DOES MOBILE CONSOLIDATION SOLVE THE TRADITIONAL CONSOLIDATION CENTRE CONUNDRUM? A FEASIBILITY STUDY IN THE CONTEXT OF UK HEALTHCARE

INTRODUCTION

The convergence of increasingly larger numbers of people and resources within cities is creating a dichotomy between increasing demand and otherwise limited urban freight transport networks (Boerkamps and Binsbergen 1999; TfL 2007; Björklund and Gustafsson 2012; Browne et al. 2012). Such trends have led to efforts to identify the main traffic generators within urban areas in a bid to decrease pressures on transport networks, and reduce the negative environmental, economic and social externalities of freight.

In 2010, analysis of the UK National Health Service (NHS) found that it was responsible for 30% of all public sector emissions and 3% of the total CO_2 emissions in England (European Centre for Environment & Human Health 2011), with 65% being attributed to the procurement of goods and services (NHS SDU 2012). Previous research has identified that this is largely due to the dominance of an agile supply chain structure required to accommodate the unpredictable nature and poor communication of demand present within the medical supply chain (Bailey et al. 2013), which encourages sub-optimal product flows yielding low vehicle load factors (McKone-Sweet et al. 2005; Jarret 2006; Black and Zimmerman 2012; Azzi et al. 2013). As is typical with high delivery frequencies and low fill-rates, freight consolidation is often the prescribed solution. However, in spite of the NHS Supply Chain (NHS SC) a freight consolidation network established in 2006 **(ref)**, supplier participation remains to be low, with increased supply chain costs, loss of visibility and control of products, and sub-optimisation of supplier's logistics services often cited as the main reasons for poor uptake of the service; resulting in high numbers of ad-hoc deliveries continuing to service hospital Trusts. This paper attempts to address these issues with the proposal of a novel mobile consolidation centre (MCC) model for healthcare supply, using Great Ormond Street Hospital for Children's NHS Foundation Trust (GOSH) as a case study.

HEALTHCARE SUPPLY CHAINS

Public Perspective: UK Healthcare

Inventory in the NHS is largely managed using a parallel supply chain structure, whereby goods are procured through one of two routes, Figure 1.0: The NHS SC 'Stock' route, through which all ambient temperature goods are stocked, consolidated and distributed; and the 'Non-Stock' route whereby items are ordered direct from the supplier, and delivered to the hospital via independent couriers or dedicated supplier delivery services, in an ad-hoc manner.

Based on hospital spend reports approximately 30 per cent of inventory is procured as stock, at GOSH; with the remainder of stock being obtained through the non-stock route. A 5-day survey conducted at GOSH between 07:00 and 17:00 indicated that non-stock deliveries represent a significant traffic generator for the hospital with 403 individual deliveries being made to the trust during the survey period, with an average load factor of 40%. By comparison NHS SC deliveries are consolidated within one or two articulated lorries delivered 'out-of-hours' (17:00 – 07:00). Analysis of other NHS trusts, such as University Hospital Southampton (UHS), indicates that similar proportions of stock and non-stock goods are procured, with 30 to 37 per cent of inventory accounting for NHS SC goods.

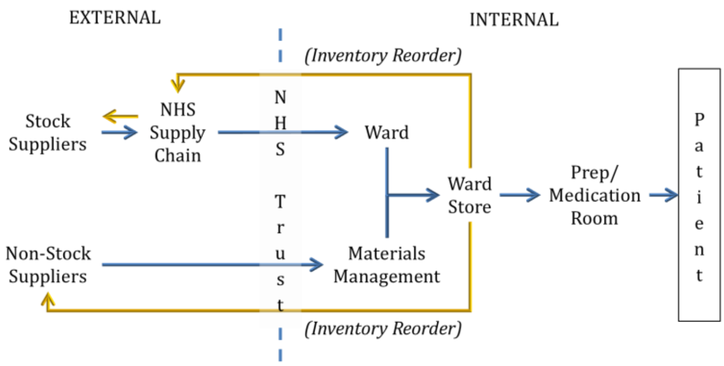

Figure 1.0 NHS Model of Supply

Private Perspective: U.S. Healthcare

Owing to the privatised nature of the U.S. healthcare system, hospitals are responsible for generating their own income, providing their own specialised set of services, and therefore negotiating rates and deals with suppliers; giving rise to Group Purchasing Organisations (GPOs). GPOs represent a single purchasing entity, often for multiple hospitals. Their primary function is to negotiate contracts with suppliers, utilising aggregated purchasing volumes to leverage significant purchasing power to achieve discounts with manufacturers, distributors and other vendors (Burns 2002; Nollet and Beaulieu 2005; Varghese et al. 2012). It is estimated that approximately 4,800 of the 5,000 healthcare facilities in the U.S. belong to one or more GPOs, with two GPOs acting as the supply contracting company for a combined 4,000 hospitals (Panero et al. 2011).

There are generally three types of GPOS: for-profit, which are independent of the hospital system, owned by a third party; not-for-profit, Integrated Delivery Networks (IDNs) whereby member hospitals are all part owners; and a hybrid of the first two, which have participation from both members and owners (i.e. shareholders) (Panero et al. 2011).

The role of the GPO often extends to the procurement, warehousing, consolidation and delivery of goods to their member trusts, Figure 1.1. A study conducted by Varghese et al. (2012) summarises the inventory management practices employed by a large healthcare system in the mid-west, comprising 26 hospitals, 4,650 medical staff and 3,638 licenced beds, referred to as 'Health System'.

