 2 end points: last GPS point *before* activity & 1st GPS point *after* activity
  - Within 630m (0.004 decimal degree) buffer of undergrd/indoor travel route entrances (e.g. subway stations)
- Assignment:

No. of end points within buffer (630m)	Mode 1	Mode 2
2	Subway	--
1	Subway	Signal Loss
0	Signal Loss	--

Module 4: Off-road Travel Detection

- For walk and cycle mode segments
- Characteristic:
  - GPS points with steady heading directions without matched links

Module 5: Treatment of Warm/Cold Starting Problems

- No GPS data collected during satellite acquisition (warm/cold start)
- Treatment after subway travel
  - Gap filling between exit subway station & 1st link of following mode segment
- Treatment after activity
  - Gap filling between last link of last mode segment & 1st link of next mode segment
- Gap filling uses General Case in the "Treatment of Link Matching Failure" Module

Test Results

- Collected Data: Total 58 one-day trips in Toronto Area
  - For Version1: 28 trips were used to calibrate the Fuzzy model
- Activity identification (Version1)
  - All activities are detected
  - Results show some overestimation of activities for traffic congestion, long traffic signal
- Mode identification (Version1 & Version2)
  - Good detection rates
    - Version1 (91%) and Version2 (94%): 3% Improvement
  - Good detection rates for Auto and Walk
  - Lowest detection rate for Bus
- Link identification (Version2)
  - Good detection rate (94%)

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4. A proposed architecture for Location Aware Device (LAD) aided personal travel surveys

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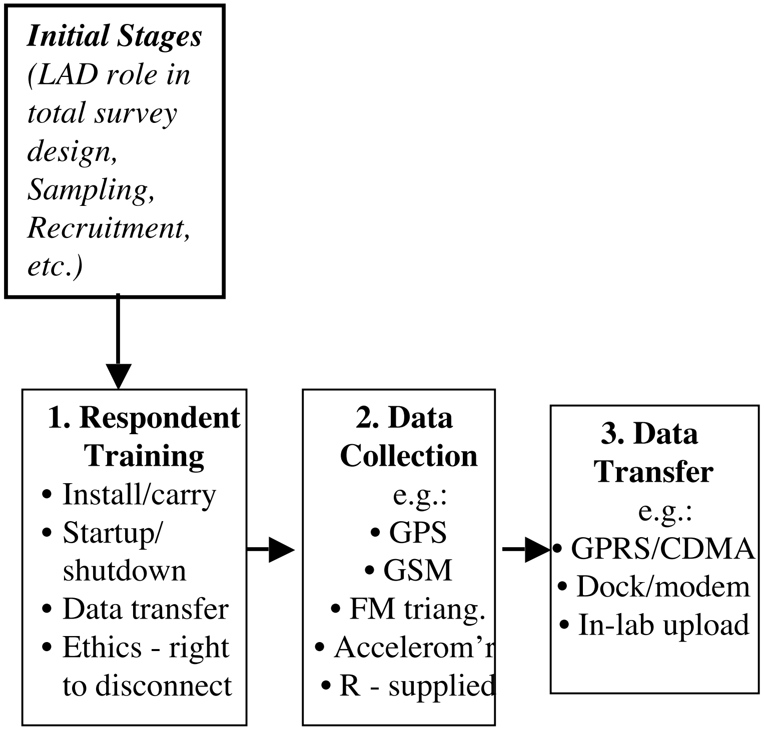

Stages of Location/time Aware Device aided surveys

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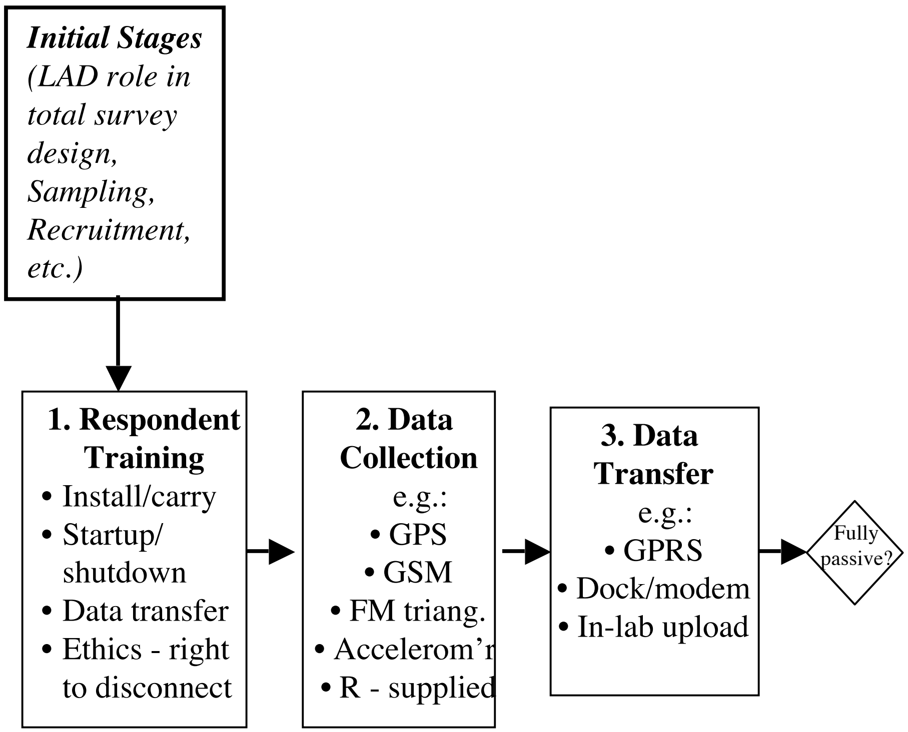

