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RESEARCH PAPER

# Transportation and vehicle fleet management in humanitarian logistics: challenges for future research

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**Abstract** Transportation and vehicle fleet management in humanitarian logistics have characteristics virtually unexplored by OR researchers. We provide evidence-based insights into the logistics challenges imposed by the dual objective of relief and development, decentralization, earmarked funding, and field operating conditions. We comment on why these characteristics help explaining the persistence of aging fleets, excessive fleet sizes, low fleet standardization, and service delays: problems humanitarian fleet managers fight on a daily basis to improve their service levels. We propose avenues for future research to address strategic, tactical, and operational challenges derived from the defining characteristics of humanitarian logistics discussed in the paper.

**Keywords** Humanitarian logistics · Transportation · Fleet management · Last mile distribution

**Mathematics Subject Classification** 90B06 transportation, logistics

## Introduction

Defining characteristics virtually unexplored by researchers make vehicle fleet management an interesting topic of humanitarian logistics. Grounded in a long-term evidence-based study of 4 × 4 fleets with the participation of important humanitarian organizations, we explore the defining characteristics of humanitarian vehicle fleet management. Some of these characteristics have been almost

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unattended by the operations research (OR) literature. In particular we focus on (1) dual objective of relief and development; (2) decentralization; (3) earmarked funding, and (4) field operating conditions. The contribution of this paper is to identify strategic, tactical, and operational challenges on transportation and fleet management resulting from the defining characteristics of humanitarian logistics.

The four defining characteristics we study help explaining the persistence of aging fleets, excessive fleet sizes, low fleet standardization, and excessive service delays: problems fleet managers from International Humanitarian Organizations (IHO) fight on a daily basis to improve operational efficiency.

We build on the findings of a series of papers that summarize the results of our evidence-based study. Here we advance the research agenda by mapping the findings of our research into specific fleet management challenges resulting from the defining characteristics of humanitarian logistics. The fleet management challenges we identify could be investigated further using OR methods. We provide some suggestions of objectives and constraints that OR models could use to explore these challenges. This paper focuses on identifying research challenges. It is our belief that the definition of parameters and variables of OR models to analyze these challenges is the next step. It is our hope that the next step will be taken by the EURO community.

The appropriateness of our research for EURO is given by the fact that transportation is a significant overhead cost to humanitarian operations (Disparte 2007) and it is critical to humanitarian programs. Implemented for relief (aid for life saving purposes) and development (services to improve the quality of life), programs are the main channel of IHO service delivery (Pedraza-Martinez et al. 2011). IHO rely heavily on field vehicle fleets ($4 \times 4$ vehicles) to reach the beneficiaries of their programs.

With the objective of understanding the way IHO manage their field vehicle fleets, in 2007 we launched an evidence-based project in close collaboration with four of the largest IHO: International Committee of the Red Cross (ICRC), International Federation of Red Cross and Red Crescent Societies (IFRC), World Food Programme (WFP), and World Vision International (WFP). This research took us to Switzerland, Denmark, Italy, United Arab Emirates, Mozambique, Kenya, and Uganda to collect quantitative and qualitative data on vehicle fleet management.

Qualitative data were collected via interviews to humanitarian staff at the headquarters, regional, national, and field level. Quantitative data were collected directly from IHO information systems and vehicle logbooks. The lack of literature on humanitarian fleet management as well as the variety of data collected, and the types of problems we found suggested the need of multiple research methodologies. By combining exploratory case studies, econometrics, OR, and system dynamics, we identified unexplored characteristics of humanitarian logistics and the fleet management challenges they impose.

## Evidence-based project

We approached humanitarian fleet managers through the Fleet Forum, an initiative created by IHO and funded by the private sector to explore solutions to fleet management problems in the humanitarian sector (Tomasini and Van Wassenhove

2006). By attending and presenting in annual Fleet Forum conferences since 2003 we learned about symptoms of structural challenges to transportation and fleet management, especially regarding field vehicle fleets. The humanitarian sector was struggling with aging fleets, excessive fleet sizes, lack of fleet standardization, raising fuel consumption, and service delays in support to programs (Pedraza-Martinez et al. 2011). With the aim of exploring the causes of these issues, we were authorized by practitioners from ICRC, IFRC, WFP, and WVI to visit their organizations during 2007 and 2008.