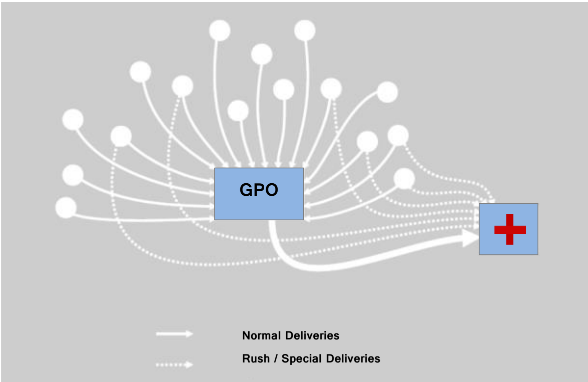

Figure 1.1 Example of GPO Supply [Adapted from: Toronto Atmospheric Fund et al. 2013]

Within this system purchases of inventory from suppliers are delivered to a distribution centre which serves eight hospital systems, each of which has one or more hospitals with a central pharmacy. Deliveries of supplies are made on a daily basis using the healthcare system's private transport fleet, which are predicated on a multi-echelon supply chain distribution centre model, whereby goods are consolidated and stocked at the distribution centre to provide a more agile supply chain. However, a single-echelon supply chain model through which the central pharmacy can place orders with suppliers directly, receiving items direct to the hospital is also available should items be required which are not in stock / supplied by the distribution centre (Varghese et al. 2012). This model may be considered comparable to that of the UK NHS model of supply.

IDN's similar to that of the U.S. system have also successfully been implemented within Singapore, wherein outsourcing logistics procurement activities of GPOs by hospital clusters within the public healthcare sector has enabled reduced costs through bulk-buying, and improved the sharing of inventories between hospitals, helping to avoid stock-outs (Pan and Pokharel 2007; Kumar et al. 2008). Similarly in Toronto, 6 hospitals (Toronto General, Princess Margaret, Mount Sinai, Toronto Rehab, SickKids Hospital and Toronto Western) have elected to consolidate their goods movement through a single company as a means to reduce vehicle traffic within downtown Toronto (Toronto Atomospheric Fund et al. 2013).

The relative success of the U.S. GPO structure and other similar models, compared to the current UK NHS SC may be attributed to the competitive market mechanisms centred on generating cost savings inherent within the system. However, it is evident within wider freight consolidation literature that the barriers and issues prevalent within healthcare consolidation are also widely referenced across many industries.

URBAN CONSOLIDATION

The concept of urban consolidation centres has been extensively research and trialled worldwide, within the U.S., Canada, Japan and Europe with the predominant number of trials being conducted in European countries such as: France, Italy, the Netherlands, and the UK (Huschebeck and Allen 2005)(Allen et al. 2012). Throughout the literature the term UCC is used synonymously with a large compendium of terms such as Freight Consolidation Centre (FCC), City Logistics Centres, Freight Transhipment Centres (FTC) and Urban Distribution Centres (UDC) (Woodburn 2005).

The underlying premise of UCCs is to address the difference between inter-city and inner-city freight transport. Whilst inter-city freight favours large trucks allowing the cost of fuel and tolls to be shared amongst larger loads; smaller trucks and vans are considered more appropriate for inner-city distribution due to smaller streets and more congested road networks (Boerkamps and Binsbergen 1999), Table 1.0.

Table 1.0 Main Activities and Benefits of UCCs [Source: (Campbell et al. 2010); pp.7]

Activity	Benefits
Consolidation	Consolidation of multiple daily deliveries to a reduced number of deliveries, increasing productivity.
Cross Docking	Delivery of consignments to a UCC at the supplier's convenience with forwarding to the customer at their own convenience.
Storage	Short, medium and long term.
Replenishment	Smaller, more regular deliveries of products for re-stocking throughout the day as opposed to a single larger consignment at one time.
Pre-retailing	For shops, pre-merchandising activities such as unpacking, sorting, labelling, size cubing and markdowns. These activities enable shops to allocate more of their retail space to sales rather than stock and storage management.

This initial concept of UCCs was implemented in the early 1970s in the UK. However, due to the distribution of loads from heavy goods vehicles (HGVs) to smaller light goods vehicles (LGVs) and vans, they generated higher volumes of traffic and emissions within cities (Boerkamps and Binsbergen 1999). This lead to the use of UCCs to increase vehicle fill-rates and decrease the number of delivery vehicles to manage the negative externalities of urban freight transport (UFT), reducing congestion, air pollution, visual and vibrational impacts as well as the potential for pedestrian-vehicular conflicts (Lewis et al. 2010; Marinov et al. 2010; Malhene et al. 2012; Qiu and Huang 2013). Table 1.1 outlines the main rationalisations for the implementation of a number of UCCs worldwide.

Consolidation of deliveries is typically achieved by one of two means: temporal and vehicular consolidation. Temporal consolidation is predicated on the intentional delay of goods to a single customer until a pre-established threshold is achieved, at which point all goods are forwarded to their final destination (Häger and Rosenkvist 2012; Nguyen et al. 2013). Such practices are implemented between couriers and some hospitals, such as GOSH and UHS. However, the success of temporal consolidation in the context of healthcare relies on a high frequency of 'threshold' volumes being achieved, to ensure items reach their destinations by the time at which they are required. Therefore, as is the case at GOSH, the presence of urgent items within the non-urgent chain means that once an urgent item arrives at a courier's warehouse, the item is delivered along with any of the items they are temporally consolidating, resulting in sub-optimal load factors. This method can also be used for pre-determined delivery days (Quak 2008).