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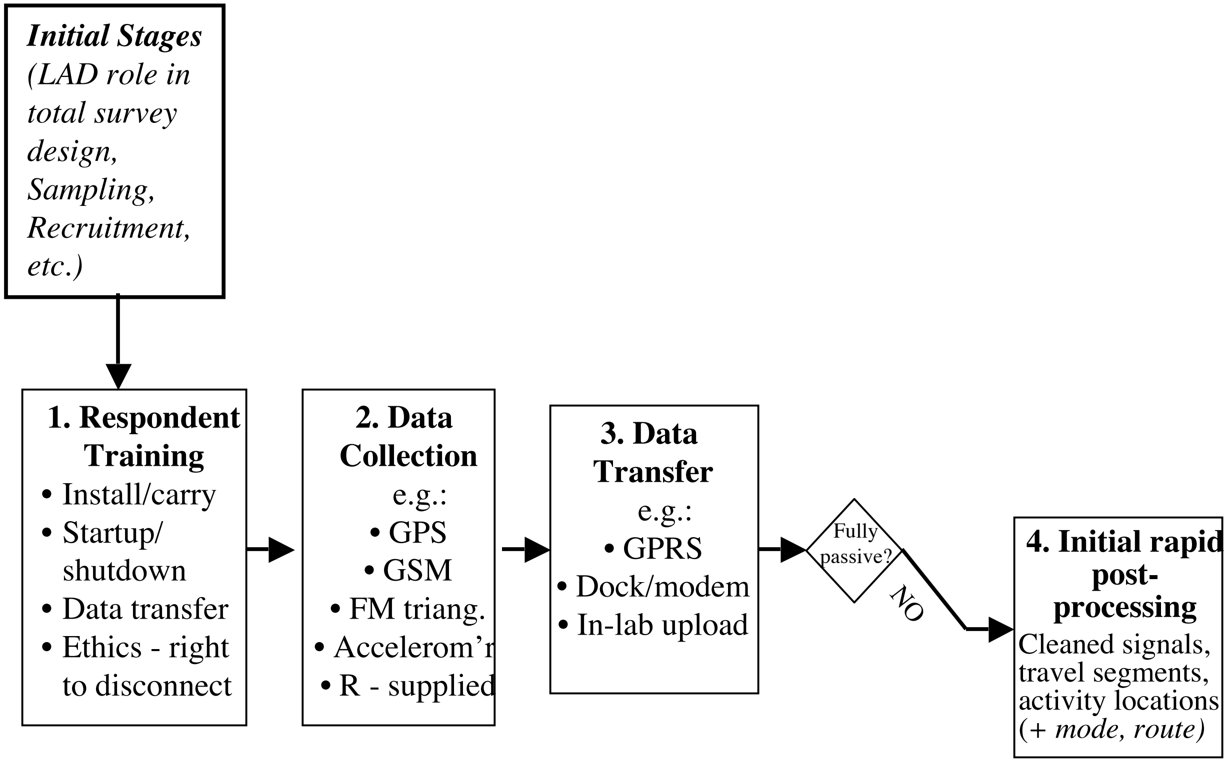

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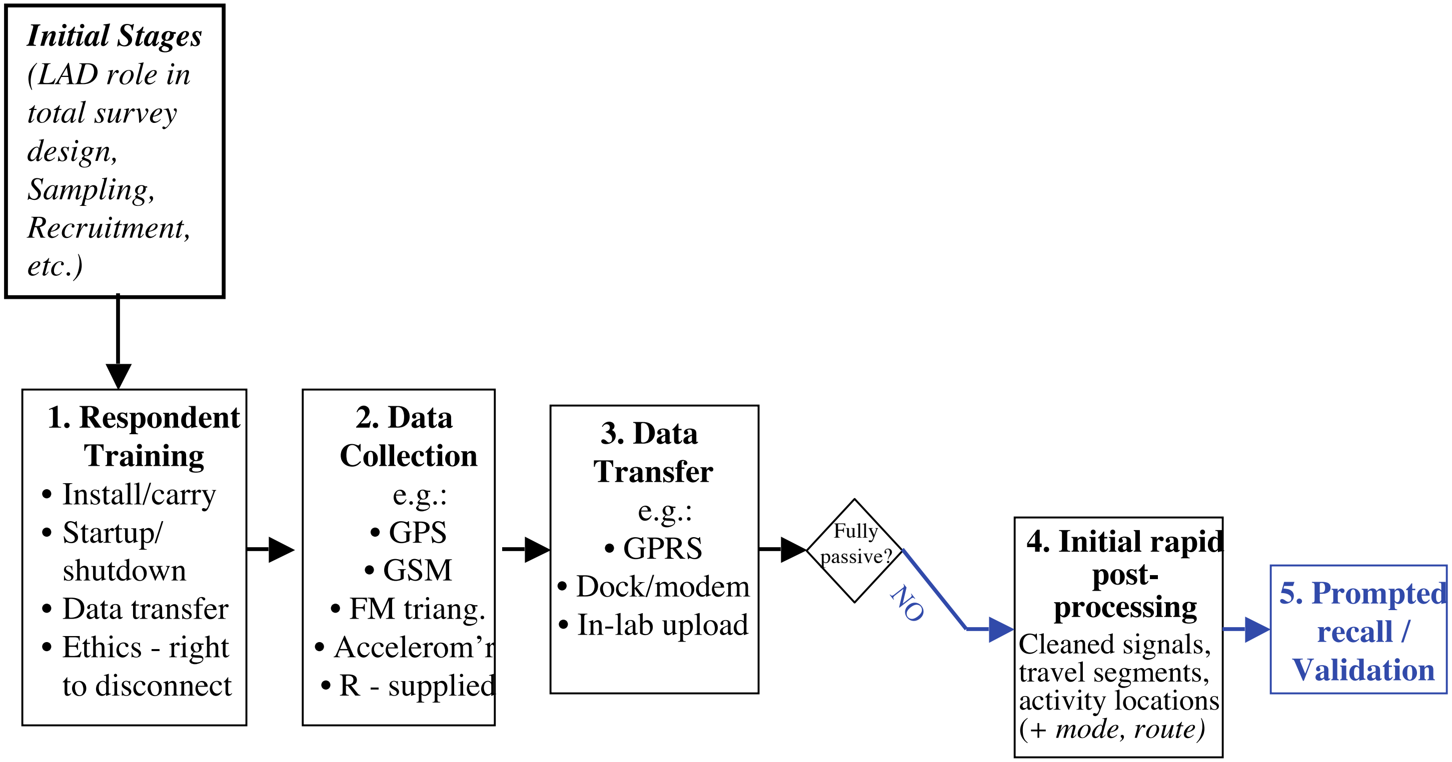