International Humanitarian Organizations uses field vehicle fleets to transport people (humanitarian field staff, and beneficiaries) as well as aid (food and non-food items), and materials (for agriculture, construction, and other activities). They use three different fleet management models named after procurement: centralized, with global procurement centralized at the headquarters; decentralized, with local procurement managed by programs; hybrid, combining global and local procurement, managed by a centralized party (Pedraza-Martinez et al. 2011). The system is multi-level with strategic, tactical, and operational decision-making spread geographically and organizationally. The main objectives are minimizing time of response to program needs and keeping operating costs low.

To understand the problem better we first looked into the literature. There were interesting OR papers on humanitarian routing (Cova and Johnson 2003; Han et al. 2006; De Angellis et al. 2007; Balcik et al. 2008; Campbell et al. 2008), inventory management (Beamon and Kotleba 2006a, b; De Treville et al. 2006), and network design (Batta and Mannur 1990; Chang et al. 2007; Jia et al. 2007). Extant literature had focused on tradeoffs of equity and efficiency for disaster response with both supply and demand uncertainty (Pedraza-Martinez et al. 2011). Central planning models were the dominant paradigm (Pedraza-Martinez et al. 2010; Besiou et al. 2012). We were surprised about how little from the literature we could use to understand the problems faced by practitioners regarding decentralized humanitarian logistics. Hence, we opted for a case-based field research project. The research design focused on the defining characteristics of humanitarian logistics and the factors affecting field vehicle fleet management in humanitarian operations.

## Defining characteristics of humanitarian logistics and fleet management challenges

The fleet management system under study is a complex logistics network. It involves donors, multiple logistics levels within IHO, global and local suppliers, and IHO programs (Fig. 1). We provide a succinct description of the system. A comprehensive description can be found in Pedraza-Martinez et al. (2011).

Decentralized in nature, fleet management begins with relief and development programs' transportation needs. These needs include field visits to deliver aid and services to beneficiaries as well as to monitor the advance of program objectives. They also include prepositioning emergency stocks of vehicles to respond to disasters. Program staff in the field determines transportation needs (Pedraza-Martinez et al. 2010). While the needs of relief programs are characterized by high

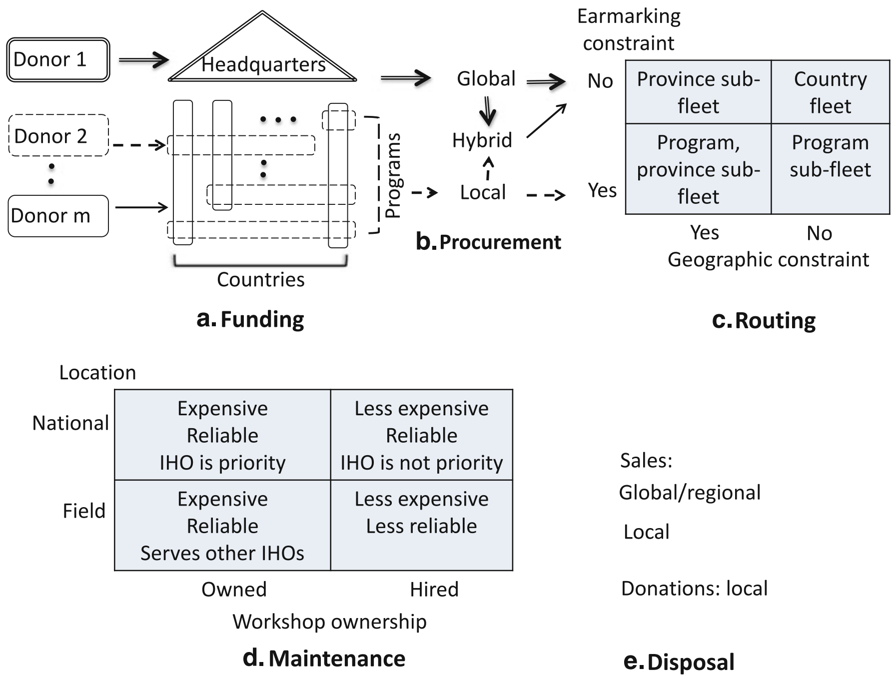


**Fig. 1** Humanitarian field vehicle lifecycle

demand uncertainty, high urgency, and short duration, the needs of development programs are characterized by low demand uncertainty, low urgency, and long duration (Pedraza-Martinez et al. 2010).