Table 1.1 Factors for the implementation of UCCs [Source: Lewis 1997 in Visser et al. 1999; pp.4]

	Monaco	Kassel	Zurich	London	Winchester	Barcelona	Bologna
Congestion				X		X	X
Environment	X				X		X
Noise					X		
Safety					X		
Intrusion	X				X		
Political Considerations	X			X			
Cost							
Lack of Loading Facilities						X	
High Percentage of In-House Transport		X	X				X
Poor Utilisation of Vehicles		X	X				X
High Proportion of Commercial Traffic							X
Restore Balance Between Retail and Transport Services				X			X

Vehicular consolidation refers to the traditional means of increasing vehicle fill rates, whereby a central warehouse location is established to receive all goods for either a single large customer or a group of multiple customers within the same location. This model of consolidation can be classified into one of three types according to the specific set of operations and services required for customer(s): UCCs serving all or part of an urban area such as a city centre or town, e.g. Bristol City Consolidation Centre (BCCC), to reduce local congestion, serious environmental problems, freight driving and parking restrictions, pedestrianized areas and narrow streets; UCCs serving a single large site with a single landlord possessing the governance to make use of the centre mandatory, such as Heathrow Airport Retail Consolidation Centre; and, UCCs serving construction projects which operate with restricted available space, such as the London Heathrow Terminal 5 construction project and the London Construction Consolidation Centre (LCCC), whereby goods are held off-site until they are required (Panero and Lopez ; Huschebeck and Allen 2005; Panero et al. 2011).

The majority of UCC scheme are typically supported either fully- or in part- by public funding from central, regional / local government, or the owner of the site, e.g. Amsterdam, Monaco, La Rochelle, Nuremburg and Bristol (Huschebeck and Allen 2005). For a detailed review of UCCs implemented worldwide, see: Nemoto (1997); Browne et al. (2005); Woodburn (2005); Browne et al. (2007). Despite significant support for UCCs and worldwide implementation, a small proportion of UCC schemes achieve commercial self-sustainability.

As demonstrated by many of the consolidation services and trials implemented, under 20% have succeeded in becoming permanent features, Table 1.2, largely owing to associated longer lead times, larger administrative workloads, and increased supply chain costs (Lewis et al. 2010; Häger and Rosenkvist 2012). Such results indicate that despite the economic and environmental savings offered, UCC concepts have a proclivity to fail.

Table 1.2 Synthesis of the main European Experiences [Source: Gonzales-Feliu et al. 2012; pp.3]

Country	Number of UCCs	Operational UCCs, 2011	Success Rate
United Kingdom	32	13	41%
Italy	16	10	63%
France	16	8	50%
The Netherlands	14	6	43%
Germany	14	3	21%
Sweden	4	0	0%
Switzerland	3	1	33%
Spain	3	0	0%
Austria	1	0	0%
Belgium	1	0	0%
Finland	1	0	0%
Greece	1	0	0%
Portugal	1	0	0%

Barriers to Consolidation

The most significant objection to UCCs is the increased costs associated with delivery operations for schemes (Huschebeck and Allen 2005). As demonstrated by the literature UCCs typically require stable financing from the public sector to overcome this issue. The majority of UCC initiatives are supported in this way, e.g. Bristol, Leiden (Netherlands), Malaga (Spain) (Kaszubowski 2012). However, such involvement from public sector institutions often leads to fears of municipal monopolies in the UFT market, and claims that regulatory and market based measures can achieve similar results to UCC (Huschebeck and Allen 2005; Woodburn 2005). This is further compounded by opposition from large businesses / freight operators who claim that third party consolidation sub-optimizes their own supply chain activities which are currently consolidated with optimized vehicle routing (Lewis et al. 2010). Therefore, participation in UCC schemes is perceived to incur additional costs for their own logistics network and acts to sub-optimize their vehicle fleet, thereby making their own operations less economically and environmentally sustainable.

Additional opposition is met from suppliers of varying sizes, regarding the lack of control, visibility of customer's and product demand information.

Supplier opposition to UCCs represents one of the most significant barriers to the successful implementation of initiatives. In order for UCCs to achieve a critical mass whereby the cost of services provided are significantly less than the costs of traditional supply routes for suppliers, they require support from suppliers to buy into the services. If this does not happen, the initiative is unlikely to become self-sufficient, and will require continued significant subsidies to maintain operations (Gonzales-Feliu et al. 2012).

With respect to the environmental benefits provided by UCCs, research has found that the use of UCCs to reduce large freight traffic within city centres often leads to an increase in emissions (Boerkamps and Binsbergen 1999).

As demonstrated a significant amount of literature exists identifying the main barriers to successful UCC, much research has focussed on the financial and operational incentives available to augment greater supplier participation. However, little has been done to address the barriers to implementation through the redesign of the consolidation centre model in order to make them more attractive to suppliers. With the application of a mobile depot concept equipped with ICT enabling secure-electronic receipting of goods (Bailey et al. 2013) the need for fixed-based infrastructure may be eliminated thereby potentially reducing the overall operating costs of a UCC, increasing the visibility of items to the end-customer for suppliers, and aiding to optimise the physical location of centre in the context of supplier's supply chains.