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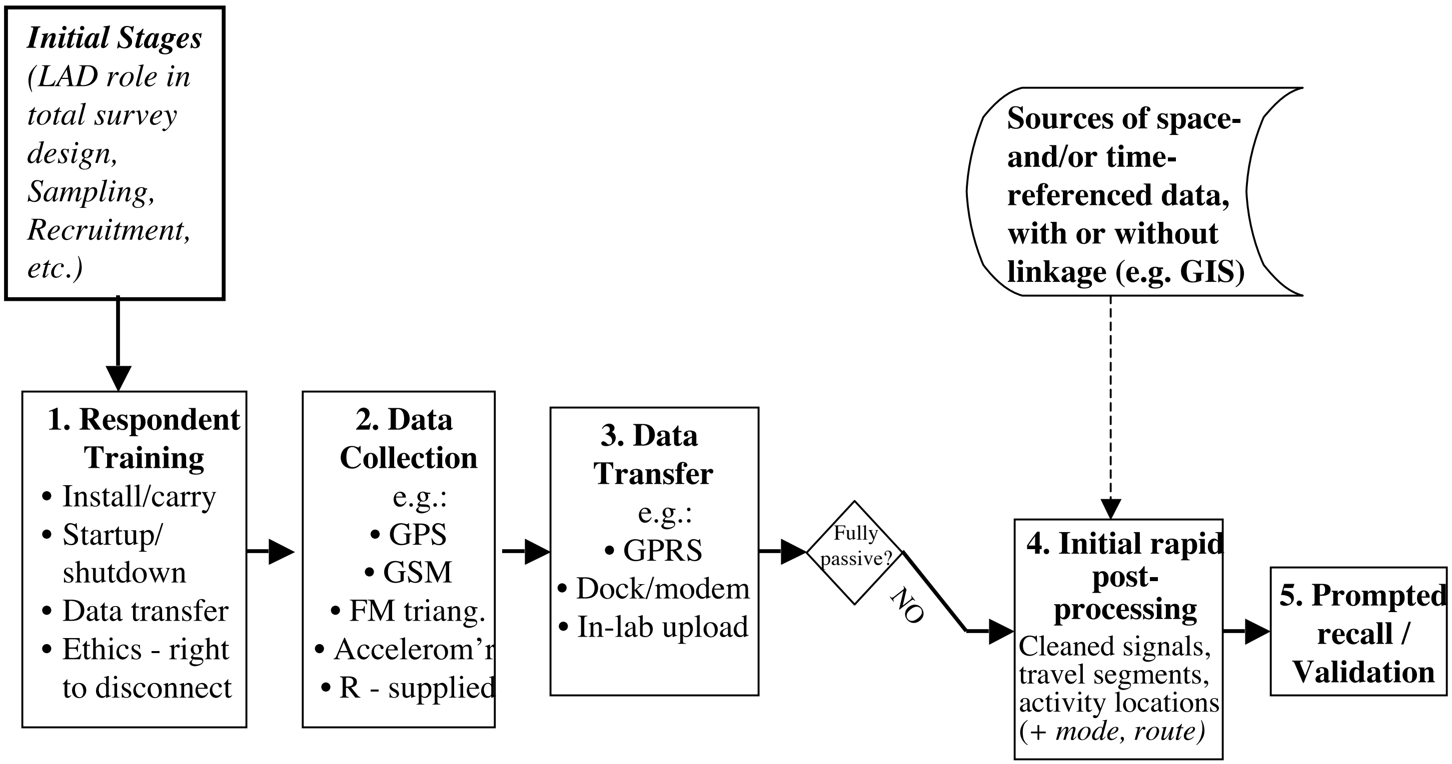

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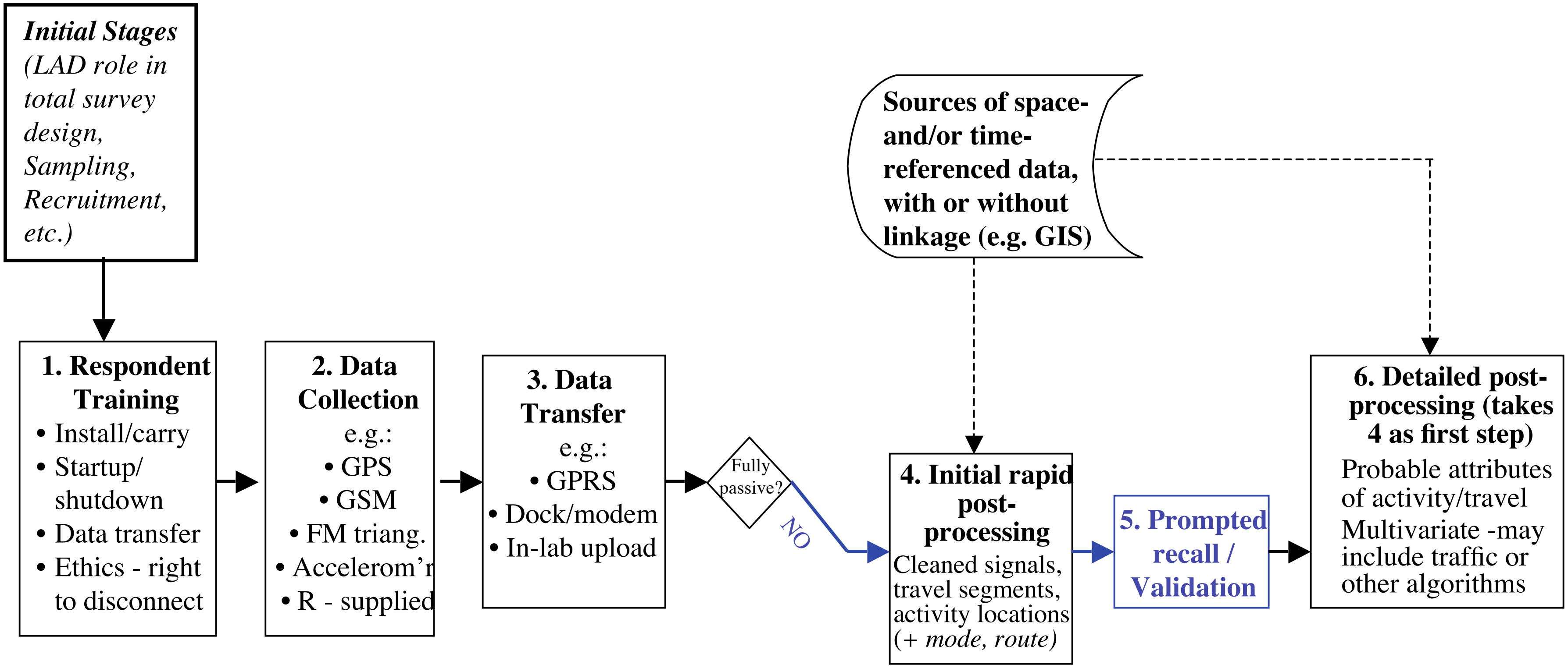