Donors fund transportation needs either transferring cash to the IHO headquarters, or transferring cash and (or) vehicles directly to programs, and (or) countries (Fig. 1a). Procurement can be either global (centralized), local (decentralized), or hybrid (Fig. 1b). Global procurement is usually managed at the headquarters level by a central entity. Global procurement is characterized by low purchasing cost and high lead-time. Local procurement is managed directly by programs or by IHO's national logistics offices. It is characterized by low lead-time and high purchasing cost. Local procurement and vehicle donations occur when donors fund program transportation needs directly.

Fleet routing is planned on a weekly basis. Nevertheless, dispatching is updated on a daily basis. Although several programs may deliver services to the same geographic location, the constraints in the use of vehicles imposed by donor's earmarked funding may deter routing coordination and fleet pooling (Fig. 1c). It is not rare to observe suboptimal routing assignments in practice. Although fleet managers are aware of this situation, it is difficult for them to get rid of earmarked vehicle use constraints imposed by donors. Routing is also affected by security conditions.

Vehicle maintenance is done either in IHO's owned workshops or in service supplier's workshops (Fig. 1d). Often vehicles have to travel long distances for regular inspections (Pedraza-Martinez et al. 2011). Spare part management is an additional challenge. For instance, in case of unexpected need of spare parts following accidents the lead-time for procurement can reach several months. In general, due to hard operating conditions, maintenance costs of humanitarian field fleets are greater than the ones for commercial companies working in USA and Europe (Pedraza-Martinez and Van Wassenhove 2012).

Vehicle disposal consists of re-sales and donations (Fig. 1e). Vehicle re-sales are done either at the local level or at the global level. The re-sale value usually goes back to the party that 'owns' the asset according to the IHO's financial system. Following donor recommendations, vehicle donations are done at the local level usually to implementing partners. The interaction between IHO and implementing partners is an important and unexplored aspect of humanitarian fleet management that we do not consider in this paper.

The system we have described has some challenging characteristics. These include tradeoffs of equity and efficiency as well as supply and demand uncertainty, which have been actively studied by OR researchers. Here we focus on less explored but equally challenging characteristics of humanitarian logistics affecting transportation and fleet management: the dual objective of relief and development, decentralization, earmarked funding, and field operating conditions.

## Dual objective of relief and development

The dual objective of humanitarian logistics comes is embedded in the concept of disaster management lifecycle (Carter 1991; Norman 2003; Tomasini and Van Wassenhove 2009). Responding to disasters, relief programs alleviate the suffering of affected people. Following the 3- or 4-month duration of relief programs (although relief programs following devastating disasters like Haiti may last up to 6 months), development programs are implemented to support the rehabilitation of affected communities as well as to improve community preparedness for the next disaster. The same logistics system makes short-term decisions under high uncertainty with time of response as the main objective as well as long-term decisions under low uncertainty with cost efficiency as the main objective. This creates challenges at different logistics levels. We highlight those challenges following the time horizon decision-making logic (Bramel and Simchi-Levi 1997; Ghiani et al. 2003) and classify them as strategic, tactical, and operational.

### *Strategic challenges (long-term)*

The dual objective of relief and development affects network design. Geographically, the dual objective suggests keeping emergency stocks of vehicles at the regional level to serve several countries (Stapleton et al. 2009a). The dual objective also suggests prepositioning emergency stock of vehicles at the country level to serve several provinces when the probability of disaster is high, for instance in cyclical disasters. The challenge is complicated further by the fact that the network must respond to two different kinds of uncertainty while struggling to find the right balance between cost and service level. To capture the dual objective of relief and development, OR models could minimize the time of response for relief program subject to a budget constraint while minimizing the operational cost for development programs subject to a predetermined service level. Models should include a mechanism to transfer spare capacity from development to relief.

