Master's thesis in Business Administration
Specialisation in Business Analysis and Modelling

Discovering feasible strategies reducing the environmental impact of International Humanitarian Organisations' transportation of personnel

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Outline of the Master's thesis

1. Introduction

The demand for humanitarian aid in developing countries has been rising annually for the last decade (Grafham & Lahn, 2018) and is likely to continue increasing (Abrahams, 2014; IARAN, 2017). Addressing the growing caseload, International Humanitarian Organisations (IHO-s) raise the number of humanitarian operations, which are performed via transportation of vital goods, equipment and aiding personnel to the hosting countries, resulting in growing number of road and air travels (Abbasi & Nilsson, 2012). Consequently, the IHO-s' consumption of fuel is increasing, leading to more emissions of the locally and globally damaging air pollutants, such as carbon dioxide (CO2) (Grafham & Lahn, 2018). Apart from not complying with the internationally accepted Paris Agreements, seeking for the reduction of the carbon footprint of transport operations (Torjesen, 2017), this trend also contributes negatively to the climate change in the target areas of humanitarian aid (IPCC, 2014). In fact, negative environmental impact of humanitarian fleet in the hosting countries increases the risks of emergence of a new local natural disaster, which can trigger socio-economic crises in the long-term perspective and thus, increase the demand for assistance in these areas even further (Halldórsson & Kovács 2010; Abrahams, 2014; IPCC, 2014). Research by Kelly (2013) confirmed that "the failure to address environmental considerations within humanitarian interventions, can lead to a web of unintended adverse impacts on people and environment" (p. iii). These considerations unveil the cruciality of environmental dimension in the IHO-s' fleet management.

At the same time, the tension that IHO-s, though aiming to aid displaced areas, simultaneously negatively influence local territories through the environmental impact of transporting operations, is becoming more alarming. These organisations face controversial trade-offs between the amount of aid delivered and the effects of air pollution contributed to the target areas, between remaining within budgetary constraints and implementation of environmentally friendly strategies of fleet management (Holweg & Miemczyk, 2002). While not being able to reduce the number of humanitarian operations, as the demand for aid is expected to grow annually, or exceed the limits of donors' funding, the IHO-s must search for solutions, enabling delivery of same amount of goods and personnel within budgetary constraints with less environmental harm from physical transportation, or help target areas through alternative ways, not involving transportation. However, until recently IHO-s have been neglecting environmental aspects (Abrahams, 2014; Haavisto & Kovács, 2014; Kunz & Gold, 2015) mainly because they keep prioritising the speed of delivery over other criteria of humanitarian aid (Grafham & Lahn, 2018). Moreover, there is evidence that about 10% of the fuel consumed by IHO-s, and therefore of carbon emissions and corresponding environmental local impact, are the result of inefficient fleet management, which could be avoided by better coordination (Fleet Forum, 2017). Therefore, the development of alternative organisational policies, focusing on environmental impact, is vital for future functioning of IHO-s.

Apart from lacking environmental practices within IHO-s' operations, the academic literature in this field is also scarce. Pedraza Martinez, Stapleton, and Van Wassenhove (2010) researched the organisational processes of IHO-s and pointed out the importance of further studies on the environmental sustainability of humanitarian logistics. Later, Dubey and Gunasekaran (2015) suggested that "there is a unique opportunity for the humanitarian logistics and supply chain community to integrate disaster relief supply chain networks with ecological footprints". Additionally, Grafham and Lahn (2018) researched energy costs of humanitarian organisations and claimed that "until recently, however, little attention has been paid [...] to the environmental impact […] associated with their activities". It demonstrates that the importance of the topic in scientific society has been highlighted for the past decade, while it remains still under-researched. Although some studies attempted to discover factors discouraging IHO-s from taking actions towards more optimised and environmental-friendly fleet (Abbasi & Nilsson, 2012; Abrahams, 2014; Grafham & Lahn, 2018), further research on identification and assessment of such actions was stressed to be important in academic works (Haavisto & Kovács, 2014). To sum up; apart from social urgency, the topic of IHO-s' environmental impact has a significant scientific relevance.

On the other hand, there are multiple studies addressing environmental impact of transportation in general. According to van Wee, Banister, Annema, and Geurs (2013), emissions of air pollutants are the direct function of the type of fuel and its amount used by vehicles, which depends on the driven distance. Age of the vehicle is another relevant factor to the emissions, with newer models having more advanced engines, consuming less fuel per kilometre driven (Pedraza Martinez et al., 2010; Grafham & Lahn, 2018). At the same time, there is a parallel effect of ageing, increasing the average fuel consumption per certain distance due to declining efficiency of engine with time (van den Brink & van Wee, 2001; Bai, Ping, Chen, & Shen, 2012). Moreover, Pedraza Martinez et al. (2010) pointed out the impact of driving conditions and infrastructure on fuel consumption and resulting air pollutant emissions. This theoretical framework can be applied within the specific context of humanitarian aid delivery to research its environmental effects. Additionally, while referring to the knowledge gap highlighted by Haavisto & Kovács (2014) regarding the potential actions towards more environmentally sustainable humanitarian fleet, it is also important to assess the costs of transportation, which were previously studied by van Wee (2013) and described as a sum of constant (e.g. procurement costs) and variable (e.g. fuel costs, maintenance costs) expenditures. Cost-efficiency of actions is defined as delivering the targeted amount of aid while remaining within the budget constraints (Hirschinger, Moser, Schaefers, & Hartmann, 2015). Finally, apart from environmental and financial dimensions, another crucial outcome of interest of actions for IHO-s is undoubtedly operational, estimated as the amount of delivered aid to the target area, being the main mission of such organisations (SPHERE, 2011).

Overall, this study will address the gap in academic knowledge described above, while being based on existing academic literature in IHO-s' management and general sustainable fleet management. The focus will be narrowed down to the perspective of IHO-s' transportation of personnel to the areas of aid, due to possession of an access to the data, describing the fleet involved in such operations. The scope of the research will be limited to the development programmes rather than relief programmes, as environmental issues of IHO-s' transportation is noticeably under-researched topic and relief operations imply higher research complexity of uncertainty factors and speed logistical planning (Pedraza Martinez et al., 2010).

Finally, this research will *aim* to build a System Dynamics model to identify cost-efficient strategies that can enable International Humanitarian Organisations to reduce the environmental impact of the transportation of their personnel, while providing the demanded level of aid. The methodology will include quantitative analysis and System Dynamics modelling and simulation tools. The results of the research will support IHO-s in decision-making regarding transportation of their personnel from the environmental perspective and systemic view. This study is conducted as a part of the internship on a position of a researcher at Fleet Forum, which is a joint venture established in 2003 between the United Nations World Food Programme (WFP), International Federation of Red Cross (IFRC), World Vision International (WVI) and the global express services company TNT to improve humanitarian logistics in developing countries (Martinez et al., 2010). In the later years, it attracted more members, such as UNICEF, DHL, and FedEx.

To reach this study aim, the following *research question* will serve as a guideline for this study:

What are the cost-efficient strategies that can enable International Humanitarian Organisations to reduce the environmental impact of the transportation of their personnel, while providing the demanded level of aid?

2. Theoretical background

The goal of humanitarian aid delivery is to address the needs of people, being in a difficult situation or conditions (Haavisto & Kovács, 2014). The two core principles, underlying humanitarian operations are helping to and saving lives of people, who were affected by disaster or conflict, while taking all possible measures to bring relief to human suffering (SPHERE, 2011). This global mission of IHO-s is performed through logistical planning of supply chains and efficient fleet management, a big part of which is mobility of aiding staff to the remote areas. According to Pedraza Martinez et al. (2010), humanitarian aid from the perspective of transporting operations has two dimensions. On the one hand, this is the rapid reaction to emergency situations, which is a short-term and less predictable focus, prioritising the efficiency of the delivery in the sense of speed of bringing relief to the target areas. On the other hand, IHO-s have long-term development programmes, which are oriented towards areas with long-lasting socio-economic crises and aiming at the improvements there.

Although environmental impact of humanitarian fleet had a scarce academic attention, environmental aspect of transportation in general was researched by multiple authors. The first scientists, who addressed the systematic view on the sustainability of supply management, were Carter and Rogers (2008). Through the complex analysis of previous literature on fleet management, they attempted to unite such dimensions as social, economic, and environmental effects of organisational transportation systems, in a new theory, named "*Sustainable supply chain management*". Taking this concept as a basis, Kunz and Gold (2015) applied this theory to the context of humanitarian aid delivery by representing the existing knowledge about humanitarian fleet from the comprehensive perspective of sustainability. However, both in academic literature and through interviews with representatives of IHO-s, the authors found it impossible to analyse the environmental dimension of the concept, as the organisations limit their "sustainable performance to only social and economic factors", while exhibiting "the absence of consideration of environmental outcome". What can be observed, therefore, is that lack in environmental practices results in scarce academic literature on the topic.

Nevertheless, there were a few studies, attempting to address environmental impacts of humanitarian fleet. Abrahams (2014) conducted a case study of an IHO and sustainability of its aiding operations after the earthquakes in Haiti in 2010. The author came up with a list of barriers, which prevented the organisation from environment-oriented actions, such as a "perceived trade-off between speed and environmental sustainability", "lack of personnel with environmental sustainability expertise", etc. Through literature analysis on humanitarian operations, addressing sustainable supply chain management, Abbasi and Nilsson (2012) also identified factors influencing sustainable decision-making, such as "costs, uncertainties, complexity, operationalisation and cultural changes". Despite these outcomes, the authors pointed out the necessity of further research with holistic view, including environmental sustainability of humanitarian fleet management. Moreover, the authors claimed that previous literature is lacking in calculations related to environmental effects of the IHO-s' transport. Finally, regarding possible strategies and actions towards the reduction of air pollutants' emissions of humanitarian fleet, Abbasi and Nilsson (2012) found out that previous literature was limiting their view on alternative measures only to the perspective of improvement of fuel usage efficiency, while Haavisto and Kovács (2014) declared that "further research is though needed to identify greening initiatives" for IHO towards more environmentally sustainable fleet.

The academic literature analysis of previous studies regarding environmental impact of the IHO-s' fleet reveals the number of limitations and represents an existing gap in scientific knowledge. Based on it, the main guidelines for further research are summarised in *Table 1*.

Table 1. Existing academic knowledge gaps and guidelines for future research

Authors	Existing gaps or guides for future research
Pedraza Martinez et al. (2010)	(1) Importance of further studies on the environmental sustainability of humanitarian logistics.
Abbasi & Nilsson (2012)	(2) Lack in calculations related to environmental effects of the IHO-s' transport; (3) Alternative strategies researched only from the perspective of fuel usage efficiency; (4) Opportunity for the research of environmental impact of IHO-s' fleet from the holistic perspective.
Haavisto & Kovács (2014)	(5) Necessity of the research, identifying possible strategies for IHO-s to improve environmental sustainability of their fleet.
Kunz & Gold (2015)	(6) Absence of research on evaluation of environmental performance of IHO-s' fleet.
Dubey & Gunasekaran (2015)	(7) Opportunity for the research, integrating disaster relief supply chain networks with ecological footprints.

In order to address the research gap (1), this study will introduce the estimators of environmental impact of IHO-s' fleet to the general evaluation of humanitarian aid's performance, which also includes costs and the aid delivered to the target area (Pedraza Martinez et al., 2010). Therefore, the first research sub-question, that this study aims to answer to fill in abovementioned gap, is the following *(SQ1): What are the factors influencing the environmental, financial and operational performance of the IHO-s' transportation of personnel?* By doing so, this research would be of a systemic nature, also addressing the research guide (4), requiring the holistic view of the IHO-s' fleet. This paper will also contribute to the research gaps (2) and (6) by introducing the data regarding the fleet composition and fuel usage, in order to conduct further numerical calculations of the environmental effect of the humanitarian fleet, involved in the transportation of personnel. Thus, the second research sub-question that is addressed in this paper is *(SQ2): How can environmental, financial, and operational performance of the IHO-s' transportation of personnel be estimated?* The policy analysis, aiming to discover cost-efficient strategies, meeting the demanded level of delivered aid and decreasing environmental impact of staff transportation, will address the gaps (3) and (5). Therefore, the following two sub-questions will be investigated as well: *(SQ3) How can external factors impact the IHO-s' transportation of personnel?* and *(SQ4) What are the possible alternative strategies that can improve the environmental sustainability of the IHO-s' transportation of personnel?*

The issue (7) will stay outside of the scope of this research, as requires more in-depth integrated and complex performance metrics development for relief programmes. Therefore, by answering the research question and corresponding sub-questions, this study will fill in the gap in the theory of sustainable humanitarian supply chain management, initiated by Kunz and Gold (2015). Moreover, it will expand the existing knowledge about environmental sustainability of humanitarian fleet and the ways it can be improved, expanding the works of Abbasi and Nilsson (2012) and Haavisto and Kovács (2014). The research will use a conceptual model (*Figure 1*), represented in System Dynamics notation, to demonstrate a holistic overview of the environmental impact of humanitarian fleet, involved in transportation of IHO-s' personnel, and other relevant outcomes of interest of IHO-s.

The conceptual model (*Figure 1*) is based on the general findings of van den Brink and van Wee (2001), Bai et al. (2012), van Wee et al. (2013), which described and explained main factors, influencing environmental impact of the transportation. By bringing these findings into the context of humanitarian logistics of aiding personnel, applying the framework of humanitarian logistics by Pedraza Martinez et al. (2010), the model was created. First, number of personnel-trips, which will be a measurement of operational performance of IHO-s being the amount of delivered aid, are defined, responding to the demand for aid in the target area (Pedraza Martinez et al., 2010). This amount influences the number of kilometres driven by the fleet of an IHO, involved in the mobility of the staff, which is also affected by the average maximum capacity of the fleet's vehicles, average ratio of seats loading and the average trip distance. With an increase in distance driven by the fleet vehicles, the amount of fuel consumed increases in the scale, which is defined by the characteristics of vehicle and its year of production, meaning that older models assumed to have less efficient technology and increase the amount of fuel consumed per each kilometre driven (Pedraza Martinez et al., 2010; Grafham & Lahn, 2018). On the other hand, age of the vehicles defines the ageing effect, which represents the decrease in engine efficiency with the yearly use of it (Bai et al., 2012). Additionally, the average kerb weight of the fleet vehicles and the number of passengers they transport influence the average fuel economy. The amount of CO2 emissions increases with the rise of the amount of fuel consumed by the fleet. Finally, fleet size, being the number of vehicles which an IHO owns, has an impact on the procurement costs, while maintenance costs defined by the driven annual mileage (van Wee, 2013).