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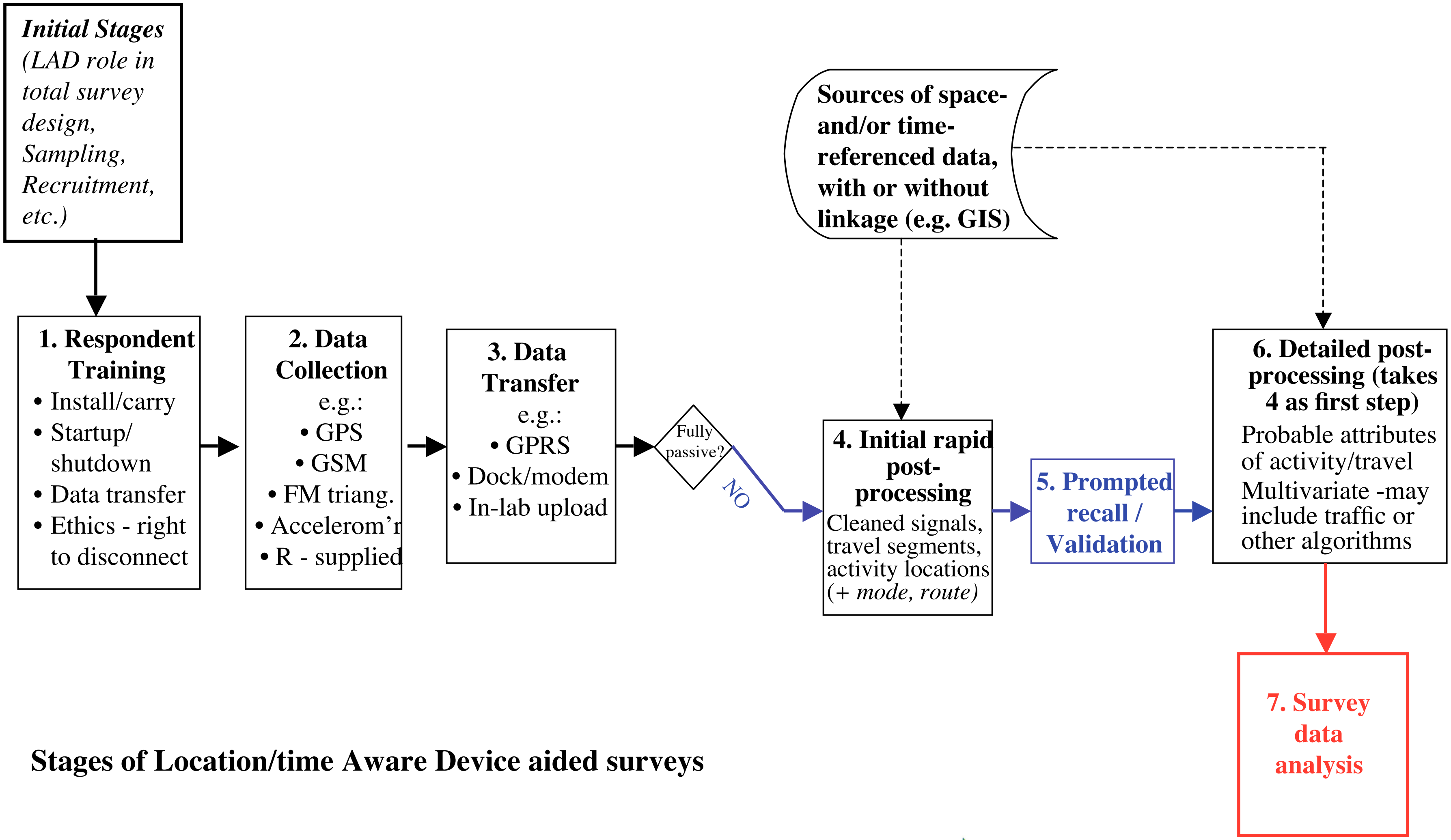

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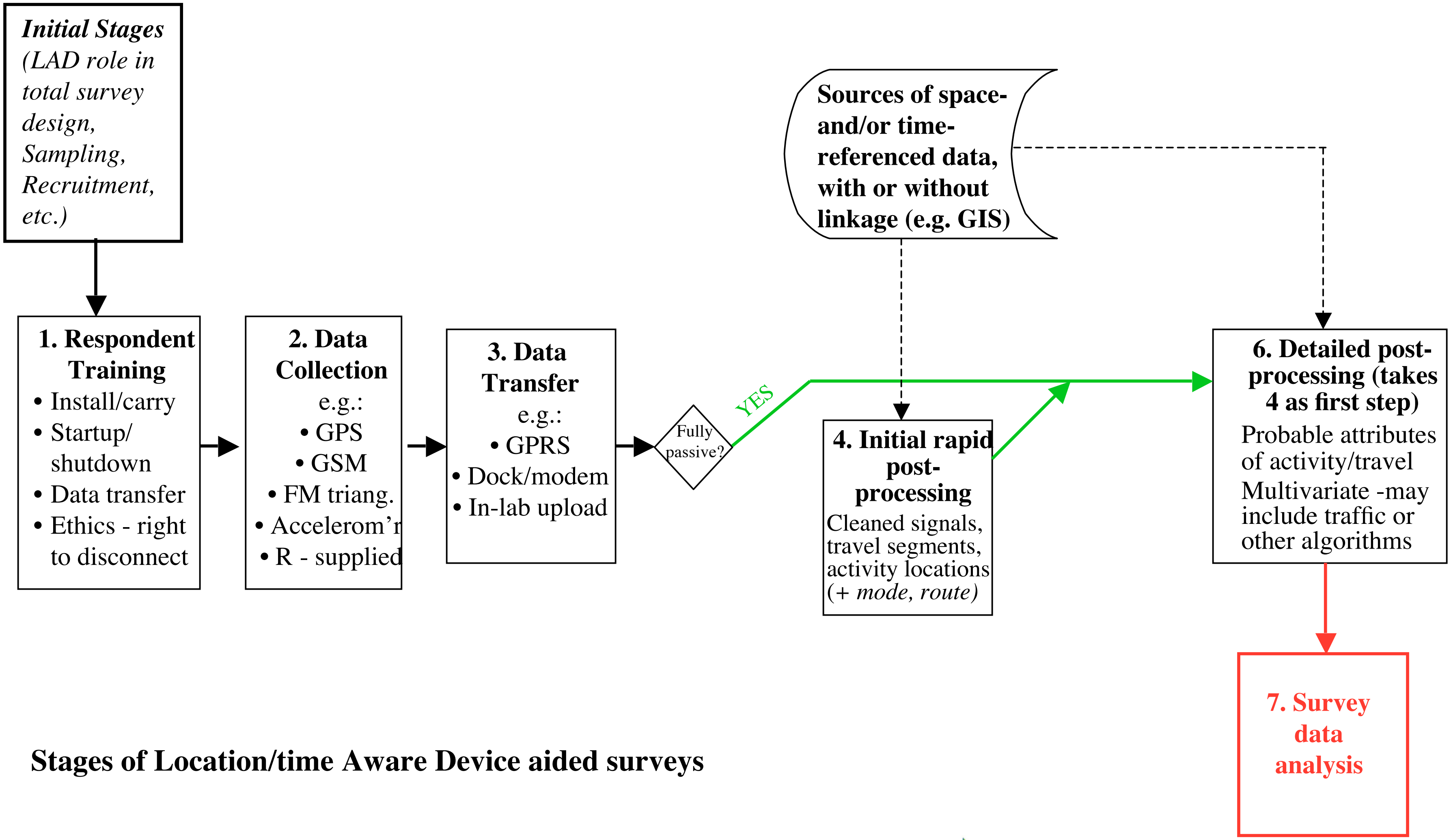