*Tactical challenges (medium-term)*

The dual objective makes demand estimation a critical challenge. Serving two different types of stochastic demand is not an easy task. Demand estimation is the main driver of fleet size to respond to both relief and development transportation needs (Pedraza-Martinez et al. 2010). Regarding relief, it helps determining the optimal emergency stock of vehicles for disaster response. Regarding development, it is a variable to determine the country fleet size.

*Operational challenges (day-to-day)*

Vehicle dispatching is critical in the aftermath of disasters (Pedraza-Martinez et al. 2011). Empirical evidence suggests that IHO have the rule of thumb of sending their most reliable (younger) vehicles to the hardest missions as long as these vehicles are available (Pedraza-Martinez and Van Wassenhove 2010). In relief operations hard missions are the ones in charge of assessing damages and coordinating initial response. In development operations hard missions usually involve long journeys in bad road conditions. Balancing fleet utilization to decrease both the over-use of young vehicles and the lack of use of older vehicles is a challenge faced by humanitarian fleet managers.

Decentralization and conflicting objectives

Contrary to the dominant paradigm in humanitarian logistics literature, vehicle fleet management is decentralized. Strategic decisions are made at the headquarters level using information provided by the field. Tactical decisions are spread at headquarters, regional, national, and field level. Operational decisions are often made at the field level. Additionally, different parties in IHO's logistics network may have different and often conflicting objectives (Van Wassenhove and Pedraza-Martinez 2010). For instance, while the logistics function is efficiency driven, the program function is equity driven (Pedraza-Martinez et al. 2010). Moreover, we observed that in many IHO the logistics function is subordinated to the humanitarian function making policy implementation an additional challenge. In a decentralized network conflicting objectives result in incentive misalignment that may deter the implementation of OR models based on central planning solutions. The fleet management challenges resulting from humanitarian logistics decentralization are as follows:

*Strategic challenges*

The decentralized nature of decision making in humanitarian logistics affects network design. Incentive coordination in humanitarian logistics networks is an extremely challenging topic and we have not seen much research about it. Coordinating a multi-level, multi-objective logistics network is so complex that it may involve even the development of new methodological tools to explore the problems and find insights on possible solutions.

*Tactical challenges*

Decentralization and conflicting objectives affect demand estimation. For instance, equity oriented programs estimate their demand for transportation in the field. These programs are not fully accountable for the operating cost of the fleet and may have incentives to distort their demand when reporting to the logistics function. Targeting a service level to balance equity and efficiency, the logistics function is fully accountable for the cost of the fleet. In consequence, the fleet size that would minimize the system's costs is lower than the fleet size that would minimize the program's costs. Unfortunately, monitoring does not prevent programs from providing distorted reports. This situation results in a fleet excess that is costly to the system (Pedraza-Martinez et al. 2010).

OR models could compare the performance of different fleet configurations, i.e. dedicated fleets, pooled fleets, and mixed fleets (partially pooled). Performance can be modeled as a balance between cost and service level. Performance could be compared to a benchmark centralized solution.

*Operational challenges*

Decentralization and conflicting objectives affect the implementation of vehicle replacement policies. The issue is complicated further by earmarked funding, as we will discuss in the following subsection's operational challenges.

Earmarked funding

Earmarked funding consists of donations with specific destination. The destination can be a program, a country, or a business unit like the headquarters (Fig. 1a). The humanitarian wisdom is that donors prefer earmarking donations to increase fleet accountability. Earmarked donations allow donors to choose what program to support and it also allows them to know the impact of their donations. It has been argued that earmarked funding helps IHO getting more donations. We have found that earmarked funding also generates logistics challenges.

*Strategic challenges*

Earmarked funding affects vehicle procurement and fleet composition. Take the case of institutional donors that donate vehicles instead of cash. Usually, these donors procure vehicles from their national manufacturers, i.e. while USAID donates American brands ECHO may prefer other brands. These donations do not take into account either the current IHO fleet composition or the existing facilities for maintenance in the operating countries (Pedraza-Martinez et al. 2011). Lack of standardization may result in high costs, greater down times, and low service levels.