Applying the perspective of Walker (2000), the connections, described above, form the system of IHO's mobility of personnel. This system connects the relevant to the problem variables, that are under control of an organisation. There are three corresponding outcomes of interest for an IHO, that each its action is controlled by. First, it is the environmental impact. The model limits the environmental effect solely to carbon dioxide emissions (CO2), which is one of the most emitted and damaging gas pollutants for the climate and human well-being (van Wee et al., 2013). This focus will simplify the process of numerical estimations and increase visibility of main causal links. Second, it is overall costs of IHO-s' aid delivery, which are composed of the costs of fuel, procurement, and maintenance costs of vehicles (van Wee et al., 2013). Number of kilometres driven increases naturally the amount of fuel used. The third outcome of interest is the amount of delivered aid, which is estimated by the number of performed personnel-trips.

Moreover, there are external factors, that influence IHO-s' transportation of personnel, while not being controlled by the organisation (Walker, 2000). For example, driving infrastructure and traffic are the characteristics of the locations, where transportation is performed. These facilities influence the amount of fuel required for a vehicle to drive a certain distance (Pedraza Martinez et al., 2010). Additionally, the amount of funding by donors, which is the main source of finances for IHO-s, affect the costs, that an IHO can spend. Finally, the demand for aid in target locations can change depending on vulnerable socio-economic conditions or natural disasters, which lead to the adjustment of the number of personnel-tips, that an IHO is required to perform (Abrahams, 2014).

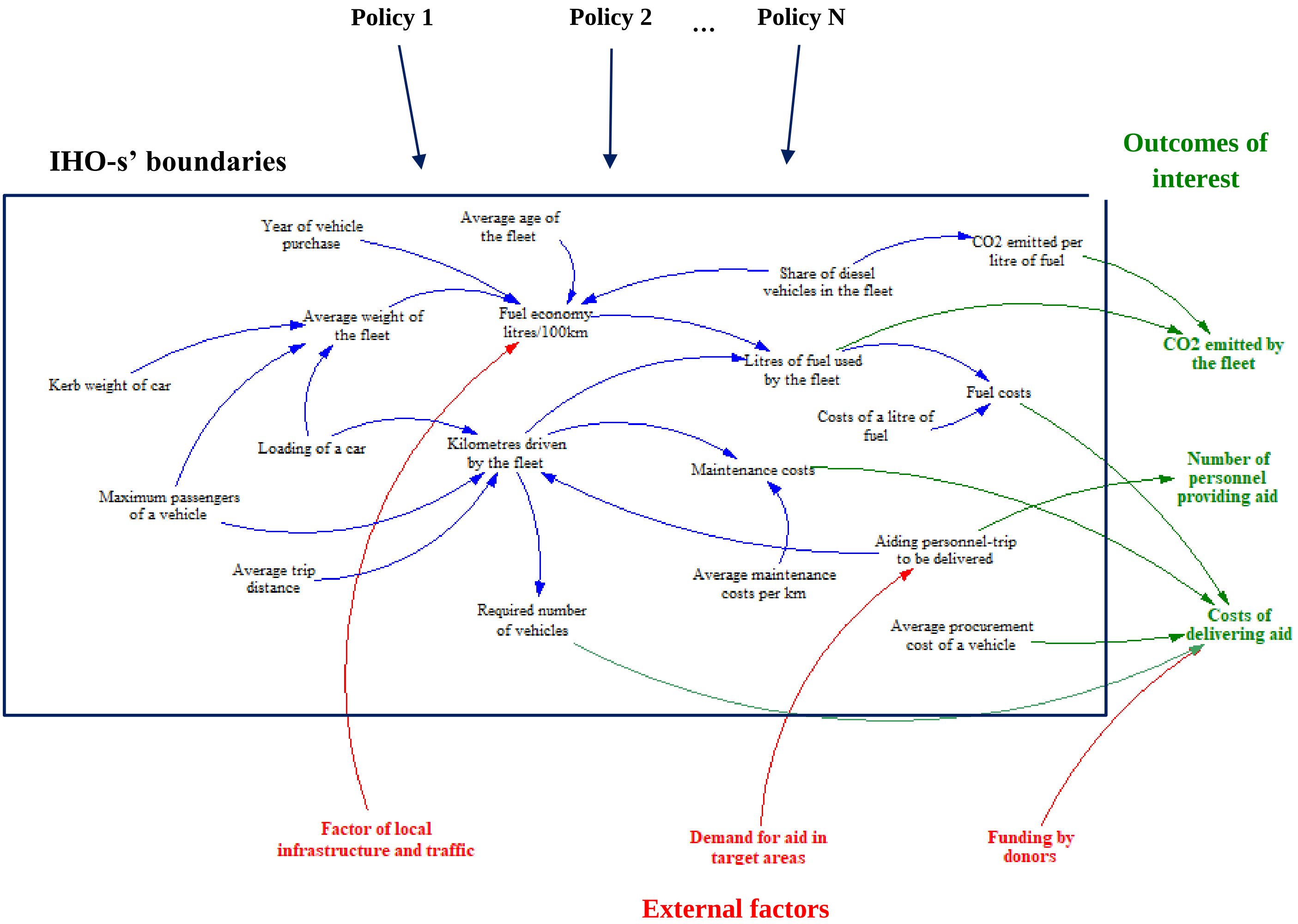

Figure 1. Conceptual model of the proposed research

The model will be tested, following the methodological plan, described in the following chapter. This will enable this research to define the boundaries of the discussed problem. After that, policy alternatives will be tested, by changing the system's parameters or structure accordingly, while controlling for the evaluations of the three key outcomes of interest. Elaboration on the techniques of this analysis are also presented in Chapter 3.

3. Methodology

This study in its planning and research strategy followed the guidelines of policy analysis developed by Walker (2000), while also applying System Dynamics modelling tool and data analysis. The steps that this study undertook to answer the research (sub-)questions with the corresponding data collection and analysis methods are described below.

3.1. (SQ1) What are the factors influencing the environmental, financial, and operational performance of the IHO-s' transportation of personnel?

3.1.1 Step 1. Identification of the problem and its boundaries. As this research aims to represent a holistic view on environmental impact of IHO-s' fleet, involved in the transportation of personnel, the range of relevant and most influential factors must be included under the focus of the study (Walker, 2000). In order to define these factors, or 'boundaries of the system', the test of the hypothesis (*Figure 1*), depicting the context of the research, was conducted by validating the model with the existing academic research, practical findings and available dataset of an IHO's fleet usage and composition. The details of this procedure are described below.

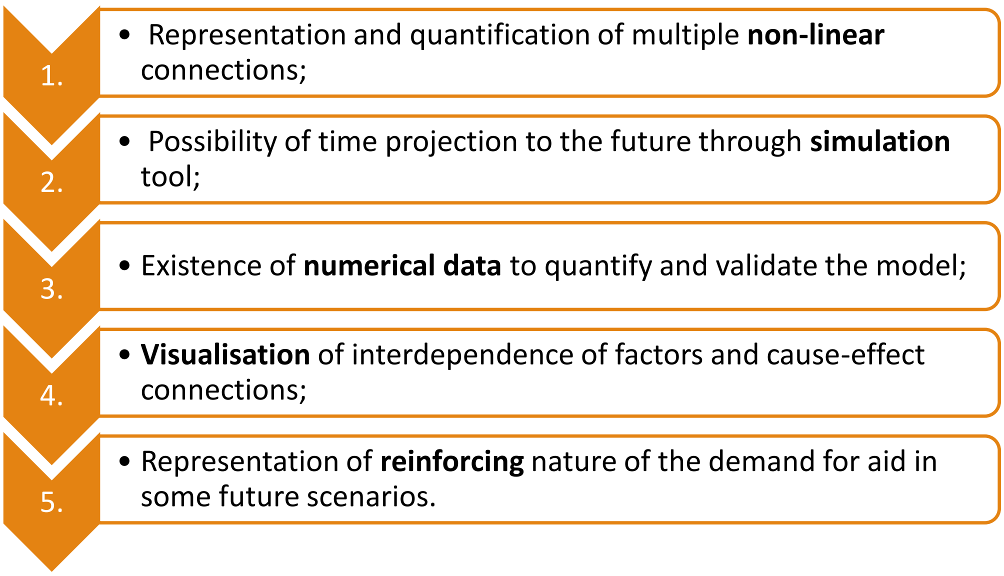

Figure 2. Arguments supporting methodological choice of System Dynamics tool and Vensim software

To illustrate the systemic perspective of this research, uniting environmental factors of the fleet with the costs and amount of performed personnel-trips, the System Dynamics modelling was applied, using Vensim software. This method allows to visualise main factors and cause-effect connections between them, quantify these relationships, and perform simulations for the future periods. Additionally, possession of an access to the fleet data enables validation of the model developed in System Dynamics methodology, while reinforcing nature of the demand for aid growth in some future scenarios (IARAN, 2017) can be represented in this method by loop connection. The reasons supporting the choice of this method are summarized in *Figure 2*.

Before proceeding to the verification of the model, available dataset required to be processed. Because this study is conducted as a part of an internship on a position of a researcher at Fleet Forum, an access to a dataset regarding fleet composition and its usage of an *Organisation A* (name was changed due to anonymity request) was granted. This IHO has over 10 000 employees worldwide, delivering humanitarian aid to around 80 countries, majority of which are African and Middle Eastern. The IHO possesses over 3000 light vehicles, enabling the transportation of aiding personnel. *Organisation A* delivers assistance to the target areas to bring relief to local healthcare systems after natural or socio-economic disasters. The dataset has the recordings of over 3000 vehicles, declaring their type, procurement costs, country of operation, maintenance and fuel costs, litres of fuel consumed, number of kilometres driven and the year of purchase, reported for the whole period from the date of procurement of a vehicle until October 2018. Therefore, before using the data for model validation, the age of each vehicle was calculated and used to define average annual fuel consumption, distance driven and related costs. For further model validation purposes, the data was aggregated by country. Out of all countries, where *Organisation A* operates, 9 were chosen with the biggest number of vehicles, possessed by the IHO there. Those countries are Afghanistan, Central African Republic, the Democratic Republic of Congo, Iraq, Jordan, Kenya, Mali, Nigeria, and South Sudan. The vehicles were filtered to only the passenger vehicles, following the objective of this research, focussing on transportation of personnel. Those vehicles are light-duty vehicles, vans, and motorcycles. Kerb weight of vehicles, maximum number of seats and the type of fuel used was found manually per each vehicle type based on the information about the model in the dataset. Finally, per each country the data of the fleet was aggregated in overall or average characteristics (*Figure 3*).

In order to avoid during validation stage the misleading influence of an assumption that all vehicles drive on average same amount of kilometres, available data per each single vehicle about the distance driven was used to calculate weighted averages of fleet age, maximum passengers seats, kerb weight and share of diesel vehicles per country, using the coefficient of the driven distance of a vehicle per year in relation to overall annual mileage of a fleet in a particular country.

Country	Total Procurement Costs (USD)	Average consumption L/100 km	Average age (Oct 2018) (years)	Maintenance costs per year (USD)	Fuel costs per year (USD)	Fuel used per year (litres)	Distance driven per year (km)	Fuel (share of diesel vehicles in the fleet)	Average maximum passenger seats	KERB Weight (tonnes)	Number of vehicles
Afghanistan	3557758	14,9	7,3	113382	84868	102769	690733	1	7,6	2,25	142
Central African Republic	2349075	14,4	5,9	156293	150842	103025	715636	0,99	7,0	2,19	110
D.R. Congo	4254553	12,9	4,4	448699	226735	208500	1618082	1	6,6	1,87	240
Iraq	3498733	9,5	4,6	97553	137609	179953	1892805	1	5,5	1,7	177
Jordan	1734340	10,3	5	63366	113488	109080	1054724	0,38	5,1	1,5	95
Kenya	2607710	13,4	5,7	126510	116744	115036	858876	0,4	6,6	1,9	117
Mali	2392863	13,9	4,6	65782	181074	99596	716236	0,54	6	2	125
Nigeria	3303813	10,8	3,7	150475	250102	226318	2086851	1	8,1	2,2	148
South Sudan	4770693	14,5	5,3	286497	192166	186534	1284996	1	8,4	2,25	190

Figure 3. Aggregated data about Organisation's A fleet for 9 chosen countries

Factor of local infrastructure and traffic was obtained by aggregating multiple estimators: Roads Quality Index (theglobaleconomy.com with reference to World Economic Forum), Traffic Inefficiency Index (numbeo.com) and Infrastructure and Timeliness aspects of Logistics Performance Index (lpi.worldbank.org). The Roads Quality index is based on data from one question of the WEF Executive Opinion Survey, where the respondents evaluated the roads in their country on a scale from 1 (underdeveloped) to 7 (extensive and efficient) (theglobaleconomy.com). The data was available only for D.R. Congo, Iraq, Jordan, Kenya, and Mali and relates to 2018 year. Traffic Inefficiency Index aggregates the information about long commute times, poor traffic laws and other traffic-related factors (numbeo.com). The measurements were only available for Jordan and Kenya and represents the state of 2018. Logistics Performance Index is an aggregated estimator of efficiency of logistical transportation in different country and consists of 6 dimensions, out of which this research focuses on two: Quality of Local Infrastructure and Timeliness, meaning the ability to perform trips in accordance with planned time. These assessments are based on survey of experts in the field and available for all 9 countries, which this research uses the data from. The evaluations are available for 2018. The coefficients, measured per each category, were calculated by counting the ratio to the global average of the same parameter, with the coefficient higher than 1 being less efficient in the corresponding aspect in comparison to global average of the same factor. Additionally, the coefficients sometimes were derived from the researches, which addressed specifically the fuel economy issues in the target country (for example, Shrestha (2015) researching Afghanistan fuel economy). Finally, all available coefficients were averaged per each country to obtain the final index that was used for the model validation. This coefficient aims to represent general idea about the extent to which local infrastructure and traffic are less efficient comparing to global averages. The underlying assumption in this case is, that the fuel consumption is increasing relatively to the original level with the same proportion, that the traffic and driving infrastructure are less efficient than the global average. The summary of the findings about the local infrastructure is presented below (*Figure 4)*.