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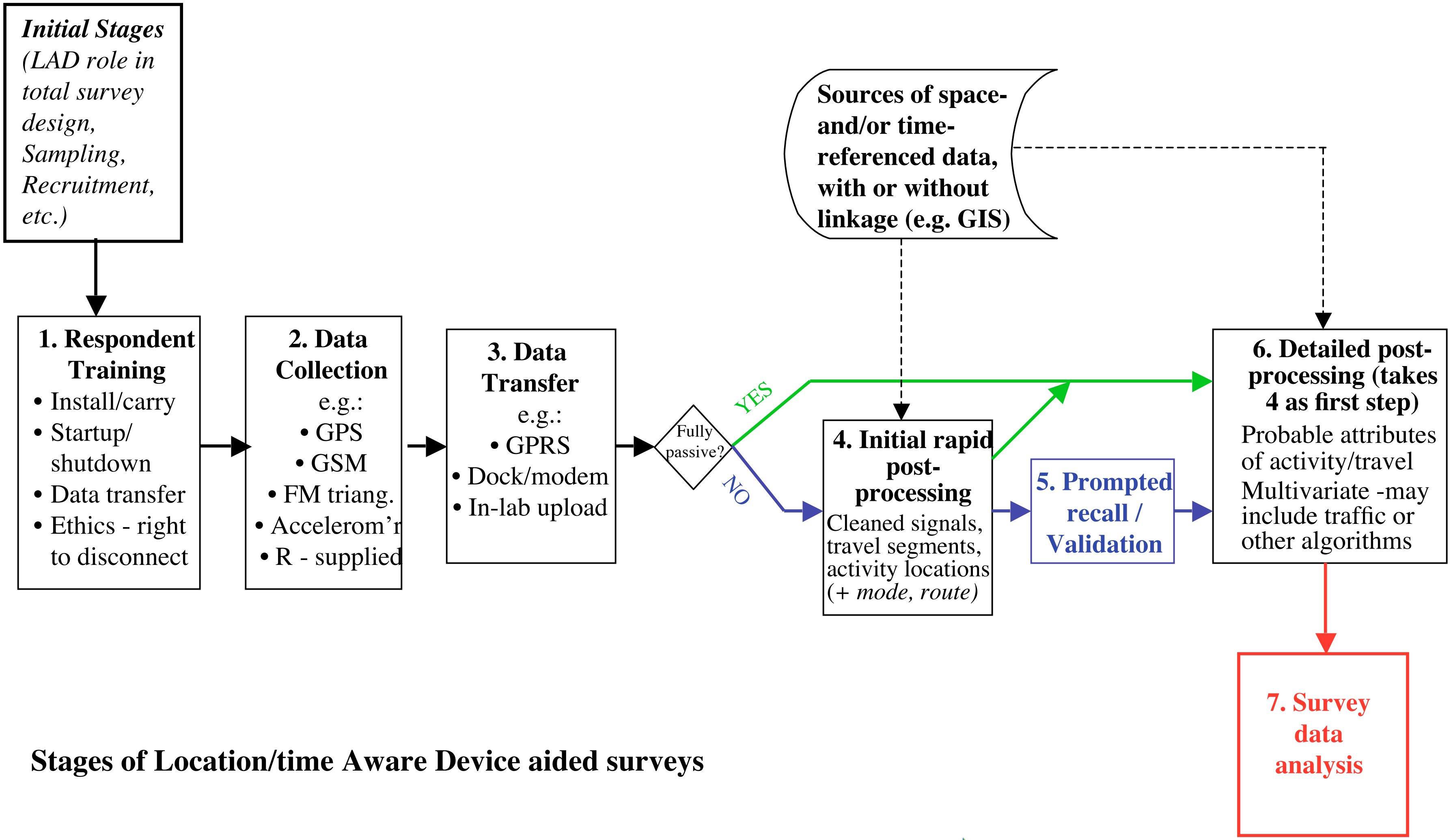

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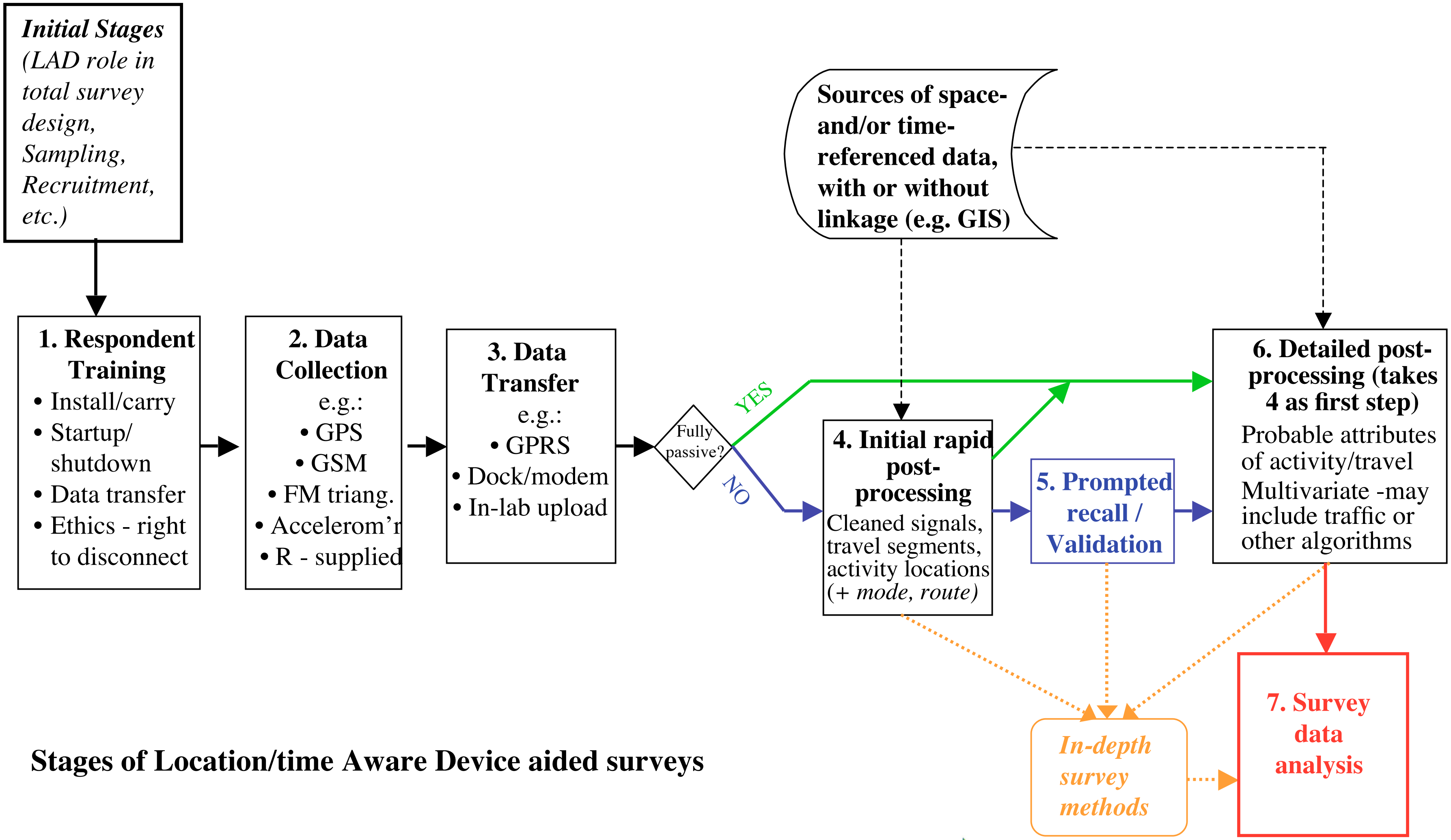