A direct consequence of earmarked vehicle funding, earmarked vehicle use also impacts on humanitarian fleet management. On the one hand, earmarked vehicle use increases resource accountability to donors. The fact that donors may obtain reports on vehicle use directly from programs keeps them informed on the use of their donations. This may result in more donations. On the other hand, earmarked vehicle use results in lack of coordination within programs in the IHO, affecting program accountability to the IHO and decreasing operational efficiency (Besiou et al. 2012).

*Tactical challenges*

Earmarked vehicle use resulting from earmarked funding affects fleet size and deters resource sharing. Take the case of a large IHO in northern Mozambique implementing two development programs with perfect overlap in geographic coverage. Different donors fund both programs. Those two programs cannot coordinate their field visits because there are explicit agreements with donors penalizing the use of vehicles beyond the activities of each program (Pedraza-Martinez et al. 2011; Besiou et al. 2012). As a result, there is an unnecessary duplication in the number of vehicles.

*Operational challenges*

Earmarked funding affects humanitarian vehicle replacement. Take the case of the ICRC, a benchmark IHO studied by Pedraza-Martinez and Van Wassenhove (2010). The ICRC purchases vehicles directly from manufacturers using headquarters budget. Vehicles are transferred to countries and programs using an internal rental mechanism. The recipient of the vehicle pays depreciation on a monthly basis during 5 years. The replacement policy states that vehicles should be sold at the end of the 5th year in the local market. But the salvage value is transferred to the headquarters. In consequence, national offices (delegations) keep vehicles longer than prescribed by the headquarters to benefit from savings in the cost of capital. This practice, however, increases the operating cost of the system. Transferring the salvage value from headquarters to national offices would easily solve this problem. Nevertheless, different donors fund these two parties and financial transfers are not allowed. How to coordinate this system without financial transfers is an open question.

Additionally, earmarked vehicle use has a significant impact on the IHO's ability to provide transportation for relief purposes. Besiou et al. 2012 show that the interaction between decentralization and earmarked vehicle use may result in a fleet management system with local procurement and low lead-time taking consistently longer to respond to disasters than a system with global procurement and high lead-time. Creating incentives to coordinate the system donor-IHO to regulate earmarked vehicle use offers research opportunities in OR.

To capture earmarked funding, OR models could explicitly label the sources of funding to programs. Constraints in the use of capacity given by the source of funding should be added. It would be interesting to compare earmarked funding constrained models with unconstrained models to determine the operational cost of constraining budget reallocation.

Operating conditions

Regarding transportation, humanitarian operating conditions include social and economic instability, incomplete networks, lack of local facilities, conflict areas, and high mobility of demand. Although operating conditions have been modeled as a source of demand uncertainty, the effect of context also creates challenges on network design, procurement, maintenance, and replacement policies. These challenges are discussed below.

*Strategic challenges*

Humanitarian operating conditions have a strong effect on network design. Often IHO are forced to choose their logistics hubs based on considerations far away from cost or proximity to field operations. For instance, in some African regions IHO may choose hubs based on expectations of social and political stability. Exit strategies as well as contingency planning based on OR methods would help informing those decisions.

At the local level, lack of facilities often pushes IHO to build their own workshops. Due to the use of original spare parts and well-paid staff, these workshops are more expensive than the local ones but are also more reliable (Fig. 1d). Furthermore, in some cases when the IHO owns its workshop, vehicles wait less to be served than in a hired workshop. Determining the right time for transition from owned workshops to hired workshops is a problem several IHO face at the moment. Additionally, outsourcing is becoming attractive for IHO and suppliers. However, designing the right service and contract is an ongoing challenge (Stapleton et al. 2009b).

*Tactical challenges*

Operating conditions affect spare part management. IHO like WFP and IFRC send vehicles to the operating countries with the necessary spare parts for the first service. Other IHO using local suppliers rely on the local market, which sometimes does not hold enough inventory. During our field research we documented cases of vehicles staying up to 1 year in workshops waiting for a spare part to arrive. Operating conditions also affect fleet size. In conflict areas ICRC vehicles travel in convoys to increase staff security.