MOBILE CONSOLIDATION

New models of consolidation have been trialled utilising more sustainable, low impact transportation, whereby a mobile unit is loaded with consignments at a consolidation warehouse and transported to a central city location during night-time hours. From this point all forward deliveries of items are made by sustainable means such as standard- / electric- bicycles.

However, as stated in Table 1.3, the main issues with such concepts are the limited range and capabilities of the bicycles, concerns regarding security, and the need for a large fixed-based infrastructure such as a warehouse in which to process the orders. Therefore, the implementation of such consolidation concepts requires the addition of further nodes within the supply chain, and may be seen to exacerbate some of the issues currently perceived by traditional consolidation methods.

The proposed mobile consolidation concept, Figure 1.2, is predicated to maintain the same number of nodes within the supply chain, by stating the mobile depot as the final point of delivery; maintain the same / higher levels of visibility between suppliers and customers, using ICT; and reduce the overall costs of the depots implementation by avoiding the use of fixed-based infrastructure, and off-setting the actual costs by the elimination of duplicate services within the hospital.

Commented [bg(1]: Overcoming low participation rates, leveraging customer power

Commented [bg(2]: Overcoming supplier fears

Commented [bg(3]: Overcoming significant barrier for both suppliers and customers

The mobile consolidation centre concept is similar in design to a groupage lorry and the TNT Mobile Depot demonstration, with the addition that deliveries can be made direct to the unit, automatically sorted, receipted and consolidated for forwarding on-board the same trailer to the final destination(s).

The concept comprises a mobile trailer equipped with electronic receipting capabilities; and secure deposit facilities, situated in a location (hospital trust / dedicated stabling facility) in an outer-city location, to which the receiving hospital trust instructs all deliveries to be made. Upon arrival at the depot, the supplier / courier scans each consignment, Figure 1.2, at which point the console on the unit instructs the items to be deposited within a specific partition of the trailer. This acts to automatically sort the items within the trailer by their destination ward. Upon deposit of the item, the unit locks and delivery is confirmed.

Table 1.3 New Age Consolidation Concepts

	Office Depot: Cargo Cycles	TNT Express: Cycle Logistics Mobile Depot	TNT and Citylog: Bento Box and Freight Bus
Freight Problem	75% of Office Depot's deliveries are within the London square mile, distributing approximately 1,350 cartons of office supplies per day.	An organizational requirement to increase efficiency of operations for TNT's central Brussels parcel deliveries. Reduce impacts on congestion on delivery performance.	Heavy congestion during rush hour and air and noise pollution within urban areas
Concept	Around 900 cartons will transfer to cargo cycle, via a cycle hub in SE1 in London. The concept is intended for transportation of documentation and parcels, but is considered unsuitable for medical inventory. Running costs are estimated at £13,000 per annum to accommodate the salaries of the cyclists.	A mobile depot is loaded at the TNT depot with all deliveries for a day and carries them to an inner city location for pick up and forwarding of items by electrically assisted tricycles for the last-mile.	Mobile containers, loaded with merchandise for shopping centres in the TNT depot are delivered to an automated parcel station within a shopping centre (before / after hours). The driver initiates an alert to the customer informing them their consignment is ready for collection.
Pros	Low initial outlay for cycles; low running costs; parking and congestion charge avoidance; speed in congestion; low environmental impact.	Decreased truck-kms; reduced costs per stop; improved delivery times and punctuality; reduced COs emissions; reduced noise pollution; maintenance of information flows.	Fewer heavy weight vehicles in downtown areas during rush hour; less noise and air pollution in city centres; more flexibility for customers.
Cons	Security; limted range and payload; driver fatigue and seasonality.		Security; Insurance of contents.
	(Klaus 2005; Campbell et al. 2010)	(STRAIGHTSOL 2013)	(Citylog 2012)