Country	Road quality	Inefficiency index	Factor infrastructure & timeleness (LPI)	Local researches	Final coefficient of local infrastructure and traffic
Afghanistan	X	X	1,420	1,130	**1,275**
Central African Republic	X	X	1,399	X	**1,399**
D.R. Congo	1,905	X	1,240	X	**1,572**
Iraq	1,053	X	1,252	X	**1,152**
Jordan	0,952	1,718	1,010	X	**1,227**
Kenya	0,976	1,859	1,038	X	**1,291**
Mali	1,250	X	1,164	X	**1,207**
Nigeria	X	X	1,060	X	**1,060**
South Sudan	X	X	1,242	X	**1,242**

Figure 4. Factor of local infrastructure and traffic for 9 chosen countries

The initial model (*Figure 1*) was extended and quantified based on the number of researches about fuel consumption, environmental impact of the fleet, etc. (Wee et al., 2013; Zacharof & Fontaras, 2016), but also from the analysis of trends in global fuel economy of newly registered cars and the dynamics of their average weight (IEA, 2012). Further, by using the processed data from the *Organisation A*, the system was tested, meaning that the structure and parameters of the system were validated (Angerhofer & Angelides, 2000). This structure and connecting formulas were validated, applying System Dynamics verification testing methods, developed by Forrester and Senge (1980), Barlas (1996) and Drobek, Gilani, and Soban (2013). The validation pursues the goal of building higher confidence in the developed model, its cause-effect connections and linking mathematical formulas. These tests are described below.

Structure verification test aims to ensure clear and adequate representation of real-world system of factors and connections between them. It also means, that all causal links must be present in real life (Forrester & Senge, 1980). To test this, the model was checked on absence of any contradictions with existing knowledge in the field, basing on the literature review. Control for the cross-correlation effects between factors was considered as well.

The second way of structure verification was exposing the findings to the knowledgeable experts in humanitarian operations (representatives of Fleet Forum), seeking for feedback, criticism, and corresponding adjustments (Forrester & Senge, 1980). Additionally, underlying assumptions, on which the model is based, were tested on realism with the experts. This procedure was implemented through one discussion sessions and three individual consultations with Fleet Forum practitioners. The group discussion session took place online with three experts altogether, where first version of the model was demonstrated and explained. After receiving the feedback, the adjustment and extending of the model happened (regarding ageing effect of the fleet and fleet size changing). This final version was then sent individually to the experts, requesting further criticism and feedback, after which final corrections in the model were made.

Parameter verification test checks constant parameters, through which dynamic variables are connected. After the structure of the model has been validated, the mathematical underlying connections must be checked. The first way to do this is to address existing researches, focusing on numerical estimations of the relevant for the model parameters. However, parameter check can be also performed based on empirical evidences (Barlas, 1996; Drobek, Gilani, & Soban, 2013), which in this research is a dataset of the International Humanitarian *Organisation A* (*Figure 3*). As available data covers not all variables of the system, it was used to check the parameters of the fraction of the overall model, containing only the variables present in the dataset. Regarding maintenance, procurement and fuel costs, the advised approach of Drobek et al. (2013), referring to Graham (1980) was used, because the nature of these parameters is disaggregated, meaning that it refers straight to a particular measurement in the real world and directly represents it numerical estimation, which is available through data collection. The method suggests evaluating of the corresponding parameters directly from the data within the interval of observed numbers. In this case, the data not only verified the parameters but also defined them.

At the same time, to verify the parameters defining the fuel economy, the comparison between the observed values and predicted by the model estimations was made. Although the model assumes the existence of ageing effect, the data available by *Organisation A* does not represent per-year details of the fleet usage, but rather the cumulative estimations for the whole period of usage. Therefore, we assume, that the average fuel consumption, that was calculated on the basis of data, is the estimation of fuel consumption of the vehicle or fleet at the point, where the reported age was twice less, meaning right in the middle of reported period of the time. Assumption can be considered appropriate, considering that the ageing effect has a linear representation. Mass and Senge (1978) in their research, comparing the actual data with the model prediction, were accepting the error equal to 10%. This threshold was taken as an estimator for validation, while keeping in mind that Mass and Senge (1978) used models also to generate the data, comparison with real-world data in this research, may accept slightly bigger deviations (10-15%). Additionally, deviations were checked on the fact of overlaps between the areas of deviations, checking that even there is a mistake, it should be smaller than the differences in original data between countries.

Extreme conditions test requires checking the adequacy of the model's outputs and behaviour under the minimum and maximum estimations of key entry factors (Forrester & Senge, 1980). The test was made checking the CO2 emissions of the fleet that has 0 or significantly high annual mileage, average weight of a vehicle, or average age. Adequacy of the corresponding CO2 emissions, predicted by the model, was evaluated.

Boundary adequacy (structure) test implies review of the model from the perspective of the research objectives (Forrester & Senge, 1980). As the model should be the minimum possible to serve as a tool for the study (Walker, 2000), some parts can be aggregated, while the others must include all relevant details.

Dimensional consistency test aims to verify if in all the equations of the model the units of variables on the right and left sides were corresponding. The test was conducted by the analytical tool for System Dynamics, which automatically check the dimensional consistency of all mathematical connections.

When the initial structure was not explaining adequately the actual data or were not meeting the requirements of tests, the parameters and variables were re-checked in further academic research, adjusted and other factors, which are relevant to the system, were investigated via academic literature and industry reviews analysis and added to the model (Barlas, 1996). After the model was successfully validated with all tests, so that the differences in environmental impacts and fuel consumptions among observations are explained by causal connections between relevant factors, the boundaries of the focus of the research were defined. The research sub-question one was, therefore, answered by conducting model extension and validation, while keeping the model the smallest possible to serve further as a tool for testing strategies' effects (Barlas, 1996; Walker, 2000). Overall, the result of this step was a quantified System Dynamics stocks-and-flow diagram.

3.2. (SQ2) How can environmental, financial, and operational performance of the IHO-s' transportation of personnel be estimated?

3.2.1. Step 2. Specification of the objectives of a new strategy. During this step, academic literature regarding IHO-s' operations was analysed to find the key objectives that these organisations target to follow. The issues of costs, amount of humanitarian aid and environmental impacts of the fleet were described and the perspective of organisations on them were specified. However, these objectives are viewed differently by IHO-s while performing aid as a part of relief programmes and of development programmes (*Figure 5*).

	In-country program	Field VFM
Relief	Speed of aid delivery (equity)	Speed of vehicle delivery (efficiency)
Development	Access to and coverage of identified demand (equity)	Cost-efficiency, fleet availability (efficiency)

Figure 5. Multiple objectives of IHO-s (Pedraza Martinez et al., 2010)

This research rather focuses on the development programmes, as environmental issues of IHO-s' transportation is noticeably under-researched topic and relief operations, implying additional complexity of uncertainty factors and rapid logistical planning, would be a large issue to research through the perspective of fleet sustainability at this stage of academic knowledge in the field. Therefore, this study focuses more on long-term and better plannable development programmes of IHO-s. It will omit the necessity to extend the System Dynamics model to the dimension of supply and logistical planning, thus the principle of Barlas (1996) and Walker (2000) of keeping the model smallest possible to serve for the purposes of the research can be pursued.

As a result of this step, the objectives were viewed from the context of this research about the mobility of staff and the key objectives were defined, which potential strategies should meet regarding the three main outcomes of interest: environmental, financial, and operational.

3.2.2. Step 3. Development of evaluation criteria of strategy. Outcome indicators are the three key outcomes of interest for an IHO, defined before. At this step, the metrics of the extent, to which the potential strategy meets the defined in the previous step objectives, were developed. Numerical thresholds were derived from the data analysis on *Organisation A* and specified per each of the 9 countries. The criteria include the related to the main objectives consequences of policies. As a result of this step, the developed metrics for the evaluation of the environmental, financial and operational outcomes of the IHO's transportation of personnel were added to the System Dynamics model in order to control later the alternative policies' impacts with them. By finalising this step, the SQ2 of the research proposal was answered.

3.3. (SQ3) How can external factors impact the IHO-s' transportation of personnel?

3.3.1. Step 4. Development of scenarios. As was described in the initial model (*Figure 1*), the mobility of the staff by IHO is influenced by numerous factors, that are, in fact, outside of the system of control for an organisation. These factors are the local aspects, such as driving conditions and infrastructure or traffic, amount of funding by donors and the demand for aid in the target areas. As these factors cannot be set by IHO, there are multiple combination of the assessments of these factors, forming the scenarios of the future and defining the characteristics of external environment for an IHO. Later, by testing each alternative strategy within the context of each scenario, the criteria of policy robustness will be assessed. The source of the scenarios was a report by Inter-Agency Research and Analysis Network (2017), which addresses mainly the conditions, within which humanitarian aid will be performed, the different possible future caseloads of an IHO, and donors' funding. As a result of this step, the key scenarios were illustrated and explained via the framework of the developed and previously validated System Dynamics model by defining variables influenced by them and linking mathematical equations. This step answers the SQ3.

3.4. (SQ4) What are the possible alternative strategies that can improve the environmental sustainability of the IHO-s' transportation of personnel?

3.4.1. Step 5. Selection of alternative strategies for evaluation. Potential actions, that IHO-s can undertake regarding their transportation of personnel, were investigated at this step. This information was derived from the open sources on the 'greening' initiatives within humanitarian aid academic research, IHO-s' reports and general transportation industry reviews. Apart from fuel consumption and logistics optimisation solutions, the alternative vehicle types, fuels, and sources of energy were researched. These initiatives were found in such platforms as 'Greening the Blue', 'Fleet Forum: Case Studies', United Nations report (2019), etc. The result of this step is represented in the list of potentially feasible strategies, which were tested in the next step. For each strategy, the corresponding adjustments in the System Dynamics model were defined, explaining, which parameter or structural changes are required. Some strategies (such as electric vehicles implementation) were tested on feasibility by researching local infrastructure facilities through open sources and portals. Completion of this step contributed to SQ4.

3.4.2. Step 6. Analysis of each alternative. The analysis addressed the criteria, defined in the Step 3, and robustness of strategies regarding scenarios, described in the Step 4. The assessment narrowed down to the settings, related to operations of *Organisation A* in Jordan, as it was one of the few countries, in which all the strategies previously defined could be feasible (has necessary local facilities). For each alternative, by adjusting the initial structure and parameters of the System Dynamics model, developed in the first step, accordingly to the potential strategy, the environmental impacts of them, in combination with related personnel-trips and expenditures, were evaluated by the metrics, developed in the Step 3, after running the simulations for future periods. The reference point of the analysis was the evaluation of the base case – the current policy the IHO-s have regarding their fleet, involved in the transportation of the personnel (Walker, 2000). Further, by comparing the outcomes of interest for each alternative, those strategies were under focus, which proved the positive impact on the reduction of the environmental impact, while remaining within the budget constraints and delivering the required amount of personnel-trips.

Apart from evaluation of these effects, the robustness analysis of the policies was performed by conducting scenario analysis. The System Dynamics model was, therefore, adjusted according to the parameters of each scenario sequentially and each strategy was tested in the new conditions. Finally, the conclusion was made on how vulnerable each alternative is to potential changes in the future and which strategy has the best performance on the combination of the three outcomes of interest within each future scenario separately.

As a result of this step, each potential strategy, which was derived in the Step 5, got an assessment per each criterion, defined in the Step 3 for each scenario, described in the Step 4.

3.4.3. Step 7. Comparison of the alternatives in terms of future effects, including environmental. The comparison of the strategies was represented in Multi-Criteria Decision Analysis matrix, covering key outcomes assessment and test for future scenarios for every alternative strategy (Velasquez & Hester, 2013). This method enables representation of all strategies and their outcomes in a summarized way, where they can be compared. On the basis of this, the guidelines for the IHO-s were developed in order to support their decision-making regarding the fleet management, involved in the mobility of the staff, from the holistic perspective, including environmental dimension among others. After this step the outcomes were summarised and conclusions regarding the main research question were made.

3.5. Research ethics

Organisation A, content experts and academic advisors were informed in advance about research goal and objectives, as well as about expected contribution and its role in the research. Whenever required, the data and knowledge were presented in the research anonymously under another name. Participation in the research of IHO-s was fully voluntary and the final version of this research was sent to the participating IHO, whose data is used in the research, Fleet Forum experts and academic advisors, involved in the research.

The research was fully avoiding plagiarism, all references to other sources were presented according to common standards. Already existing knowledge was not exposed as personal findings and are containing the names of the original authors.

The aim of the research is an academic contribution and results will be available publicly, so that each party, both academics and IHO-s, will be able to derive economic, social and environmental value from real-life application of the findings or benefit further in academic field.

4. Research results

4.1. Step 1. Identification of the problem and its boundaries

After complex analysis of all existing research on transportation of passengers and resulting environmental effects (Ang et al., 1991; van den Brink & van Wee, 2001; IEA, 2012; Zacharof & Fontaras, 2016; Mbandi et al., 2019; IEA, 2019), the findings were viewed from the perspective of IHO-s and the following System Dynamics model was developed (*Figure 6*).

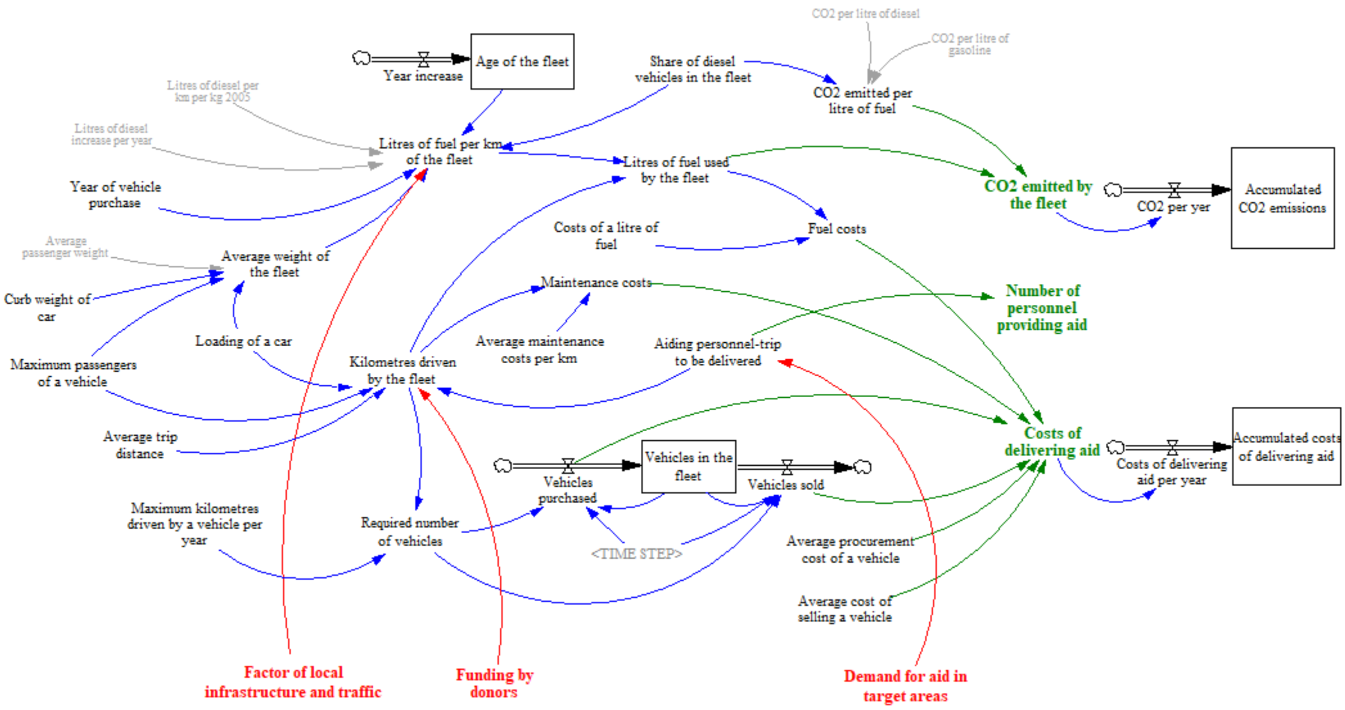

Figure 6. System structure based on academic research findings

As was stated before, the three key parameters of control, or outcomes of interest for an IHO, which each decision of an IHO is checked with, are the number if personnel-tr to the target areas, the costs of delivery of this aid, and an environmental effect. Elaboration on the cause-effect links extraction, references to previous academic findings and explanation of mathematical connections between variables are described below in the following thematical sections: CO2 emissions, fuel consumption, weight of the fleet, fleet size, driven distance, costs and aid delivery.