Stages of Location/time Aware Device aided surveys

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5.

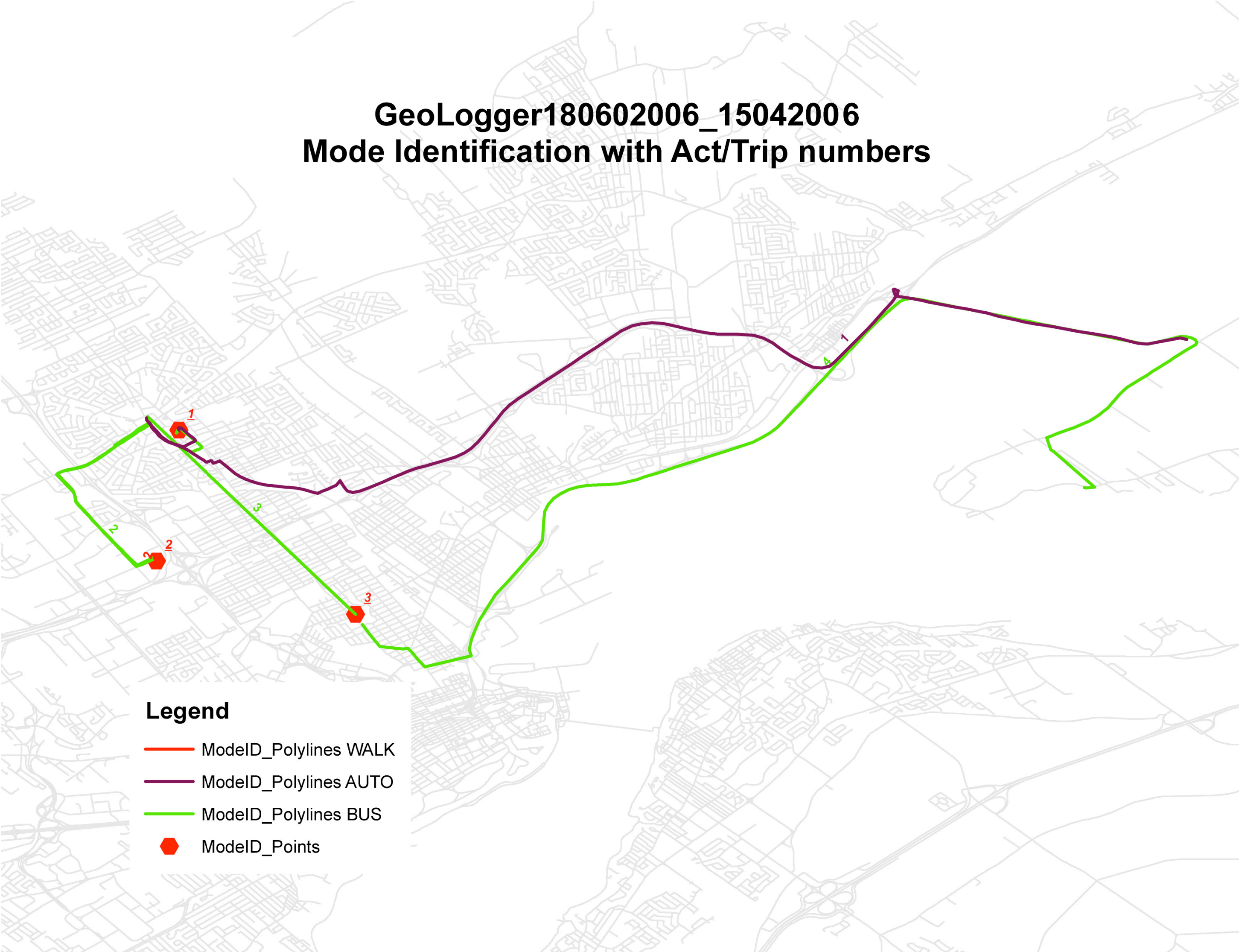
Follow-on work by the PROCESSUS Network:

- what can we operationalise now?
- where are we going?