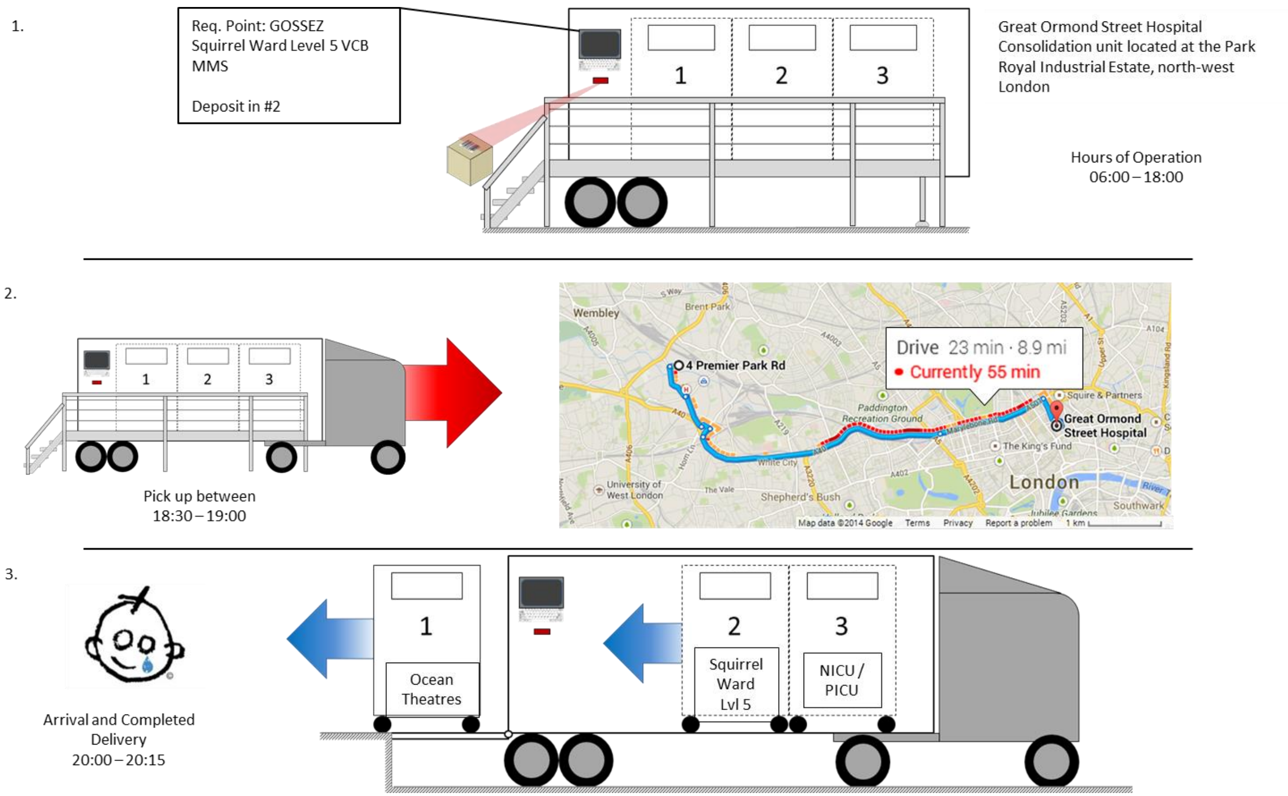

Figure 1.2 Mobile Consolidation Concept

Once all deliveries have been made during day-time hours (06:00 – 18:00) the depot unit locks, preparing the unit for collection and transportation to the destination hospital trust. Upon arrival at the hospital, the trailer is unloaded, with each separate partition being wheeled off and taken direct to the final delivery point. The overall outcome of the trailer is the displacement of delivery traffic to a location outside the city, thereby reducing inner city UFT associated with the trust. The pre-sorting of items allows for the disintermediation of the receipts and deliveries room, and streamlining of the internal supply chain within the hospital. Thereby speeding up supply and reducing the potential for loss or delay of items.

The mobile consolidation concept differs from traditional consolidation by providing an alternative single point of delivery for items being delivered to the hospital each day. It does not provide a long-term stock holding position for hospital inventory to be stored. This enables the costs of operation, associated with the holding of inventory to be avoided. Furthermore, it enables for re-location of the depot during set times of the day to provide a closer delivery location for suppliers entering urban areas from opposite directions.

METHODOLOGY

Previous reviews of consolidation centre literature highlight a lack of clear methodologies for the appraisal of urban consolidation centres, identifying the individual characteristics and objective functions (e.g. economic, environmental, social and supply chain efficiency) of centres as key barriers to the development of a single evaluation process (Browne et al. 2005).

Huschebeck and Allen (2005) advise detailed measurement of the flow of traffic and goods in the prospective location(s), followed by a period of consultation about the precise nature of the UCC scheme to be tested, and then an extended pilot that is managed and scrutinised by representatives of all the potential stakeholders (local authorities, logistics companies, retailers and other users).

MDS Transmodal Ltd and CTL (2012) identify three categories with which to appraise the impacts of UCCs: Network Impacts, Economic Impacts and Environmental Impacts, each of which can be quantified using key metrics, Table 1.4. In addition, Social Impacts can be included to consider abstract effects of metrics, such as changes in numbers of vehicles potentially reducing the number of road traffic accidents; and, reductions in noise, thereby reducing the impact of social disturbances (MDS Transmodal Ltd and CTL 2012).

Using the metrics provided in Table 1.4, Browne et al. (2005) provide the following framework methodology for the appraisal of consolidation centres: ensure consistent and clear definition of the boundaries (areas of the supply chain) being assessed, preferably fully inclusive of all supply chain activities affected by the UCC; identify and measure broad indicators (efficiencies improvements, on-time deliveries, transport and handling costs, fossil fuel consumption, emissions and congestion), and narrow indicators (vehicle-kms, vehicle trips, vehicle utilisation, space utilisation, journey times and unloading time); ensure standardisation of data collection before and after implementation; and, ensure evaluation is conducted under all practicably controlled conditions.

Economic metrics, Table 1.4 and above can be sorted into benefits and costs accrued by the relevant stakeholders of the scheme, including: suppliers, transport providers, receivers, and local authorities, to generate a 'Benefit-Cost' Analysis (BCA) for the purposes of comparison (Browne et al. 2005).

Table 1.4 UCC Assessment Criteria

Metric	**Impact**
Changes in the number of vehicle trips	Network, Economic
Changes in the number of vehicle kilometres (VKm)	Network, Economic
Changes in the number of vehicles	Network, Economic
Changes in travel time	Network, Economic
Goods delivered per delivery point	Economic
Vehicle load factor	Network, Economic
Changes in parking time and frequency	Economic
Changes in total fuel consumed	Economic, Environmental
Changes in vehicle emissions	Environmental
Changes in operating costs (vehicle operation and per km)	Economic
Changes in noise pollution	Environmental
Changes in vehicle waiting time	Economic, Environmental
Sources: (Browne et al. 2005) and (Gazzard 2013)	

Mobile Consolidation Centre Assessment

The MCC is assessed using 116 of the 403 recorded deliveries during the 2011 deliveries and servicing survey conducted at GOSH. This cross-section represents all the deliveries for which a supplier, courier, previous drop and next drop location were obtained, enabling an impact assessment of a significant portion of the supply chain, in accordance with previous review. Results from this data will be extrapolated to the entire survey population by means of a proportional uplift factor (3.474).