4.1.1. CO2 emissions

The environmental impact of IHO's fleet involved in the transportation of its staff, is measured in kilograms of CO2 emitted by the vehicles every year ('CO2 emitted by the fleet') and cumulatively for certain period ('Accumulated CO2 emissions'). Annual emissions can be calculated by multiplying the amount of fuel consumed by the fleet by the average CO2 emissions resulting from the usage of a litre of fuel, which is 2,34 kg of CO_2 per litre of gasoline and 2,64 kg of CO_2 per litre of diesel (European Conference of Ministers of Transport, 1998). To calculate the average CO_2 emissions per litre of fuel composition for a particular fleet, the share of diesel vehicles in the total number of vehicles in the fleet is used, assuming that IHO-s' vehicles have either gasoline or diesel engines (the assumption which is confirmed by the available data and expert opinion of Fleet Forum representatives). Based on this, weighted average of CO_2 emissions per litre of fuel is calculated. Another underlying assumption worth mentioning is that both diesel- and gasoline-driven vehicles are used, on average, equally in terms of distance, consume equal amount of fuel and are around same age. In case this assumption is violated, the model is likely to predict results deviating from the reality. However, it can be avoided by future users of the model by calculating weighted averages of the deviating parameters based on coefficients derived from the proportion of distance driven by certain car in all annual mileage of the fleet. The details about variables and formulas in the model regarding CO_2 emissions are presented in *Appendix 1*.

4.1.2. Fuel consumption

At the same time, the total amount of fuel that a fleet consumes per year is dependent on the average fuel economy of it, meaning the average amount of fuel required for driving 100 km distance. This parameter is a complex function of multiple factors influencing fuel consumption, which were previously researched and estimated by multiple studies. These factors are engine characteristics, aerodynamics features, driving behaviour, weather, vehicle condition and mass, road and traffic conditions, etc. (van den Brink & van Wee, 2001; Zacharof & Fontaras, 2016; Fontaras, Zacharof, & Ciuffo, 2017; Mbandi, Böhnke, Schwela, Vallack, Ashmore, & Emberson, 2019). However, between certain pairs of these factors high correlation can be observed. For example, engine capacity of a vehicle is correlated with its weight, therefore the model can include one of the parameters (Ang et al., 1991). This research will opt for weight, which already contains the effect of more powerful engines being heavier, due to better representability for final non-expert users of this research and availability of data of this characteristic.

Further, the age of a vehicle plays an important role in fuel economy. However, it is an indicator of two parallel effects: ageing of a vehicle and technical characteristics regarding vehicle 'generation', being a new-car specific fuel consumption estimation (van den Brink & van Wee, 2001). The first effect, called 'ageing' represents yearly increase in average fuel consumption due to previous use and thus decrease in engine efficiency (Bai et al., 2012), which also explains a high correlation of this factor with the cumulative kilometres driven by a car (Ang et al., 1991). Therefore, this research chooses to keep the variable ‘age’ rather than cumulative distance driven as the ageing effect can be described in a linear function, researched by Ang et al. (1991) and characterised by 0,18 litres/100 km of gasoline consumption increase with each year the vehicle gets older (or 0,16 litres/100 km of diesel, 1,12 times less than gasoline, calculated based on the amount of kWh energy production of one litre of each fuel). In the model, weighted average of an increase in fuel consumption by one year of the fleet gets older will be calculated based on share of diesel/gasoline vehicles in the fleet composition. It is worth mentioning, that this parameter, obtained from Ang et al.’s (1992) research is purely the ageing effect, as derived from the model which also includes the engine characteristics separately and without intercorrelation with the age.

Apart from the ageing effect, the year of vehicle purchase can be considered an indicator of the technological advancement of a vehicle with the newer cars being more fuel efficient (van den Brink & van Wee, 2001; Busawon & Checkel, 2006). The global annual average improvement in the light-duty vehicles engines was calculated based on the database of International Energy Agency (IEA, 2019). It provides information about over 50 countries worldwide and the measurement of average fuel economy of all newly registered vehicles per each year from 2005 until 2017, although with some missing values. Even though the general trend of yearly improvement in fuel economy can be observed globally, it is also important to look at the dataset representing the dynamics of vehicle weight. The dataset shows the average weight of the newly registered cars for same periods and countries, which enabled the creation of the new dataset, where the average amounts of litres of fuel per 100 kilometre transportation of one kilogram of the mass of the vehicle were calculated per year and per each country. After that, the global annual averages were calculated per each year, extrapolating linearly the missing values, when both previous and successive measurements were available (*Appendix 2*). The calculations revealed, that in 2005 on average the globally newly registered cars, according to their primarily stated characteristics, were requiring 0,0064 litres of gasoline equivalent for transportation of one kilogram of vehicle for 100 km. Applying the conversion scale for diesel vehicles, it corresponds to 0,0057 litres of diesel for the same distance and weight, which is 1,12 times less than gasoline. Starting from 2005, the annual improvement in such parameter was observed to be 2,65% annually. This measurement will be used as a base-year estimation but corrected by the composition of fleet using the share of diesel cars. As a result, the average age of the fleet will be used to calculate by how many years the fuel consumption per kilogram per 100 kilometres was improved due to technology development.

To check the validity of this finding, the comparison with other researches can be made. Ang et al. (1991) claim that an increase in 100 kg of fleet weight results in 0,2-0,3 l/100 km of gasoline consumption increase (excluding the effect of engine capacity); according to van den Brink and van Wee (2001) the same increase results in 7-8% increase in fuel consumption, including the effect of engine capacity (0,56 – 0,64 l/100 km); according to report by International Energy Agency (2019) same increase in weight results in 0,45 l/100km increase in gasoline consumption; in the research of Zacharof and Fontaras (2016) it is 6-7% (0,42 – 0,56 l/100 km improvement). We can conclude that the estimation, derived from the analysis of the datasets by IEA (2019), goes in line with the previous research as implies 0,64 l/100 km of gasoline increase with the rise in weight in 100 kg for the models, produced in 2005 and the decrease of this parameter yearly to lower numbers.

The underlying assumption of adding these findings to the model are the equal usage of the vehicles of all present in the fleet ages and weights. Violating these assumptions may imply deviations of predicted by the model estimations of fuel economy from the real-world measurements. To minimise this effect, potential users of the model can insert in the model weighted average of fleet age and weight, based on the coefficients derived from the proportion of distance driven in the overall annual mileage of the fleet.

Factor of local infrastructure and traffic conditions is another influential aspect, which defines the average fuel consumption. It is included in the model as a coefficient that estimates by how many percent the local infrastructure in the hosting countries is more or less efficient than the global average (*Figure 4*). This coefficient is thus multiplied by the predicted fuel consumption that is defined by all abovementioned factors. The underlying assumption of this parameter is the permanence of the driving and traffic conditions among all trips of the vehicles of the fleet. Violation of this assumption may result in significant deviations of the model prediction in case of large variety of conditions in one country among regions or cities. The solution to this issue can be aggregating data per smaller regions and estimating coefficients particularly for them. Summary of all variables and equations related to fuel economy and consumption is presented in the *Appendix 3*.

4.1.3. Weight

As was derived from the analysis of previous works on fuel economy, weight (or mass) of the vehicle is one of the most essential factors defining average fuel consumption (Ang et al., 1991; van den Brink & van Wee, 2001; IEA, 2012; Zacharof & Fontaras, 2016; Mbandi et al., 2019; IEA, 2019). It is largely dependent on the fleet composition and vehicles characteristics, such as kerb weight (a total weight of fully equipped car without passengers) and number of seats. However, the characteristics of usage of a car, such as average loading of car, meaning the percentage of the total number of available seats being filled with passengers, defines further the average overall operating weight of a car. The findings and numerical connections of variables related to weight are presented in *Appendix 4*.

4.1.4. Driven distance

Defining average fuel consumption per fixed distance enables the calculation of overall fuel consumption per year to be defined by multiplying it by the total annual mileage, which all the vehicles of the fleet drives per year. However, the overall distance driven by the fleet is also a function of multiple factors. First, as the focus of this research is the fleet, which is involved in transportation of personnel, the total amount of personnel-trips needs to be estimated. On the basis of it the total annual number of trips can be calculated by dividing the total passenger-trips number by the number of passengers transported on average in one run, which is equal to multiplication of loading of a car by average maximum passengers of a vehicle. After that, knowing the average distance of one trip, the overall annual mileage can be calculated and applied further in total fuel consumption estimation. Detailed description of all variables and linking equations is exposed in the *Appendix 5*.

4.1.5. Fleet size

Fleet size, being the number of vehicles possessed by an IHO, is based on the estimation of the annual distance driven by the fleet. Knowing the yearly mileage that one car can drive, which represents organisational logistical and operational routines, the required number of the vehicles in the fleet can be calculated. Based on this parameter, which is estimated annually, the model adjusts the number of vehicles in the garage either by adding more of them or declining them by the number of extra non-used vehicles. The summary of connected to fleet size variables and mathematical connections are presented in the *Appendix 6*.

4.1.6. Costs of aid delivery

Despite the focus of this research on environmental outcomes of the IHO-s' transportation of personnel, any strategy may not be assessed without controlling it for another organisational outcome of interest, which is financial. The overall costs of delivering the aiding personnel are composed by fuel, maintenance, and procurement costs (van Wee, 2013). Fuel costs are calculated by multiplying the total amount of fuel consumed by the fleet per year by the average price of one litre of the fuel (or weighted fuel composition based on the amount of gasoline/diesel vehicles in the fleet) in the target area. Maintenance costs are the function of kilometres driven and are measured by multiplying the total annual mileage the fleet drives by the average cost of one-kilometre maintenance work. Finally, procurement and selling costs are calculated on the basis of the change in the stock of vehicles possessed by an IHO and takes into account the average costs of purchasing an average car of the fleet and selling them after the average lifetime it is used in the fleet. Nevertheless, the costs have an upper limit which is fixed by the total amount of funding IHO-s receive yearly from their donors. All parameters and equations related to costs are summarised in the *Appendix 7*.

4.1.7. Aiding personnel

Apart from the environmental and financial outcomes, the aid itself, or delivery of the aiding personnel to the target area, which is the key function of an IHO, is another measurement, by which every strategy must be controlled. The number of personnel-trips is an annual number of overall trips that are needed to be conducted if performed via transportation of each staff member solely. This can be considered a workload of an IHO and is defined by the external factor, which is the demand for aid in the target area. The number of personnel providing aid, measured in annual personnel-trips, is the third key element of the strategy check. The equations and variables regarding personnel-trips are presented in the *Appendix 8*.

4.1.8. Test of the model structure

Pursuing the goal of building higher confidence in the model developed above, its cause-effect connections and mathematical formulas linking them, the range of tests for model validity was conducted. These tests follow the guidelines by Forrester and Senge (1980) and consist of structure verification, parameter verification, extreme conditions, boundary adequacy and dimensional consistency tests. The findings and related conclusions are presented below.

4.1.8.1.Structure verification test

Valid structure of the model means clear and adequate representation of real-world system of factors and connections between them. Given that the model cause-effect connections and mathematical links are grounded on and derived from the existing research on fuel economy and environmental impact of the transportation vehicles in a way, that was previously described, this test can be considered to be successful. Moreover, the issue of factors correlations was considered, also basing the conclusions on the existing research (Ang et al., 1991), so that only unique, non-overlapping effects can be represented. Additionally, iterating consultation with humanitarian fleet management experts from Fleet Forum and feedback fostered extension of the model to the area of fleet size adjustment and parallel effects of the factor of age. Final version of the System Dynamics model, presented in this study, was considered satisfactory, thus verified by knowledgeable parties.

To sum up, the structure verification test was successfully applied and used for further improvements in the model until the current version presented in this research was established.

4.1.8.2.Parameter verification test

Checking parameters, which are constants, through which dynamic variables are connected, is the second step. As the majority of the constants in regard to fuel consumption were obtained from the analysis of previous research or global data overview (Ang et al., 1991; IEA, 2019), these parameters can be considered as verified, also taking into account that the model was controlling for the cross-correlation effects between factors.

Additionally, the dataset of the International Humanitarian *Organisation A* was used to validate the parameters. As available data covers not all variables, it will be used to check the parameters of the following fraction of the overall model (*Figure 7*).