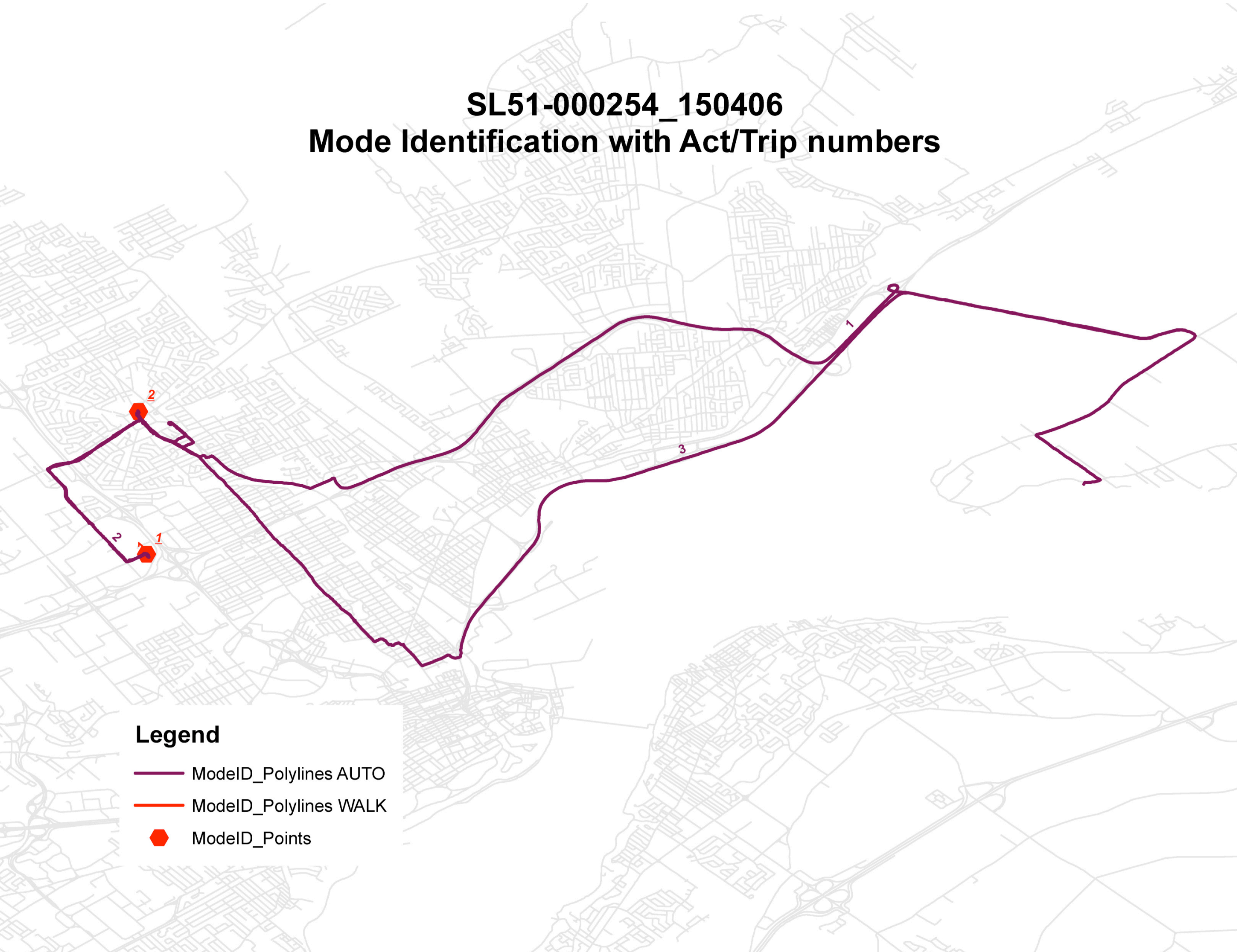
Current priorities

- Field testing of the StepLogger with accelerometer (real effects of different settings of selectable parameters)
- Installation of the Neve “GSM” server in Québec City
- Minor revision of stop, travel segment and mode-detection algorithms to take advantage of new data profiles resulting from:
  - Improved reception at activity locations
  - Consequences of sleep/wake behaviour with accelerometer
- Deployment of the system (with GSM transmission and Prompted Recall) in a subsample of an ongoing Québec City Panel Survey of spatial and temporal organisation, by households, of their activities and associated travel

GeoLogger180602006_15042006
Mode Identification with Act/Trip numbers



SL51-000254_150406
Mode Identification with Act/Trip numbers



StartID	EndID	StartHour	EndHour	Act	Trip	Duration	SigLoss	SL_EDist	RetRec	TotRec	AvgSpd	Spd95	PosAc50	Walk	Cycle	Bus	Auto
1	765	142045	145004		1	1759		0	659	764	48.43247344	106.05	1	0	0	0	1
765	1123	145004	150409		1	845		0	319	358	28.5830721	56	1.625	0	0	0	1
1123	1186	150409	153202		1	144		0	46	63	4.239130435	7	0.75	0.870150689	0	0.129849311	0
1186	1187	153202	153204	1		1529	Vrai	78.55144481	1	1	0	0	0	0	0	0	0
1187	1485	153204	155353		2	831		0	253	298	27.21343874	55	1.5	0	0	0.089518668	0.910481332
1485	1486	155353	155355	2		478	Vrai	0	1	1	0	0	0	0	0	0	0
1486	2337	155355	162434		3	1837		0	821	851	51.1047503	97.95	1.5	0	0	0	1

Chronological summary output from post-processing (extract)

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CRAD

Log : SL51-000254_150406 Date : 04-15-2006

Start (UTC Time)	End (UTC Time)	Duration (min.)	Stop / Trip	1st Probable Mode	2nd Probable Mode	GPS Signal
2:20:45 PM	2:50:04 PM	29:19	Trip #1	Auto		
2:50:04 PM	3:04:09 PM	14:50	Trip #1	Auto		
3:04:09 PM	3:32:02 PM	2:24	Trip #1	Walk	Bus	
3:32:02 PM	3:32:04 PM	25:29	Activity #1			Signal Lost
3:32:04 PM	3:53:53 PM	13:51	Trip #2	Auto	Bus	
3:53:53 PM	3:53:55 PM	7:58	Activity #2			Signal Lost
3:53:55 PM	4:24:34 PM	30:37	Trip #3	Auto		

Simplified chronological summary for use by interviewers during Prompted Recall

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GRIMES

CRAD

a) Initial results of event detection algorithm, showing color-coded event attributes (see text for explanation)	b) Completed diary after filling gaps, confirming all attributes, updating location/activity labels, and adding involved persons/passengers.

[Tue, Jul 6, 2005] [Previous | Today | Next]

Time	Event	Location	Other	
8 Hours 10 Minutes [Fill]				
8:10 AM 8:28 AM	Activity	Residential		☒
8:28 AM 8:44 AM	Trip: Bus	N/A		☒
8:44 AM 9:05 AM	Activity	UNIVERSITY		☒
9:05 AM 9:15 AM	Trip: Auto	N/A		☒
9:15 AM 9:33 AM	Activity	Commercial		☒
9:33 AM 9:55 AM	Trip: Auto	N/A		☒
9:55 AM 10:14 AM	Activity	Resource and Industrial		☒
10:14 AM 11:00 AM	Trip: Bike	N/A		☒
11:00 AM 5:48 PM	Activity	Residential		☒
5:48 PM 6:00 PM	Trip: Auto	N/A		☒
6:00 PM 6:24 PM	Activity	Resource and Industrial		☒
6:24 PM 6:27 PM	Trip: Auto	N/A		☒
6:27 PM 6:57 PM	Activity	OTHER		☒
6:57 PM 7:13 PM	Trip: Auto	N/A		☒
7:13 PM 11:59 PM	Activity	Residential		☒

[Tue, Jul 6, 2005] [Previous | Today | Next]

Time	Event	Location	Other	
12:00 AM 8:28 AM	Activity: AT HOME	My House		☒
8:28 AM 8:44 AM	Trip: Auto	N/A	☺	☒
8:44 AM 9:05 AM	Activity: Work/School: Work	U. of Waterloo		☒
9:05 AM 9:15 AM	Trip: Auto	N/A	☺	☒
9:15 AM 9:33 AM	Activity: Shopping: Household	Conestoga Mall	☺	☒
9:33 AM 9:55 AM	Trip: Auto	N/A	☺	☒
9:55 AM 10:14 AM	Activity: Services: Post office	Post Office	☺	☒
10:14 AM 11:00 AM	Trip: Auto	N/A	☺	☒
11:00 AM 5:48 PM	Activity: Work/School: Work	My House		☒
5:48 PM 6:00 PM	Trip: Auto	N/A	☺	☒
6:00 PM 6:24 PM	Activity: Cat sitting	Cats House	☺	☒
6:24 PM 6:27 PM	Trip: Auto	N/A	☺	☒
6:27 PM 6:57 PM	Activity: Shopping: Other	Best Buy	☺	☒
6:57 PM 7:13 PM	Trip: Auto	N/A	☺	☒
7:13 PM 11:59 PM	Activity: AT HOME	My House		☒

Interactive self-administered Prompted Recall interface, web or (later) PDA, developed by Doherty et al

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What can we operationalise now?