Performance Indicators

Given the theoretical nature of the study and the data made available from the deliveries and servicing survey, the following indicators will be assessed: 'Broad Indicators' - fuel emissions, fuel consumption and traffic impacts; and, 'Narrow Indicators' – journey distance, journey time, driver cost-time.

Journey Distance and Time

The shortest journey distances and quickest journey times will be calculated using the ArcGIS Network Analysis tool, both with the omission of time of day dependent variables. The eastings and northings for all supply chain nodes are obtained using postcode data, compared against Ordnance Survey 'Code-Point' data **(ref)**.

Emissions Analysis

Carbon emissions data derived from DEFRA used according to vehicle weight (obtained via the DVLA number plate database.

Emissions for the consolidation centre HGV are assumed to be in accordance with an xx tonne articulated lorry at 100% load factor.

Scenario Testing

As per the guidance given by Browne et al. (2005), the analysis will incorporate the greatest number of nodes possible. The supply chain for GOSH will therefore comprise of the following: Supplier to Courier, to Previous Drop, to GOSH, to Next Drop, to Courier, to Supplier. Where a supplier identity / address were not obtained, the supply chain will begin and end at the courier address **(Give proportion of cases for this)**.

For the journey distance, journey time and emissions assessments the following analyses will be conducted:

1 BASE CASE SCENARIOS

1.1 Full supply chain including GOSH, to determine the full range of impacts for the current operating scenario;

1.2 Full supply chain excluding GOSH, to identify the impacts of all journeys associated with GOSH;

2 Return journeys to the proposed consolidation centre, including return forwarding journeys from the consolidation centre to GOSH.*Consolidation Centre Locations*

Prospective locations for the consolidation centre were determined using a 'gravity model' approach provided by DPS Logix, a commonly used tool within the logistics industry. This approach assesses the distances of each supplier to GOSH (n=775), and their distribution nationwide, indicating a location central to the suppliers. From this analysis, the exact location of the depot will be varied for the following operating scenarios:

2.1 Situation of the MCC within the parking facilities of an NHS Trust outside central London, at northern and southern locations; and,

2.2 Situation of the MCC at a dedicated parking facility outside of central London, near existing large logistics and distribution operations, at northern and southern locations.

2.3 Selection of best performing northern and southern MCC options from 2.1 and 2.2, with analysis of a combined scenario for a time variable depot location, assuming suppliers / couriers will make deliveries to the closest respective north and south London locations.

Focus Groups

PENDING

RESULTS

Consolidation Centre Siting

Analysis of the 775 suppliers for GOSH indicates a large concentration within: the M25, Oxford, Cambridge, Birmingham, Liverpool and Manchester areas, Figure 1.3.Analysis of the gravity model results, Figure 1.4, indicates the 'Ideal' location for the MCC being situated near junction 21 of the M25 (A).