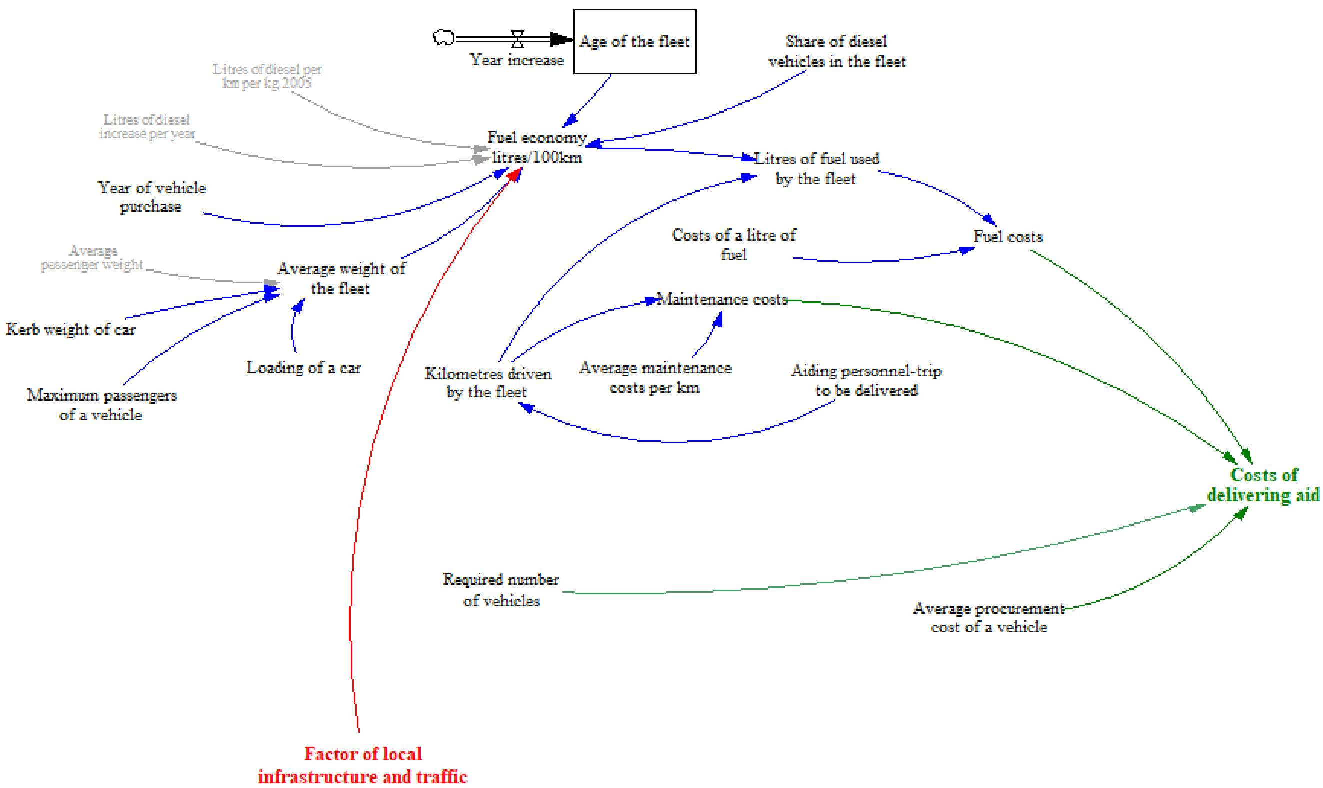

Figure 7. Model used for empirical parameter test

To verify the parameters defining the fuel economy, the comparison between the observed values and predicted by the model estimations was made. The outcomes of the test of actual and predicted by the model fuel consumption are presented in *Figure 8* and *Table 2*.

Taking 10% as a strict threshold for acceptance of deviation, seven out of nine countries demonstrated acceptable difference between estimated and data measurements. However, the other two countries did not go significantly far beyond that with 16% the biggest (which roughly fits the moderate threshold explained in Chapter 3). This gap can relate to the absence of actual data about loading of a vehicle, which is assumed now to be 0,3, based on the expertise of fleet management representatives. Additionally, as can be seen from the *Figure 8*, representing the sizes of deviations, there are few overlaps between the areas of deviations, which means, that when there is a mistake, it is smaller than the differences in original data between countries.

Table 2. Estimated and actual meanings of fuel consumption

Country	Actual average fuel consumption (L/100km)	Model estimated fuel consumption (L/100km)\	Difference with data
Afghanistan	14,9	15,863	7%
Central African Republic	14,4	16,150	12%
D.R. Congo	12,9	14,913	16%
Iraq	9,5	9,984	5%
Jordan	10,3	10,330	0%
Kenya	13,4	13,935	4%
Mali	13,9	12,854	-8%
Nigeria	10,8	11,526	6%
South Sudan	14,5	14,568	0%

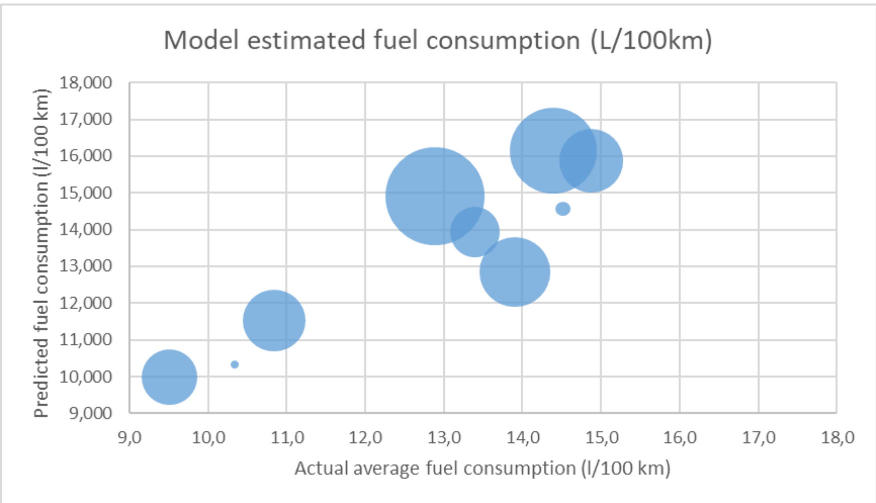

Figure 8. Comparison between differences in data-model deviations and differences in actual data.

4.1.8.3. Extreme conditions test

The test requires checking the adequacy of the model's outputs and behaviour under the minimum and maximum estimations of key entry factors. The test was made checking the CO2 emissions of the fleet that has 0 annual mileage, which logically resulted in no fuel burnt and, therefore, absence of environmental impact. This condition also leads to zero maintenance costs, which is also demonstrated by the model. At the same time, setting the yearly kilometres driven to extremely high numbers still demonstrates linear increase in the fuel consumed and CO2 emitted, but makes the slope much steeper.

Another test was conducting with the average weight of a vehicle. Setting it to the minimum mass of a motorcycle (of 100 kg), the model demonstrates around 1,3 litres per 100 km of fuel consumption at the beginning of its usage and around 2,8 litres/100 km after 8 years of exploitation, which also corresponds with the average motorcycle characteristics (Seedam, Satiennam, Radpukdee, Satiennam, & Ratanavaraha, 2017). By radically increasing the average weight of the fleet, a dramatic rise in fuel economy of the fleet can be observed, resulting in the steep increase in fuel consumption and resulting from them fast growing CO2 emissions.

At the same time, setting the average age to the minimum conditions leads to the observation of the most efficient average fuel economy during the whole life period of a vehicle, which also corresponds with the underlying assumptions of ageing yearly effect making the engine less efficient (Bai et al., 2012). Moreover, by observing the fuel consumption and CO2 emission estimators, resulting from high average age of the fleet, 20-year old vehicles may result in average fuel consumption from 13 l/100 km for a car of 1300 kg weight, up to almost 20 l/100 km for a vehicle of 2300 kerb weight, which also goes in line with previous research estimations (Mbandi et al., 2019).

4.1.8.4.Boundary adequacy (structure) test

The next test implies review of the model from the perspective of the research objectives (Forrester & Senge, 1980). As the model should be the minimum possible to serve as a tool for the study (Walker, 2000), some parts can be aggregated, while the others must include all relevant details. As this research aim to fill in the gap in a knowledge about environmental impact of IHO-s' fleet, involved in the transportation of the personnel, this part of the model, which includes fuel consumption and CO2 emissions, was represented with more details. At the same time, as was discussed before, any strategy of an IHO may not be viewed without checking for the parameters of costs and amount of delivered humanitarian aid, therefore, these aspects are also included to the model. However, they are presented in rather aggregated way, not uncovering what leads to change in average maintenance or procurement costs, fuel prices in the target area, logistical aspects of staff transportation planning. This choice, nevertheless, is supported by the fact, that financial and delivery aspects are more of a controlling nature in the model than of a central focus. Therefore, by adding more details on those aspects, marginal benefits to the overall research will be minimal. Thus, these concepts are presented in an aggregated way, omitting more details. Keeping this logic in mind during the whole process of model building, the test can be considered successfully passed.

4.1.8.5. Dimensional consistency test

This test aims to test if in all the equations of the model the units of variables on the right and left sides were corresponding. Given the equations, presented above, the test demonstrated the absence of mistakes regarding this issue, therefore, the test can be considered satisfactory.

Overall, the structure validation demonstrated mainly positively results, which provides this research with a scientifically verified System Dynamics model for further application. The research sub-question one is, therefore, answered as validated factors and mathematical links between them, related to the environmental impact of IHO-s fleet and connected financial and operational objectives, are presented in *Figure 6*.

4.2. Step 2. Specification of the objective of a new strategy

In order to answer the second sub-question of this research, addressing the estimation of the three key aspects of IHO-s' activity, it is important to elaborate why these particular outcomes of interest are taken and which particular objectives they should meet.

First, according to Pedraza Martinez et al. (2010), humanitarian aid from the perspective of transporting operations has two dimensions: relief and development programmes (*Figure 5*). This research focuses on the latter due to higher predictability and long-term plannability. In these programmes, efficiency in the terms of costs and availability of the fleet, which can deliver required amount of aid, are the most essential criteria of IHO-s' activity.

At the same time, Hirschinger et al. (2015) also described the diversity of objectives, that different perspectives on IHO-s' transportation operations have (*Figure 9*). This study defines the speed of delivery as 'effectiveness', which, in the classification of Pedraza Martinez et al. (2010) can be referred to relief-focused operations. 'Efficiency' here, which can be linked to the development programmes, is extended from solely costs-specific to the utilisation rates efficiency. ‘Effectiveness’ is presented as long-term optimised fleet composition and logistical planning.

Context	Issue	Dimension	Major Challenges
Humanitarian logistics	Efficiency	Costs	Limited budgets
			Misaligned incentive systems
			High incurred fix costs (e.g., insurance)
		Utilization rates	Aged fleets
			Distorted mileages
			Restrained vehicle sharing
			Oversized and thus idle capacities
	Effectiveness	Speed of aid	Restricted vehicle availability
			In-country vehicle transports
			Delayed vehicle delivery time
Sustainable development	Effectiveness	Long-term development	Lack of adequate transportation means
			Time- and cost-intensive transportation

Figure 9. Issues of humanitarian operations (Hirschinger et al., 2015)

As this research addresses development programmes, the objective of cost-efficiency is crucial for organisations, thus must be included in this research (Pedraza Martinez et al., 2010; Hirschinger et al., 2015). It will be preferred over utilisation rates efficiency due to less complexity of representation in the model and possibility to omit the necessity to extend the System Dynamics model to the dimension of supply and logistical planning, that is a crucial factor for utilisation rates. Moreover, the second objective of development programmes must be availability of the required amount of fleet facilities, which can enable the delivery of required amount of aid (Pedraza Martinez et al., 2010). It can be controlled by the number of personnel-trips delivered to the target area, which is the strongest condition that every IHO’s strategy should meet. This is the operational objective of the policies of IHO-s’ development programmes regarding transportation.

Finally, the objective concerning environmental impact resulting from the usage of IHO-s’ fleet is an innovative suggestion, which this research makes. The necessity of it is supported by multiple existing initiative of IHO-s regarding sustainability of their operations (Red Cross, United Nations Environment Programme, etc.) and collective agreements, such as

‘Humanitarian Charter and Minimum Standards in Humanitarian Response’ (Kelly, 2013). As far as this dimension of humanitarian operations is relatively new, the objective can be specified as maximally possible minimisation of the negative environmental impact of the IHO-s’ fleet.

Bringing these findings in the context of the current research, related to the transportation of aiding personnel performed as a part of humanitarian operations by IHO-s, the three key objectives of strategy development for IHO-s are the following:

1. **Environmental**: reducing environmental impact of the IHO-s’ fleet, involved in the transportation of staff to the target areas;
2. **Financial**: being cost-efficient by transporting the aiding personnel within the budgetary constraints of IHO;
3. **Operational**: delivering the required number of personnel-trips to the target areas.

4.3. Step 3. Development of evaluation criteria of a strategy

After defining three key objectives of IHO-s’ strategies regarding transportation of staff, the measurements, indicating to which extent a certain alternative policy meets objective, must be developed. The main findings are presented below.

4.3.1. Environmental impact

Environmental impact of transportation is diverse and influences nature and society in multiple ways. It contributes to the pollution of air, soil, and water, creates noise pollution, damages biodiversity, accumulates vast amounts of difficultly recyclable waste, negatively impacts health conditions of local population, stimulates climate change, etc. (van Wee et al., 2013). According to Gudmundsson (2004), for the research conducted in the style of policy and system analysis, which this study can be referred to as well, the measurement of the environmental impact of transport must be an indicator, rather than aggregated index (suitable for decision-makers and public users) or data and statistics (preferable for technicians). Therefore, this study will focus on one out of the abovementioned list of environmental impacts. Gudmundsson (2004) made an analysis of multiple studies focusing on estimation of environmental effect of transportation, from which can be concluded that indicator of total amount of CO2 emitted by vehicles is one of the most common measurements. The importance of this air pollutant and its effect on environment is also highlighted by van Wee et al. (2013). Keeping in mind, that one of the objectives, specified in the previous step, is reducing environmental impact of the fleet, involved in the transportation of personnel of IHO-s, it will is reflected in the model and variable counting CO2 emissions is added. Further strategy assessment will consider objective of minimisation of total CO2 emissions. It will be calculated as the direct function of the total amount of fuel consumed by the fleet for a fixed period of future projection, multiplied by the average CO2 emissions per litre of fuel, characterised by the fuel composition (gasoline/diesel) of the fleet. At the same time, the amount of fuel consumed is a function of average fuel economy of the fleet, being dependant on multiple factors, described in the *Step 1*, which will be set while strategy testing. The strategies will be compared by this factor and those will have a priority, that demonstrate lower accumulated CO2 emissions during the fixed period of time, chosen for this project as 10 years, following the examples of the timeframe of the UN strategic goal setting regarding sustainability of transport (United Nations System, 2019) and scenario planning projection of the research by Inter-Agency Research and Analysis Network (2017).

