WP 2.4 : Sustainable Refrigerated Road Transport

Christina Francis-Rowe
Centre for Air Conditioning and Refrigeration
London South Bank University
Email: francc17@lsgu.ac.uk

Loughborough University,
June 29, 2015
WP2.4 Sustainable refrigerated road transport (RRT)

Background
• UK primary food distribution by RRT uses 40% more energy than non-refrigerated vehicles
• Environmental Impact
  • Indirect emissions -
    • Transportation - 2 Mtonnes of indirect CO₂ emissions from the engine alone.
    • Refrigeration - ????
  • Direct emissions -
    • RRT units leak up to 30% of their total refrigerant charge per year
    • System Durability & Reliability

Deliverables
• Development of a model to investigate direct and indirect emissions
• Optimising system performance
Research objectives

1. Investigate different types RRT vehicle technologies

2. Analyse maintenance and leakage records to:
   a) Identify problematic components/ sources of refrigerant leakage
   b) Suggest generic solutions for leak tight systems

3. Develop a model to;
   a) Estimate direct/ indirect carbon emissions
   b) Evaluate the effectiveness of various concepts

4. Measure actual RRT data

5. Validate and optimise model

2. Analyse maintenance and leakage records

A refrigerant leakage and analysis tool has been developed

- MS Excel Based
- Captures essential information
- Itemizes and maps each fault to distinct categories and sub-components.
- Easily sort data and analyse to determine where leaks or faults are commonly found.
2. Analyse maintenance and leakage records

A refrigerant leakage and analysis tool has been developed

Statistical analysis will then be performed to determine frequency (%) and total refrigerant mass added (kg) of the following:

• per fault category-type;
• per fault location-refrigeration system level;
• per fault location refrigeration component level;
PART 1-RESEARCH STUDY

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Existing historical data available in paper or electronic base on service/maintenance records on refrigerant leakage incident reports.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparatus/Equipment:</td>
<td>N/A</td>
</tr>
<tr>
<td>Parameters i.e. data to be collect:</td>
<td></td>
</tr>
<tr>
<td><em>Incident/repair:</em> date, work summary report</td>
<td></td>
</tr>
<tr>
<td><em>Incident work summary report:</em> brief description of fault type, fault/leak location, repair service action and quantity net refrigerant added (kg)</td>
<td></td>
</tr>
<tr>
<td><em>Vehicle data:</em> make and model, vehicle age, mileage (km), fuel type, drive mechanism for refrigeration system</td>
<td></td>
</tr>
<tr>
<td><em>Refrigeration unit:</em> installation date, unit and series type, type of refrigerant, quantity refrigerant charge (kg)</td>
<td></td>
</tr>
<tr>
<td>Estimated Duration</td>
<td>8 months</td>
</tr>
</tbody>
</table>
3. Develop a model to estimate carbon emissions

A preliminary model to predict the performance of RRT systems has been developed.

- MS Excel Mathematical model
- Focuses on typical last-mile RRT vehicle (i.e. small vans to medium rigid refrigerated trucks) used for urban distribution.
- Calculates relative proportion of various refrigeration heat loads and corresponding indirect carbon emissions:
  
  i. Wall transmission  
  ii. Natural infiltration due to gaps, cracks  
  iii. Door infiltration  
  iv. Product load  
  v. Other loads such as evaporator fans
3. Develop a model to estimate carbon emissions

i. Wall transmission
ii. Natural infiltration due to gaps, cracks
iii. Door infiltration
iv. Product load
v. Other loads such as evaporator fans
3. Develop a model to estimate carbon emissions
Challenges and solutions

Issues with direct drive RRT units:

- Large amount of heat entering during door openings
- Refrigeration system stops working when vehicle stops
  => system is off when load is at its highest
- Running time between stops may be short
  => time insufficient for temp pull-down

Common solutions include:

- Oversize unit; use door protection; employ a hybrid system

Next immediate steps

- Continue development of Excel Based model to incorporate transient parameters
- Measure actual RRT data
Project Plan flow chart

Conduct Prelim Study & Data Analysis I → Develop Model → Collect Data & Analyse → Validate & Optimize Model → PhD Thesis → Report for Transport Industry
### 4. Measure Actual RRT Data

<table>
<thead>
<tr>
<th><strong>PART 2-RESEARCH STUDY</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Source:</strong></td>
</tr>
</tbody>
</table>
| *Electronically available telematics software and/or manual-paper-based logistic records*  
| *Otherwise directly measure key parameters on the refrigerated vehicle* |
| **Apparatus/Equipment:** |
| *For readily available data: N/A*  
| *Otherwise commercially available temperature monitoring equipment will be used.* |
| **Parameters i.e. data to be collected and/or measured:** |
| **Environment/weather details:** |
| **Journey/time details:** |
| **Product details:** |
| **Refrigerated vehicle details:** |
| • Vehicle/Engine |
| • Insulated body  
| • Refrigeration unit |
| **Estimated Duration:** |
| 15 days for actual data collection  
| 1 month for data analysis |
4. Measure Actual RRT Data

**PART 1 Refrigerant Leakage Study**
Make arrangements:
- Select vehicles to survey
- Collect historical data

**PART 2 Energy Efficiency Study**
Make Arrangements for:
- Selection of vehicles to survey
- Installation of thermocouples and pressure transducers
- Collection of operational data

- Establish target group contact
- Acquire verbal consent
- Send Invitation Letter
- Obtain company endorsement letter and drivers consent letter for access to commercial data

- Check data consistency, liaison with companies to rectify anomalies
- Assign pre-defined study codes
- Protect electronic files with password
- Transfer raw historical and operational data to main investigator

- Analyse historical and operational data
- Compare field performance with predicted model results
- Refine previously developed model
- Prepare industrial report on research
- Share reports with participants

*- Measures to address ethical concerns
**London South Bank University**

**Project Schedule**

- **Develop Model**: May 2014 - Jan 2016
- **Data Collection**: May 2015 - Aug 2015
- **Data Analysis**: Sept 2015 - Jan 2016
WP 2.4 Deliverables

• Internal report on leakage - Feb 2014, August 2014


• LSBU summer school conference June 2014, June 2015

• Internal report on modelling platforms - August 2014, Nov 2014

• LSBU ethics application approval - Jan 2015

• Conference paper submission for the 24th IIR -ICR 2015 - April 2015

• Impact: Manufacturer are currently changing system design to minimize leakage
SUMMARY – RRT Research

1. **Refrigerant leakage analysis tool**-
   
   • Investigate where leaks are commonly found in RRT systems in an effort to reduce leakage and aid in F-gas compliance.

2. **Performance model**-
   
   • Collect and analyse operational data for RRT systems
   
   • Validate and optimise performance model
   
   • Investigate strategies to improve energy efficiency and reduce carbon emissions