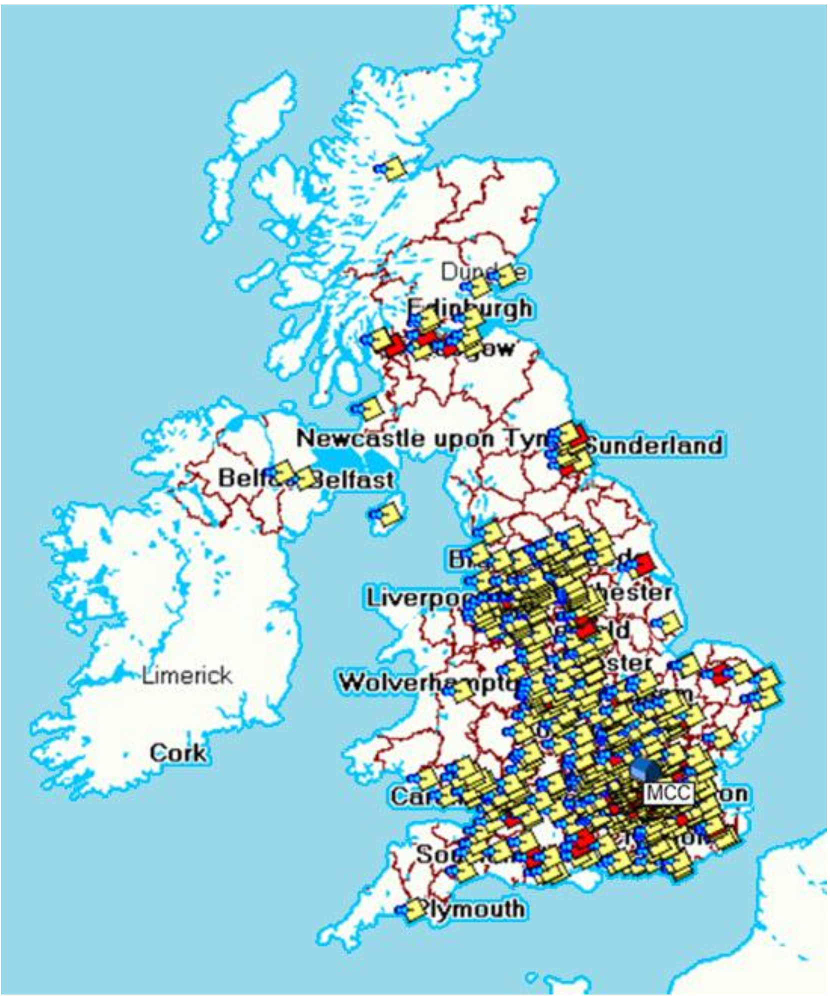

Figure 1.3 GOSH Supplier Distribution and MCC Location, DPS Logix

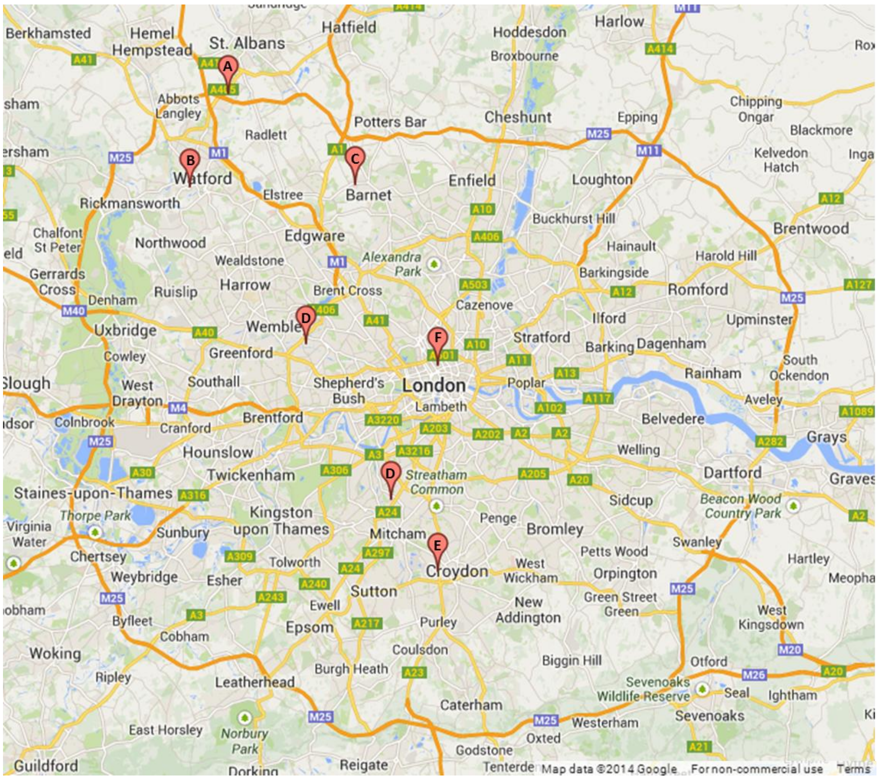

Figure 1.4 Suggested Locations for the MCC [F = GOSH]

An assessment, of the hospitals with large parking facilities within the M25 near the 'Ideal' location for the MCC, Figure 1.4, indicates that Watford General (B) and Barnet and Chase Farm Hospital (C) present potentially suitable locations for the MCC. The Park Royal Industrial Estate (D) situated in north-west London, which represents one of the major logistics hubs for the current NHS SC operations, is identified as a suitable dedicated logistics facility.

In addition to the northern sites, two additional southern sites, St Georges NHS Hospital Trust (D) and Beddington Cross Industrial Area (E) have been selected. Both have been selected for their central location within the south London, and trunk route access.

Scenario Testing

Focus Groups

DISCUSSION

CONCLUSIONS

References

Azzi, A., A. Persona, F. Sgarbossa and M. Bonin (2013). "Drug Inventory Management and Distribution: Outsourcing Logistics to third-party providers." Strategic Outsourcing: An International Journal **6**(1): 48-64.

Bailey, G., T. Cherrett, B. Waterson and R. Long (2013). "Can Locker Box Logistics Enable more Human-centric medical supply chains?" International Journal of Logistics: Research and Applicaitons **16**(6): 447-460.

Björklund, M. and S. Gustafsson (2012). The Role of Swedish Municipalities in the Establishment of Urban Consolidation Centres. The 18th Greening of Industry Network Conference, 22-24 October. Linköping Congress Centre, Sweden.

Black, D. and A. Zimmerman (2012). Mercy ROi-BD Case Study: Perfect Order and Beyond, Mercy ROi-BD.

Boerkamps, J. and A. Binsbergen (1999). GoodTrip - A New Approach for Modelling and Evaluation of Urban Goods Distribution. 1st International Conference on City Logistics, Cairns, Australia.

Browne, M., J. Allen, T. Nemoto, D. Patier and J. Visser (2012). "Reducing Social and Environmental Impacts of Urban Freight Transport: A Review of Some Major Cities." Procedia - Social and Behavioural Sciences: Seventh International Conferenec on City Logistics **39**.

Browne, M., M. Sweet, A. Woodburn and J. Allen (2005). Urban Freight Consolidation Centres. London, Transport Studies Group, University of Westminster

Department for Transport.

Browne, M., A. Woodburn and J. Allen (2007). "Evaluating The Potential For Urban Consolidation Centres." European Transport **35**: 17.