4.3.2. Financial objective

Performing humanitarian operations within the budget limits of an IHO is another objective of the fleet management strategy. The total costs of the fleet usage are combined by fuel, maintenance, and procurement costs (van Wee, 2013). Being in line with the timeframe, set in the previous objective measurement, each strategy will be controlled by the cumulative required costs of strategy implementation and practice for the future 10 years. The success of meeting this objective will be measured by checking if the accumulated costs stay below the level of 10-year available budget, obtained by the donors' funding. These budgetary limits will be set per each out of 9 countries, available in the *Organisation's A* dataset, based on the average annual expenditures registered (fuel, maintenance, and procurement costs). They will be used as a basis, which can be further adjusted by projections of donors' investments while scenario testing (*Step 4*). The corresponding baseline budget constraints are thus equalled in this research to the average annual costs from *Table 3*. The financial objective of a strategy, therefore, is to stay below this threshold. To control the system for the financial objective, the discrepancy between the available budget and the costs of delivering required number of personnel will be added as a separate variable, measured as a share of required costs that were not covered by funding. Accumulated parameter of sum of annual discrepancies will be the main controlling variable. The technical details of including the variable in System Dynamics model are presented in *Appendix 9* and *Appendix 10*.

Table 3. Data-based annual costs and person-tips per country

Country	Average annual costs (USD/year)	Assumed average annual number of person-trips
Afghanistan	440 531	78 744
Central African Republic	506 209	75 142
D.R. Congo	1 158 906	160 190
Iraq	615 458	156 156
Jordan	350 288	80 686
Kenya	472 001	85 029
Mali	506 950	64 461
Nigeria	847 038	253 552
South Sudan	928 729	161 910

4.3.3. Operational objective

The third objective requires from IHO to maintain same level of aid delivery to the target areas. It can be calculated based on the required aid demand in the target areas, which can also change with time. As a baseline, the estimations derived from the dataset of *Organisation A* will be made, finding the annual average. However, due to the absence of the data regarding loading of vehicles, some assumptions are needed to be made. As was concluded from the conversation with Fleet Forum experts, the average loading of a passenger vehicle of 50% can be considered an optimistic one, therefore, we assume that it was on average equal to 30% during past years in all regions. The average length of a trip was concluded to be 20 km, calculating the average based on the research by Ding et al. (2020), studying the United Nations agencies' utilisation of fleet involved in humanitarian operations. Taking the average annual mileage of *Organisation's A* fleet and dividing it by the average trip distance, derived from the research of Ding et al. (2020), the number of trips can be calculated. Further, multiplying it by the average maximum capacity of vehicles, adjusting for the 30% loading rate, the average annual number of person-trips can be assessed (*Table 3*). This estimation will be taken as baseline number, which can be further adjusted for the potential changes in demand for humanitarian aid in target areas during scenario analysis.

Overall, the measurements of the three key objectives can be summarized the way they are presented in *Table 4*. The measurements correspond with the System Dynamics modelled equations (*Step 1*) and variables marked initially as the outcomes of interest of an IHO's fleet, involved in the transportation of personnel.

Table 4. Measurements and corresponding objectives

Objective	Estimator (variable in the model)	Measurement	Threshold / requirement
Environmental	CO2 emissions by the fleet	= Litres of fuel used by the fleet * CO2 emitted per litre of fuel	Minimisation of the parameter
Financial	Accumulated deficit of budget	= INTEG ("Annual discrepancy costs/budget", 0)	Be not higher than 0 (no deficit)
Operational	Number of personnel providing aid	= "Aiding personnel-trips to be delivered"	Minimum limit as defined per country assumed average annual number of person-trips (*Table 3*)

4.4. Step 4. Formulation of scenarios

As the assessment of potential strategies requires evaluation of the extent to which the objectives are met in the future, the System Dynamics model will be simulated for the future 10-year timeframe. However, meeting these objectives depends, apart from the factors controlled by IHO-s, on the range of external factors. As they were defined before, these are the factor of local infrastructure and traffic, demand for aid in the target areas and funding by donors. In addition to not being controlled by organisation, these factors can be characterised by the high level of uncertainty as they depend on complex economic, social, political, technological, legal, and environmental factors (IARAN, 2017). Therefore, the development of scenarios, meaning the range of plausible futures, is necessary (Walker, 2000). According to Abrahams (2014), the demand for humanitarian aid is likely to continue growing during the next years because of increase in socio-economic crises and natural disasters. Therefore, scenarios should depict difference in growth rate of this need. In the System Dynamics model it will be represented by setting the ‘Demand for aid in target areas’ variable as a number, equal to the previous annual aid rate per country (*Table 3*), increasing annually by the ratio to which it gets higher than the initial estimation. Same nature will also have the parameter ‘Funding by donors’, which will be set in the model as an estimation representing the changes in funding compared to the dataset-derived costs (*Table 3*). Change in ‘Local infrastructure and traffic’ level will be set by adjusting current number, which was obtained through combining indexes (*Figure 4*), in the way it corresponds with a particular scenario.

Potential scenarios of humanitarian aid development in the nearest future were previously researched by Inter-Agency Research and Analysis Network (IARAN) (2017). The fit of this study with this research, among others, is the same timeframe of projection until 2030. IARAN (2017) made a comprehensive analysis of various factors, influencing the activity of IHO-s, and came up with four plausible directions of development of external environment for them. The description and corresponding settings of three main external factors, which this research considers, are presented below.

4.4.1. Scenario 1. The Narrow Gate

According to this scenario, localized crises, which can be already observed in certain Middle Eastern and Sub-Saharan African countries, will continue to exist as the issues these regions face are complex, and the fragility of states increases. These regions will remain the key target areas for IHO-s' aiding operations, requiring same type of assistance as during previous years. However, due to the intensification of these crises, the demand for aid in these areas will continue growing in the pace which was observed before during the crises' development (IARAN, 2017). In such conditions, the local infrastructure and traffic is remaining stable, without prospects for improvement. The funding will continue to increase, according to this scenario, however, in the same scale as it was in the previous years. Moreover, donors, seeking more effective financing, will re-orient towards local NGO-s, therefore, IHO-s' cooperation with them will be required.

To illustrate this scenario in the System Dynamics model and integrate this plausible future there, the variable 'Demand for aid in the target areas' will be transformed into stock with the annual inflow, depicting the growth rate. According to IARAN (2017), during the period from 2004 until 2015 the number of people exposed to the needs of humanitarian assistance tripled, thus increased by 300%. Converting it into the linear annual growth rate, it presents about 18% of the initial value at the beginning of the period, annual increase. Therefore, this measurement will be taken as a setting parameter. As the scenario implies the ability of IHO-s' donors to react adequately to the growing demand of humanitarian aid, we assume that the increase rate of the funding will be also equal to 18% of the initial value at the beginning of the period. To follow the previous logic, the variable 'Funding by donors' will be also transformed to a stock variable with the annual inflow of 18% of the initial funding level. For testing of strategies of this research, these initial values will be derived per region from *Table 3*. Overall, the model, which will be used for strategy testing of this scenario is presented in the *Appendix 9*. Additional and transformed variables with the corresponding equations are exposed in *Appendix 10*.

4.4.2. Scenario 2. Overflow

This scenario represents the situation when the need for humanitarian aid escalate dramatically worldwide due to systemic regional crises. The trans-national nature of the issues implies impossibility of the donors to cover the increasing demand for assistance in the target areas. Moreover, they will not be able to provide funding even in the scale they used to do it in normal conditions. Private donors can contribute their sources, but they will target certain areas rather than the ecosystem itself. Inability to address new nature of problem directly in the initial period will trigger the reinforcing increase of demand for aid further, involving more countries and regions (IARAN, 2017). This dynamic of crises can be characterised as exponential growth (Abrahams, 2014). In this situation, local infrastructure may suffer further and decline in quality.

Opposite to the previous scenario, this situation implies, that the increase of the demand for aid exposes its exponential trend. In this case, additional connection in the System Dynamics model, being a reinforcing loop, is necessary. We assume that now the annual growth of 18% is not regarding the initial value but linked to the demand for aid in previous period. Due to the complex global nature of the crises, we assume the growth rate of funding by donors gets smaller, than in the previous scenario, being 9% from the initial value thus still following the linear nature. Local infrastructure under these conditions are likely to decline in quality, therefore we assume the total increase in the coefficient of the corresponding variable in 0,1 in 10 years (0,01 points per year). This effect was included in the equation of the variable with a RAMP function. The System Dynamic model, which will be used for testing of this scenario, is presented in *Appendix 11*. *Appendix 13* demonstrates the additional and adjusted variables and equations linking them.

4.4.3. Scenario 3. To Each Their Playing Field

According to this scenario, the localised crises will be protracted around specific problem subjects of concern or geographic areas. These types of crises will influence further local communities, businesses, etc. and foster multiple parties, apart from IHO-s, to cooperate towards the improvement in the target area following their individual interests. Due to the long-lasting nature of the crises, the donors of IHO-s will not be able to allocate the adequate amount of finances to the area, while private donors will target only certain aspects covering their interests, rather than the whole crisis. Therefore, IHO-s will need to face and target local 'forgotten' crises within the limited amount of funding (IARAN, 2017). The state of infrastructure will not be improving, therefore stays at the same level as it used to be.

For the purposes of scenario analysis via System Dynamics modelling, the growth rate in demand for aid will be taken following the general trend of 18% from initial value per year (same as for Scenario 1). However, as the donors will not be able to finance the needs, according to the scenario, we assume the annual growth rate of funding to lower to 9% of the initial value per year. The model used for this scenario is presented in *Appendix 9*. Formulas and variables are demonstrated in *Appendix 10.*

4.4.4. Scenario 4. (R)evolutions

This future development assumes, same as in Scenario 2, international ecosystemic crises, which is growing exponentially. However, this scenario implies that large network of multiple parties, which provide financial resources or aiding services to the target area with the demand for humanitarian assistance, develops a system of highly coordinated, adequately, and timely funding humanitarian operations. In this case, the system, including IHO-s, can face and deal with the large, regional ecosystem crises. Such adaptable and strategically functioning network will require the establishment of new regulation, but is not likely before 2025 (IARAN, 2017). Therefore, this scenario will be simulated in the System Dynamics model as a branch of the Scenario 2, also illustrating the exponential growth of demand for aid globally during first 5 years, but from 2025 presenting the development of adequately funding system for such large-scale crises. The local infrastructure will be declining first but start improving from 2025.

In the System Dynamics model the exponential growth in demand will be illustrated and tested in the same way as in Scenario 2. Same as in Scenario 2 will be also the donors' funding structure until 2024. However, from 2025 to demonstrate the breakthrough in the humanitarian network, which from that moment is able to meet the needs of target areas, the growth rate in funding will increase by 30% of the funding from the previous period annually then, in addition to constant 9% defined before. Local infrastructure will be increasing the coefficient in the same manner as in Scenario 2 until 2024, after which it will gradually return to its initial place by 2030 (also using function RAMP). The corresponding model and equations are exposed in the *Appendix 12* and *Appendix 13*.

The summary of scenarios is depicted in the *Table 5.*

Table 5. Scenarios and trends

Scenario name	**Demand for aid**	**Funding by donors**	**Factor of local infrastructure**
Scenario 1. The Narrow Gate	Growth in constant tempo (annual increase: 0,18 of *'Assumed average annual number of person-trips' from Table 3 per region'*)	Growth in constant tempo (annual increase: 0,18 of '*Average annual costs' from Table 3 per region*)	Remains constant
Scenario 2. Overflow	Annual exponential growth of 18%	Growth in constant tempo (annual increase: 0,09 of '*Average annual costs' from Table 3 per region*)	Inefficiency increases by 0,01 annually
Scenario 3. To Each Their Playing Field	Growth in constant tempo (annual increase: 0,18 of *'Assumed average annual number of person-trips' from Table 3 per region'*)	Growth in constant tempo (annual increase: 0,09 of '*Average annual costs' from Table 3 per region*)	Remains constant
Scenario 4. (R)evolutions	Annual exponential growth of 18%	Growth in constant tempo (annual increase: 0,09 of '*Average annual costs' from Table 3 per region*) from 2025 improvement (annual increase 30%)	Inefficiency increases by 0,01 annually, then improves by 0,01 annually

4.5. Step 5. Selection of alternative strategies

After defining system boundaries, external factors and key objectives of new strategy, the range of potential alternative policies must be defined. They were derived from academic literature, thematic web-portals, expert opinions, and IHO-s' reports and are described below.

4.5.1. Optimisation of travelling

First strategy addresses the issues of supply chain and logistical planning of IHO-s. It was derived from a report of one of the biggest global IHO – United Nations (2019), where this strategy is mentioned as one of the main towards more climate neutral fleet. One of the examples of it is improvement of coordination of trips and performing less of them with higher loading (Fleet Forum, 2017). In the context of this research, it can be a strategy of sharing of rides by staff members, aiming to reduce the environmental impact of their fleet. Moreover, optimisation of root planning might reduce the average trip distance declining CO2 emissions of the transportation of the personnel. In System Dynamics model this strategies will be tested by applying the range of measures of such variables as ‘Loading of a car’ (from 0,1 to 1 with the step of 0,25) and ‘Average trip distance’ (in the interval between ±25% of the current estimation of 20 km: 15 km – 25 km with the step of 5 km).

4.5.2. Optimisation of fuel use

This strategy was also obtained from United Nations report (2019) as one of the keyways to reduce environmental impact of transportation of IHO. Average fuel consumption per 100 kilometres can be declined by making the fleet lighter, so that the average weight of the vehicles is reduced. It can be also achieved by renewing the fleet composition, replacing old ones with more technically advanced and having minimized inefficiencies of engine related to accumulated in the past mileage (Ang et al., 1991). In the System Dynamics model this alternative will be tested by varying the variables ‘Kerb weight of fleet’ (from 150 kg, equal to motorcycle, until 3200 kg, equal to minibuses, with around 750 kg step) with corresponding adjustment of the variable ‘Maximum passengers of a vehicle’; ‘Year of vehicle purchase’ (from 2005 until 2020 with 5-year-step) and related adjustment of the initial value of the stock variable ‘Age of the fleet’ (from 15 to 0 years).