- For the first time, battery cycles of “pocketable” devices (better batteries, better power management) allows “real respondent” deployment -- but with nightly recharging
- In urban region applications, detection algorithms for stops, travel segments (including interchanges) and travel modes perform in the 80-90% range, providing that some calibration is done on local characteristics (e.g. fluidity of public and private modes)
- Prompted Recall feasible with algorithm input
- In longer distance/NTS applications, infrequent GPS sampling rates combined with efficient power management opens new opportunities
- BUT expect a “beta test” environment for some time to come….

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Future priorities (not yet funded)

- More classes of LAD/GPS-aided survey (NB: physical activity)
- Passive track is very promising in the longer term, assuming cheap "always on" devices
- Joint strategy for the active track and the passive track:
  - Shorter term focus on Prompted Recall as stand-alone method, but also as an input to learning algorithms that should be incorporated in post-processing
- Major revision of stop, travel segment and mode-detection algorithms to use accelerometer *data*
- Activity type estimation using land-use data
- My proposal: develop a multi-scale (time/space) logger package that shifts between urban modes and inter-urban modes using geofencing technologies

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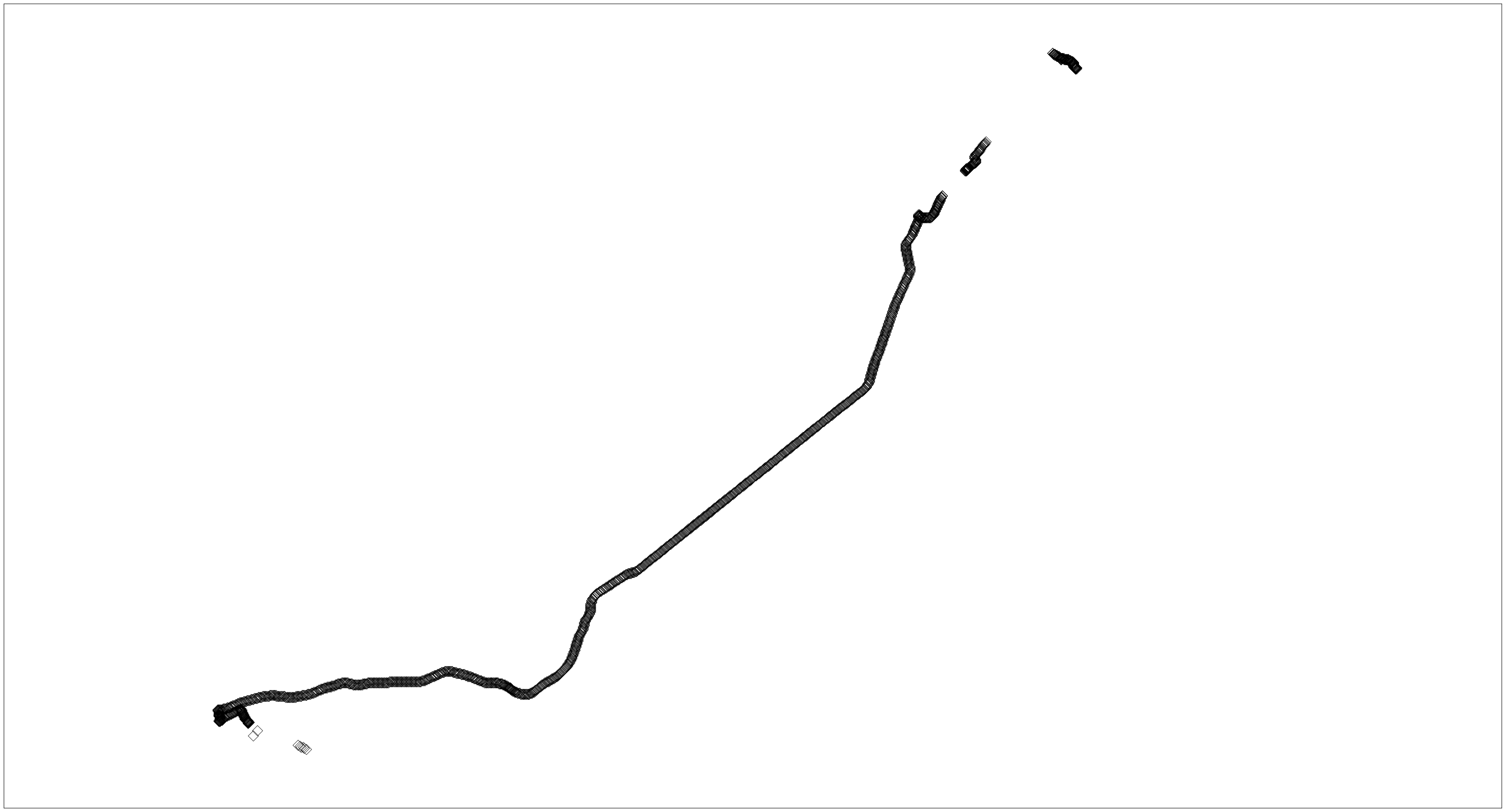

To keep in mind..

- Data transmission from private individuals is illegal in some countries
- The privacy issues for GPS data are sensitive problems that require sensitive solutions:
  - Written consent overcomes most concerns about collection
  - Microdata archiving constrained or sunsetted in some countries
  - Special care is needed not to publish confidential details such as home location (but situation not much worse than for CATI geocoding)
  - Access to/use of “my” data: alibis, speeding defence, etc.
- Are we ignorant of relevant technologies developed by the asset-tracking, defence and security industries?

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Recent papers, 2006 Meeting of the Transportation Research Board

An Enhanced System for Link and Mode Identifications for GPS-Based Personal Travel Surveys

S. Y. A. Tsui and A.S. Shalaby

Field Testing of a Person-Based GPS Tracking Device to Support Internet-Based Prompted Recall Diary with automated GPS Activity-Travel Detection: System Design

S.T. Doherty, D. Papinski and M.E.H. Lee-Gosselin

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