Burns, L. (2002). The Healthcare Value Chain: Producers, Purchasers, and Providers, Jossey-Bass.

Campbell, J., L. MacPhail and G. Cornelis (2010). SEStran (South East Scotland Transport Partnership): Freight Consolidation Centre Study. P. b. S. Wilson.

Citylog (2012). "Citylog: Sustainability and efficiency of city logistics." Retrieved 25th September, 2012, from http://www.city-log.eu/en/lyon.

European Centre for Environment & Human Health (2011). "New Research Could Help NHS Reach Carbon Targets." Retrieved 09/08, 2013, from http://www.ecehh.org/news/new-research-could-help-nhs-reach-carbon-targets.

Gazzard, N. (2013). Phone interview with Nick Gazzard regarding current techniques for appraisal of consolidation centres. G. Bailey.

Gonzales-Feliu, J., J. M. S. Grau, J. Morana and E. Mitsakis (2012). "Urban Logistics Pooling Viability Analysis via a Multicriteria Multiactor Method." HAL.

Huschebeck, M. and J. Allen (2005). D1.1 BESTUFS Policy and Research Recommendations I: Urban Consolidation Centres, Last Mile Solutions**:** 22.

Häger, K. and C. Rosenkvist (2012). Freight Consolidation's Impact on CO2 Emissions and Costs: An Evaluation of DHL Global Forwarding's Control Towers' Work and of Factors Concerning Consolidation. Department of Management and Engineering, Linköping University Institute of Technology. **Masters**.

Jarret, P. G. (2006). "An analysis of International health care logistics." Leadership in Health Services **19**(1): 10.

Kaszubowski, D. (2012). "Evaluation of Urban Freight Transport Management Measures." Scientific Journal of Logistics **8**(3): 13.

Klaus, P. (2005). A Future Role for Urban Consolidation Centres? German Experiences and Prospects, Boston University: for BESTUFS.

Kumar, A., L. Ozdamar and C. N. Zhang (2008). "Supply chain redesign in the healthcare industry of Singapore." Supply Chain Management: An International Journal **13**(2): 95-103.

Lewis, A., M. Fell and D. Palmer (2010). Freight Consolidation Centre Study, Department for Transport.

Malhene, N., A. Trentini, G. Marques and P. Burlat (2012). Freight Consolidation Centres For Urban Logistics Solutions: The Key Role of Interoperability. 2012 6th IEEE International Conference on Digital Ecosystems Technologies (DEST), , Campione, Italy.

Marinov, M., T. Zunder and D. Islam (2010). "Urban Freight Consolidation Concepts: Is There Something Missing." Transport Problems **5**(2): 7.

McKone-Sweet, K. E., P. Hamilton and S. B. Willis (2005). "The Ailing Healthcare Supply Chain: A Prescription for Change." The Journal of Supply Chain Management **Winter**: 14.

MDS Transmodal Ltd and CTL (2012). DG Move European Commission: Study on Urban Freight Transport, MDS Transmodal Ltd.

Nemoto, T. (1997). "Area-wide inter-carrier consolidation of freight in urban areas." Transport Logistics **1**(2): 87-101.

Nguyen, C., A. Toriello, M. Dessouky and J. Moore II (2013). "Evaluation of Transportation Practices in The California Cut Flower Industry." Interfaces **43**(2): 12.

NHS SDU (2012). NHS England Carbon Footprint, NHS Sustainable Development Unit.

Nollet, J. and M. Beaulieu (2005). "Should an organisation join a purchasing group?" Supply Chain Management: An International Journal **10**(1): 6.

Pan, Z. X. and S. Pokharel (2007). "Logistics in hospitals: a case study of some Singapore hospitals." Leadership in Health Services **20**(3): 195-207.

Panero, M. and J. Lopez.

Panero, M., H. Shin and D. Lopez (2011). Urban Distribution Centres A Means to Reducing Freight Vehicle Miles Travelled. NY, The NYU Rudin Centre for Transportation Policy and Management.

Qiu, X. and G. Q. Huang (2013). "Supply Hub in Industrial Park (SHIP): The Value of Freight Consolidation." Computers and Industrial Engineering **65**: 11.

Quak, H. (2008). Sustainability of Urban Freight Transport Retail Distribution and Local Regulations in Cities. Erasmus Research Institute of Management (ERIM). Netherlands, Erasmus University Rotterdam. **Doctorate:** 262.

STRAIGHTSOL (2013). "StraightSol: Strategies and Measures for Smarter Urban Freight Solutions." Retrieved 13/08, 2013, from http://www.straightsol.eu/.

TfL (2007). London Freight Plan, Sustainable Freight Distribution: A Plan for London. T. f. London. London, Transport for London**:** 108.

Toronto Atomospheric Fund, MetroLinx and Ministry of Transportation of Ontario (2013). Freight Consolidation for Toronto's Healthcare Sector, University of Toronto.

Varghese, V., M. Rossetti, E. Pohl, S. Apras and D. Marek (2012). "Applying Actual Usage Inventory Management Best Practice in a Health Care Supply Chain." International Journal of Supply Chain Management **1**(2): 10.

Visser, J., A. van Binsbergen and T. Nemoto (1999). Urban Freight Transport Policy and Planning. First International Symposium on City Logistics, Cairns, Australia.

Woodburn, A. (2005). Overview of Consolidation Centres for Urban and Specialist Use, University of Westminster: for BESTUFS II - First Workshop 13-14th January.