4.5.3. Electric vehicles

Another strategic option, which is suggested by International Energy Agency (IEA) (2019), is increasing the number of electric vehicles in the fleet. In this case, however, to give an objective estimation of CO2 emission, it is important to have information about the source of electricity, which is used for the IHO’s vehicle. This parameter is largely defined by the region of the IHO-s’ feet operations. Moreover, it is important to check feasibility of this strategy in each of the country under focus, obtaining the information about facilities for electric vehicles’ smooth functioning. The analysis of the open sources regarding the number of electric charging stations in countries or their capitals (*Appendix 14*) demonstrated, that for the 10-year perspective this strategic option of fleet electrification might be considered only for Jordan and Nigeria. To test this strategy in System Dynamics model, CO2 emissions will be calculated based on source of electricity in these countries, which is gas for both countries. For both countries, over 85% of all electricity is obtained from gas. Average electric car can drive 1 kilometre consuming 0.2 kWh of electricity, the weight of an electric vehicle has very little effect of electricity consumption (IEA, 2019). To produce one kWh of electricity from natural gas, the emissions of 0,2 kg CO_2 are attributed (IEA, 2019). The policy regarding number of electric vehicles in the fleet will be reflected in the variable 'Share of electric car' being between 0 and 1. The strategy will be tested by changing this variable on the interval of the range from 0 to 0,75 with the step in 0,25. The variation of the initial System Dynamics model, which will be used in this step, is presented in the *Appendix 15*. The additional variables with linking equations, used in this strategy modelling, are presented in *Appendix 16*.

4.5.4. Remote aid

Another trend of the recent years, especially in the field humanitarian medical assistance, is delivering humanitarian aid remotely, for example, by using telecommunication tools (Murillo, Paco, & Wright, 2015). To test this strategy, additional variable will be inserted in the model, called 'Share of aid delivered remotely', which can be by definition between 0 and 1. It will be tested by the model for the range of measurements between 0 and 0,5 (due to newness of the strategy) with the step of 0,1. The variable is connected to the number of overall driven kilometres by the fleet, reducing it, aiming at the reduction of CO_2 emissions of the fleet as a consequence. The costs of usage of telecommunication are relatively small comparing to transportation expenditures, therefore they will not be included in the model. The equations of new and adjusted variables are presented in *Appendix 17* and the corresponding model – in *Appendix 15*.

There are other potential ways to reduce environmental impact of the fleet, such as usage of biofuel. However, the facilities, which can enable IHO-s to apply these strategies, needs to be developed in the target areas still, the timeframe of which will exceed the focus of this research until 2030. Considering this fact, the list of four directions of 'greening' strategies can be considered complete, answering the third sub-question of this study.

4.6. Step 6. Analysis of each alternative

With this step, the range of strategies was tested by using System Dynamics simulation method. Out of 9 target regions, that this research highlighted at the stage of model validation with actual fleet data from *Organisation A*, we focused on a region, where all strategies can be applied. Taking Jordan as an example, where all alternatives, including electric vehicles, can be implemented, this region was the basis of the simulation procedure. Therefore, the initial settings of the model were derived from the available dataset or derived manually (such as

Local infrastructure, Chapter 3). These settings are presented in *Appendix 18*. To increase the efficiency of further analysis of strategies, one of the outcomes of interest of IHO was chosen to be fixed – 'Demand for humanitarian aid', which was changing purely as a consequence of scenario adjustment, but not by strategy change. This measure complies with one of the key objectives of a strategy, which is to continue delivering required amount of aid. Therefore, the strategies were compered by the amount of accumulated CO2 emissions during the period from 2020 until 2030 and by the accumulated discrepancy between costs of delivering of the defined amount of aid (personnel) and actual funding by donors, which should not exceed 0. When a certain strategy required some extent of initial renewal of the fleet (such as with strategies regarding fleet age or changing the average kerb weight of the fleet), it was added to the parameter of initial estimation of the stock 'Accumulated deficit of budget'.

The extended outcomes of the testing are presented in matrix in *Appendix 19*. The analysis of them is conducted in the following step.

4.7. Step 7. Comparison of the alternatives in terms of future effects, including environmental.

Analysis of strategies requires addressing the key objectives. As was described in the previous step, the operational objective (regarding the number of transported personnel) in our model is met by all strategies and it defines the costs of aid delivery. These costs were controlled for being within the budgetary constraints ('Accumulated deficit' variable). However, due to 4 various scenarios, same strategy, applied in different future settings, might meet the limits of budget in one plausible future, while not during other. Therefore, such estimator as 'Robustness' of a strategy was implemented. It can be also considered a measurement of risk of a strategy, where high robustness is linked to the low risks. If a strategy can be performed within the budget in 3 or 4 scenarios, it is labelled as 'HIGH' in robustness (low in risks), if in 2 scenarios – 'MEDIUM' robust (medium risks), if in 1 or 0 – 'LOW' robust (high risks). Improvement of CO2 emissions of different strategies can be compared in two ways. First, we try to adjust the key parameter of each strategy by around the same scale (20-25% comparing to base case) and compare the percentage by which the accumulated CO2 emissions during 10 years decreased comparing to base case as well. Second, it is informative to compare maximum possible improvement of CO2 emissions decrease due to change in parameter estimation. The results are presented in *Table 6*. Detailed effects of different scales of implementation of each strategy is presented in *Table 7*.

Loading of a car demonstrates the highest out of all strategies' improvement in CO2 emissions while both standardised 20-25% adjustment of parameter improvement and comparing maximal outcomes. It can be also characterised by the high level of robustness, as from the level of loading equal to 0,5, the IHO can operate in three out of four scenarios, and from 0,75 – in all four plausible futures. This is achieved also due to the fact, that the strategy enables the reduction of the size of the fleet and thus the related costs. Detailed summary of this strategy and its influence on CO2 emissions is presented in *Appendix 20*.

Table 6. Multi-criteria summary of strategic options

Parameter	Change in CO2 emissions (if 20-25% change of parameter)	Maximum possible CO2 reduction due to parameter change	Robustness
Loading of a car	-38%	-66%	HIGH
Trip distance	-25%	-25%	MEDIUM
EV	-22%	65%	LOW
Remote aid	-20%	-50%	HIGH
Weight	-19%	-37%	MEDIUM
Age of the fleet	-8%	-25%	LOW

Optimisation of trip distance exhibits 25% reduction of CO2 emissions because of 5 km decrease in root due to optimisation of logistics. However, further decrease in root length (more than 25%) cannot be considered a probable option, therefore 25% improvement in CO2 emissions is also maximal. The strategy is medium robust, as can cover the costs of delivering required number of personnel only in Scenario 1 and Scenario 3. Detailed summary of this strategy and its influence on CO2 emissions is presented in *Appendix 21*.

Electric vehicles. This strategy demonstrates one of the highest among all alternatives maximum in potential decrease in accumulated during 10 years CO2 emissions, which can be reduced by 65% comparing to base case by incorporating 75% of electric vehicles in the overall composition of the IHO-s' fleet. Moreover, 22% improvement in environmental impact can be already achieved by introducing 25% of the electric vehicles. Significant drawback of this strategy, however, is its low robustness to potential futures, which can imply restrictions of budgets comparing to base case. The costs of developing this strategy can be met by the budget only while having 25% of the fleet driven by electricity and only in Scenario 1. This is the effect of high costs of electric vehicles purchase. Detailed summary of this strategy and its influence on CO2 emissions is presented in *Appendix 24*.

Remote aid is a remarkable strategy due to its high robustness to potential futures. From 30% of all workload performing without transportation of personnel, IHO can function within the budget in three out of four scenarios, and from 50% of remote aid – in all scenarios. Consequently, it can also contribute up to 50% of CO_2 emissions reduction. With first 20% of aid delivered without applying means of transportation, 20% of environmental impact can be reduced. Detailed summary of this strategy and its influence on CO_2 emissions is presented in *Appendix 25*.

Table 7. Scales of strategies' implementation and their effect on CO2 emissions

	Number of scenarios met without budget deficit	CO2 emissions improvement
Loading of a car 0,5	3 Scenarios	-38%
Loading of a car 0,75	4 Scenarios	-57%
Loading of a car 1	4 Scenarios	-66%
Average trip distance 15 km	2 Scenarios	-25%
Kerb weight 150 kg & Maximum seats 2	3 Scenarios	-22%
Kerb weight 900 kg Maximum seats 4	1 Scenario	-19%
Kerb weight 2400 kg & Maximum seats 7	1 Scenario	-1%
Kerb weight 3150 kg & Maximum seats 12	3 Scenarios	-37%
Age of the fleet 5	1 Scenario	-8%
Age of the fleet 0	1 Scenario	-25%
Electric vehicles 0,25	1 Scenario	-22%
Electric vehicles 0,5	0 Scenario	-43%
Electric vehicles 0,75	0 Scenario	-65%
Remote aid 0,1	1 Scenario	-10%
Remote aid 0,2	2 Scenarios	-20%
Remote aid 0,3	3 Scenarios	-30%
Remote aid 0,4	3 Scenarios	-40%
Remote aid 0,5	4 Scenarios	-50%

Weight of the fleet adjustment requires corresponding additions of new vehicles procurement and maximum seats capacity. The model simulation showed that having heavy but with larger number of seats vehicles is the most prominent strategy out of all related to weight, as it can decrease the CO_2 emissions by 37% in 10 years comparing to base case alternative. Such direction is also a robust option as can transport required number of personnel in three out of four possible scenarios. Simulation also showed, that maximum small and light means of transportation, such as motorbikes, is also s robust strategy, beneficial for environment at the same time. Detailed summary of this strategy and its influence on CO_2 emissions is presented in *Appendix 22*.

Age of the fleet as a strategy, naturally requiring fleet renewal in case of decrease in age, is a highly vulnerable strategy. Decreasing he age of the fleet by 20% will lead to only 8% decline in CO_2 emissions, with 25% maximum possible reduction due to this factor. Detailed summary of this strategy and its influence on CO_2 emissions is presented in *Appendix 23*.

After analysis of all potential strategies, it is also representative for IHO-s to demonstrate per each scenario separately which strategies are feasible. The results are presented in *Table 8*.

Table 8. Scenarios and related feasible strategies

Scenario 1	**Scenario 3**	**Scenario 4**	**Scenario 2**
Base case	-	-	-
Loading of a car (**from** 0,3)	Loading of a car (**from** 0,5)	Loading of a car (**from** 0,5)	Loading of a car (**from** 0,75)
Average trip distance (up to 20 km)	Average trip distance (up to 15 km)	-	-
Weight (lighter until 150 kg; heavier until 3200 kg)	Weight (either light of 150 kg OR heavy of 3200 kg)	Weight (either light of 150 kg OR heavy of 3200 kg)	-
Age (until 0)	-	-	-
Electric vehicles (until 0,25)	-	-	-
Remote aid (**from** 0)	Remote aid (**from** 0,2)	Remote aid (**from** 0,3)	Remote aid (**from** 0,5)

What can be observed from *Table 8,* is that in Scenario 1, which mainly represents continuation of the current way the humanitarian aid is delivered, vast majority of strategic options are feasible. In Scenario 3, assuming same demand for aid as in Scenario 1, but limited budget, lower number of strategies can function cost-efficiently. For example, loading of a car of 50% and higher, 20% of remotely delivered aid, optimised by 25% trip distance and maximum light or heavy and highly-capable vehicles – these are the measures, that can assure IHO delivers required amount of aid within the budget constraints and reducing CO2 emissions. In Scenario 4, optimisation of trip cannot be considered a feasible strategy anymore and share of remote assistance for the target areas needs to be increased up to 30%. Finally, Scenario 2, describing dramatic overflow of aid demand, while limited funding abilities of donors, requires either improvement of the loading of a car to a minimum of 75% level, or delivering half of the aid without transportation of personnel.

These findings conclude the cost-efficiency, improvement in environmental impact, and robustness of strategies, answering the main research question of this thesis.

5. Discussion of results

5.1. Results, conclusions, and contribution to knowledge

The research initially was *aiming* to build a System Dynamics model to identify cost-efficient strategies that can enable International Humanitarian Organisations to reduce the environmental impact of the transportation of their personnel, while providing the demanded level of aid. It was addressing the research gaps specified in multiple studies (Pedraza Martinez et al., 2010; Abbasi & Nilsson, 2012; Haavisto & Kovács, 2014; Kunz & Gold, 2015) and answered four research sub-questions, creating a base for answering the main research question. Summary of the research findings and their contribution to existing scientific knowledge is presented below.

5.1.1. (SQ1): What are the factors influencing the environmental, financial, and operational performance of the IHO-s' transportation of personnel?

By creating quantified System Dynamics model based on findings from academic literature and reports from transportation industry, the complex cause-effect mapping of relevant factors for IHO-s' financial, environmental, and operational activities was created. By inserting the mathematical links between them, this research could also define the characteristics of these connections. This model was also validated by the data of IHO *Organisation A*, which increases the trustability of the outcomes. *Figure 6* depicts the system of factors, while *Appendixes 1-9* the numerical relations between them. Therefore, this research contributes to the gap defined by Pedraza Martinez et al. (2010) by introducing environmental dimension to the research about IHO-s' operations, while still keeping the systemic view suggested by Abbasi and Nilsson (2012), including operational and financial aspects of humanitarian transport. This research revealed that such aspects as fuel consumption, age and weight of the fleet, fleet size, driven distance, being also interconnected with each other, are contributing to the environmental impact of the fleet, which can be evaluated as the mass of CO_2 emissions. The impact of technical advantage of new model was discovered (IEA, 2019), which also reduces the emissions, and the influence of fleet ageing was specified (Ang et al., 1991). Relations of these factors with costs of aid delivery is another aspect that this research unveiled. Overall, this research provided insight on macro level about the factors, defining environmental impact of the fleet, while also being connected with the costs and number of personnel-trips. This contributes to the academic knowledge about the role of environmental dimension in the system of IHO-s' activities.

5.1.2. (SQ2): How can environmental, financial, and operational performance of the IHO-s' transportation of personnel be estimated?

As Kunz and Gold (2015) pointed out the absence of research on evaluation of environmental performance of IHO-s' fleet, this study developed the ways how it can be assessed, while still controlling for financial and operational performance, thus keeping systemic perspective of IHO-s (Abbasi & Nilsson, 2012).

This study presents the measurement for environmental impact, being estimated in amount of annual CO_2 emissions, which is a function of the fuel composition of the fleet (percentage of gasoline/diesel vehicles), amount of consumed fuel and standard characteristics of emissions resulting from one litre of burnt fuel (*Table 4*). This researched also showed that having data about the fleet characteristics, the amount of delivered aid, which is calculated in the number of personnel-trips, can be assessed by having approximation about the average trip distance and capacity of the vehicles (Section 4.3.3). Finally, the costs of transportation, can be controlled by IHO-s, which are defined by the demand of aid and required workload, calculating annual discrepancy between required and available funding.

The combination of three metrics was developed by this research to be used all together, rather than separately, while researching and evaluating the operations of IHO-s. In this way, the current study contributes to the gap in knowledge about measurements of environmental impact of the fleet, transporting personnel, while still providing measuring techniques for other two key aspects – financial and operational. By doing so, a significant contribution can be made introducing findings to the theory of sustainable humanitarian supply chain management by Kunz and Gold (2015), which was not able to be developed due to the absence of the research on environmental effects of IHO-s logistics.