*Operational challenges*

Operating conditions affect vehicle routing. In some of the places where humanitarian logistics operates weather and road conditions change unexpectedly. IHO often rely on their vehicle drivers to decide on routes. Drivers know the local

**Table 1** Summary of defining characteristics and research challenges

| Defining characteristic | Strategic level | Tactical level | Operational level |
|---|---|---|---|
| Dual objective: relief and development | Network design | Demand estimation | Routing |
| | Procurement, sourcing | Fleet size | Dispatching |
| Decentralization and conflicting objectives | Network design | Demand estimation | |
| | Fleet composition | Fleet size | Vehicle replacement |
| Earmarked funding | Accountability | Fleet size | Routing |
| | Procurement | | |
| | Fleet composition | | |
| Field operating conditions | Network design | Fleet size | Routing |
| | Replacement policy | Spare part management | Dispatching |
| | Procurement, sourcing | | Maintenance |

language, culture, and road network. However, there does not seem to be a systematic capture of drivers' knowledge to decide optimal routes in field operations.

Field operating conditions affect vehicle routing for last mile distribution. The mobility of beneficiaries, particularly in conflict areas or following disasters, affects the localization of demand for transportation. Vehicle routing considering mobility of demand could help IHO to get more accuracy in last mile distribution.

Additional routing problems include debris removal. This has been a critical problem especially following urban disasters like the earthquakes in Armenia, Colombia (Pedraza-Martinez et al. 2009), and Haiti (Balaisyte et al. 2011). OR techniques could have a tremendous impact by providing insights into how to tackle this problem.

This section has defined a number of characteristics of humanitarian fleet management. It has also pointed out to logistics challenges created by those characteristics. A discussion summary is presented in Table 1.

## Conclusions

The academic interest on humanitarian logistics has focused on modeling centrally planned systems for disaster response. OR has been used to explore defining characteristics of humanitarian logistics like the tradeoffs of equity and efficiency as well as supply and demand uncertainty. Nevertheless, there are unexplored defining characteristics that create equally important challenges to vehicle fleet management. We identify evidence-based humanitarian fleet management challenges created by four defining characteristics of humanitarian logistics: (1) the dual objective of relief and development; (2) decentralization; (3) earmarked funding; and (4) field operating conditions.

The dual objective of relief and development affects network design. The proportion of relief and development work done by an IHO should influence the structure of the field vehicle network. The greater the orientation towards relief, the greater the focus on vehicle prepositioning and flexible procurement should be. The right balances of prepositioning and global/local procurement have not been determined yet. OR models can offer valuable insights into this topic. The dual objective also affects demand estimation, fleet size, routing, and dispatching.

Decentralization and conflicting objectives affect transportation demand estimation. Equity oriented programs, which are not fully accountable for fleet costs have private information on demand. Often they have incentives to distort their needs and ask for larger fleets compared with the optimal fleet size for the system. The fleet management system cannot be coordinated via traditional financial payments. Incentive alignment in decentralized humanitarian logistics is an interesting challenge.

Decentralization and earmarked funding affect humanitarian vehicle replacement. Often one donor funds vehicle procurement through the IHO headquarters while other donor funds operating costs through national offices and programs. At the end of the cycle, the party operating vehicles has to sell them but gives the salvage value back to the headquarters. Neither obtaining high salvage values nor replacing on time is a priority for the operating party. This situation results in aging fleets. Incentive coordination for vehicle replacement is necessary in practice and interesting from a research perspective. Earmarked vehicle use affects response times to the needs of relief programs. IHO's constraint to freely allocate vehicles to different missions results in delays to provide vehicles to programs when required. Current OR models do not consider this important but subtle aspect of humanitarian logistics.

Finally, field operating conditions result in interesting research challenges regarding routing. With disasters affecting densely populated areas with poor construction standards, debris is becoming a big problem during the immediate response phase. Algorithms for debris removal would be quite useful. Other challenges of operating conditions relate to network design, maintenance, and spare part management.

It is expected that humanitarian logistics workload will increase faster than available resources. It is our hope that OR will support practitioners to maintain and increase efficiency in such a challenging area.

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