5.1.3. (SQ3) How can external factors impact the IHO-s' transportation of personnel?

External factors influencing the activities of IHO-s have been previously researched, however, they were never viewed from the systemic perspective, which also includes environmental dimension. They were defined as 'Factor of local infrastructure and traffic', amount of 'Funding by donors' and 'Demand for aid in target areas'. They can influence the transportation activities of IHO-s in a different manner, but their change corresponds to possible scenarios, or plausible futures. IARAN (2017) analysed four potential developments of humanitarian aid. *Table 5* represents how these factors in various futures will behave and influence the operations of IHO-s. This finding contributes to the knowledge about how environmental impact of humanitarian fleet, in line with financial and operational aspects, can be influenced by these factors.

5.1.4. (SQ4) What are the possible alternative strategies that can improve the environmental sustainability of the IHO-s' transportation of personnel?

The gap in the previous research regarding definition of potential strategies for the improvement of environmental sustainability of IHO-s' fleet was highlighted by Haavisto and Kovács (2014). Abbasi and Nilsson (2012) stated that all previous studies on this topic were focusing purely on the strategies improving energy efficiency. This research, however, presents the range of six strategies, which can decrease the environmental impact of humanitarian fleet, involved in the transportation of personnel, and be feasible within next ten years. First, these strategies are increasing the average loading of a car or decreasing the average trip distance, by optimising logistical and supply chain of IHO. Second, it is a decrease in the average kerb weight of the fleet or making the fleet newer. Finally, policies may imply increase in the number of personnel aiding remotely without being transported or increase in the number of electric vehicles in the countries, where there are related facilities. By specifying these alternatives this research contributes to the academic knowledge by extending IHO-s strategic alternatives range to the area of environmental impacts.

5.1.5. (RQ) What are the cost-efficient strategies that can enable International Humanitarian Organisations to reduce the environmental impact of the transportation of their personnel, while providing the demanded level of aid?

Each out of six abovementioned strategies was tested with the System Dynamics model for the range of measurements. The level of aid, expected from IHO in a particular scenario, was defining the costs of required aid, while in parallel accumulated deficit in budget was calculated for the period from 2020 until 2030 for each strategy. These estimations enable the assessment of how feasible each strategy is in the set external conditions and thus how robust it is. The research revealed that two strategies are cost-efficient, implying no budgetary deficit, in all 4 Scenarios and at the same time decreasing the environmental impact of the IHO's fleet, involved in the mobility of staff. These strategies are improvement of loading of a vehicle up to 75% and the strategy of increasing the share of workload delivered by personnel remotely up to 50%. The first strategy can decrease the current level of CO_2 emissions by 57%, while the second – by 50%. Moreover, by increasing the loading up to 100%, the emissions may be reduced by 66%. However, IHO-s, extending multi-criteria decision matrix with the organisational or regional factors for each strategy, can adjust their prioritisation of strategies.

Additionally, IHO for choosing a strategy needs to address the trade-off between the reduction of CO2 emissions and robustness of the strategy, meaning the ability to be within the budget in all plausible futures. IHO can also develop an adaptive roadmap of strategies, by choosing their priority per each scenario separately, keeping in mind organisational costs of transition between strategies (*Figure 10*).

Overall, the research revealed, that when the scenario of current state 'The narrow gate" continues within next 10 years, meaning that already existing local crises continue to develop with the same pace and receive corresponding funding by donors (IARAN, 2017), IHO might apply majority of the strategies to reduce CO2 emissions of its transportation of personnel: increase loading of a car from 30%, optimise travel distance and weight of the fleet, arrange renewal of the fleet until 0 years, increase the share of electric vehicles in the fleet up to 25% or increase the remote aid. All the strategies in this scenario will stay within the budgetary constraints. However, the research reveals, that in case the 'To Each Their Playing Field' scenario develops, referring to 'forgotten crises' when the current crises continues to develop in the common pace, while the funding is scarce and does not meet the needs of the area in the previous operation conditions of IHO-s (IARAN, 2017), less strategies are feasible. Loading of a car in this case must be increased up to at least half of the seats, the trip distance needs to be improved by 25% or the weight of the fleet needs to be restructured either to small and light vehicles or big vans with higher number of seats. Finally, 20% of workload delivered remotely is also a cost-efficient strategy in this scenario.

On the other hand, IARAN (2017) developed 'Overflow' scenario, where international or global systemic crises outbreaks, exhibiting exponential growth in aid demand, while restricting the abilities of donors to provide even common level of funding. In addition to this, the local driving infrastructure and conditions, being a crucial factor for transportation efficiency, will suffer. This study demonstrates, that in such conditions only increasing the loading of a vehicle at least up to 75% or delivering 50% of assistance remotely can be cost-efficient strategies. However, IARAN (2017) described the fourth scenario '(R)evolution', which supposes that the 'Overflow' scenario can turn halfway, in 2025 in a change in the way humanitarian aid is delivered, implying more coordination, cooperation and optimisation among IHO-s, donors, local NGO-s, etc. In this case, from 2025 exponential growth in demand will be meeting more efficiently by donors' funding. In this case, this study shows that such strategies as loading of a vehicle 50% and higher, minimum 30% of remote aid and optimisation of fleet weight can be cost-efficient feasible strategies.

IHO-s may opt for strategies that are not feasible in all potential future scenarios, however, this implies risks. Therefore, the choice of an IHO for a future strategy is also a trade-off between environmental impact reduction and risk of not being able to finance it in case large crises scenario, such as ‘Overflow’, enforces.

These findings address the main research question of this study. It contributes to the research gaps, defined by various authors in the field of IHO-s’ transportation (Pedraza Martinez et al., 2010; Abbasi & Nilsson, 2012; Haavisto & Kovács, 2014; Kunz & Gold, 2015) by filling in incompleteness of the theory of Kunz and Gold (2015) on sustainable humanitarian supply chain by uncovering the environmental dimension of it. The research also improves understanding of the place of the environmental dimension in the whole system of IHO-s’ mobility operations, which was a guideline for future research by Pedraza Martinez (2010) and Abbasi and Nilsson (2012). It also unveils the range of strategies for the reduction of environmental impact of the IHO-s’ fleet, involved in the transportation of the staff, and moreover, test their plausibility for the range of future. This scientific contribution addresses the gaps defined by research of Abbasi and Nilsson (2012). Overall, set research (sub-)questions were addressed in accordance with the previous research guides and answered to the high extent.

5.2. Practical and managerial implications

This research was aiming to support IHO-s in decision-making regarding transportation of their personnel from the environmental perspective and systemic view. Multi-criteria decision matrix (*Table 6, Table 7*) were developed both to summarize outcomes of the research for decision-makers and to depict existing trade-offs in this field. In case IHO opts for implementation of the flexible or adaptive strategy, depending on the changing environment of key external factors, the roadmap for such decision-making will look the as presented in *Figure 10*. To follow one of the practical-oriented goals of this research towards creation of the guidelines for IHO-s on how to apply the results of the research, the stepwise tips were developed (*Figure 11*). A group decision-making session among managers and directors of IHO is necessary to give organisational evaluation to each of the strategy and address the trade-off between maximal reduction of CO2 emissions of the fleet, involved in the transportation of personal, and level of risk which each policy corresponds to and which is opposite to its robustness, meaning being cost-efficient in all plausible futures.

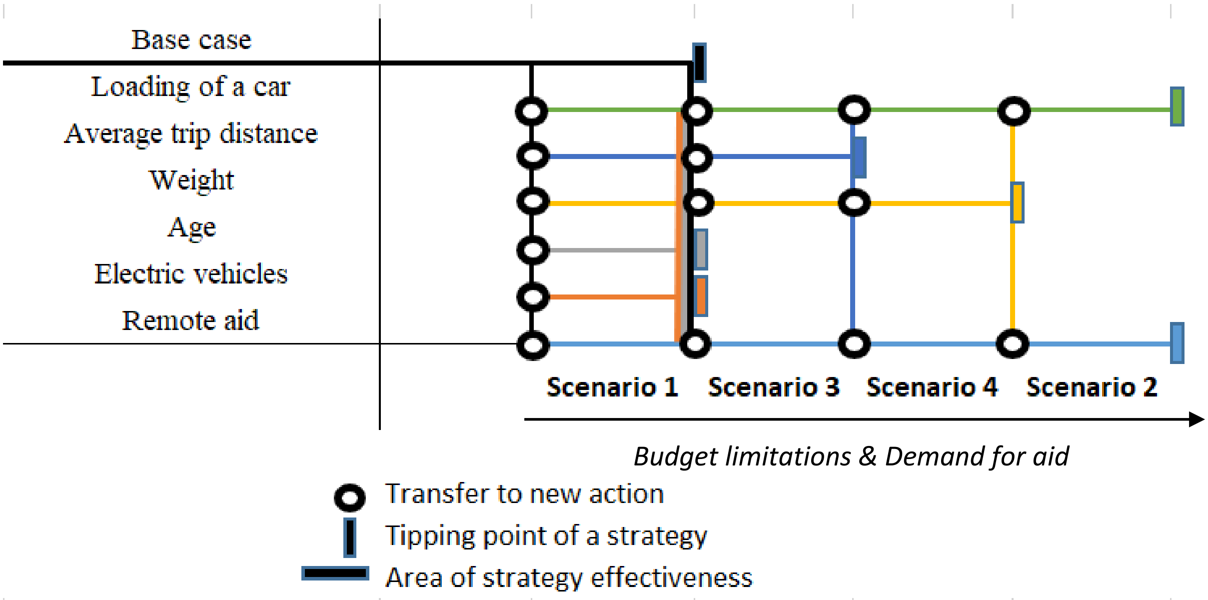

Figure 10. Roadmap of strategies

Summarizing all findings, the related guidelines for IHO-s were developed (*Figure 11*) to navigate IHO-s through the findings of this research and foster their effective usage. The trade-off between risks of not being able to implement the strategy in all possible futures and the maximisation of the reduction of the environmental impact needs to be met by the IHO-s' decision-makers during the group discussion session. By adding these findings with relevant organisational or local factors (if necessary), IHO-s can make informed and robust choice of a strategy rather in an adaptive or permanent manner. This study can be a scientifically grounded basis for IHO-s to start incorporating environmental dimension in the mobility strategic planning of their operations, which is not yet a common practice among IHO-s (Abrahams, 2014; Haavisto & Kovács, 2014; Kunz & Gold, 2015). The author of this research can provide IHO-s a System Dynamics model to IHO-s and guidance for adjusting it as tailor-made for the case of environmental impact reduction of transportation.

Guidelines for -IHO-s

1.
- Choose a **region** of strategy implementation;
- Define **local** (infrastructure, facilities) and **organisational** factors which might influence implementation of six developed strategies in the target area;
- Collect **information/data** about local and organisational factors and evaluate each strategy with this parameter;
- **Extend the multi-criteria matrix** of strategies (*Table 6*) with relevant organisational or local factors.

2.
- Organise a group discussive **decision-making session**, involving managers and directors of IHO;
- Discuss **trade-offs** and give **weights** collectively to each of strategy criteria;
- Decide on the **type** of strategy (adaptive/permanent).

3.

Permanent strategy

Choose the strategy with the **highest score** considering the weights and parameters' measurements and set a target for the strategy using *Table 7*

Adaptive strategy

For each scenario separately choose the strategy considering the weights and parameters' measurements → compare the costs of transferring and choose the **best pathway** (Figure 10) → Decide on a track of strategies with targets using *Table 7*

Figure 11. Guidelines for IHO-s on strategy choice procedure

5.3. Limitations

The research has number of limitations. Due to the access to the dataset of only one IHO and focused precisely on the transportation of personnel, the results cannot be generalised to the whole industry of humanitarian aid. The data regarding the IHO's (which was referred to as *Organisation A* due to anonymity request) fleet, involved in the mobility of the personnel, was used. The organisation has over 10 000 employees worldwide, delivering humanitarian aid to around 80 countries, majority of which are African and Middle Eastern. The IHO possesses over 3000 of light transportation vehicles, performing the transportation of aiding personnel. The *Organisation A* delivers assistance to the target areas bringing relief to local healthcare systems after natural or socio-economic disasters. Therefore, generalisation of the results to the IHO-s with other types of activities, largely deviating number of employees or composition of fleet cannot be made by the outcomes of this study.

Moreover, the research does not address organisational issues, which can be also influential for the feasibility of one or another strategy. Finally, the data used in the model verification covered only 9 countries of humanitarian operations, while strategies were tested within the settings of one country – Jordan. Therefore, generalisation for all regions and countries of humanitarian aid might not be made yet.

Additionally, environmental impact was addressed in this research only from the perspective of CO2 emissions, while technical issues of vehicle maintenance and repairing, as well as management of the waste at the end of the vehicle lifecycle are outside of the scope of this research, even though these aspects can be considered significant contributors to the environmental effects of the transport.

Underlying assumptions of the model building are another group of limitations. First underlying assumption worth mentioning is that both diesel- and gasoline-driven vehicles are used, on average, equally in terms of distance, thus consume equal amount of fuel and are around same age. The second underlying assumption is an equal usage of the vehicles of all represented in the fleet ages and weights. In case these assumptions are violated, the model is likely to predict results deviating from the reality. However, it can be avoided by future users of the model by calculating weighted averages of these parameters (fleet age, weight and share of diesel/gasoline vehicles) based on coefficients derived from the proportion of distance driven by certain car in all annual mileage of the fleet.

Factor of local infrastructure and traffic conditions is another influential aspect, which defines the average fuel consumption. The underlying assumption of this parameter is the permanence of the driving and traffic conditions among all trips of the vehicles of the fleet. Violation of this assumption may result in significant deviations of the model prediction in case of large variety of conditions in one country among regions or cities. The solution to this issue can be aggregating data per smaller regions and estimating coefficients particularly for them.

5.4. Directions for future research

Although the findings of these research are rather of a macro level nature and based on the data and information from limited number of regions, organisations, etc., it can become a solid basis for future research. For example, study about improvement of environmental impact of the fleet for a particular country or region can bring more value for practitioners in those regions, but also to academics, as it will unveil more details about the connections bringing it to the micro level. As this research was mostly focusing on transportation of personnel, further research on environmental impact and possible ways of its improvement of transportation of goods can be conducted.

Additionally, research on organisational aspects of decision-making regarding the environmental sustainability can be made. Finally, the assessment of the whole range of environmental impacts on the target areas by IHO-s can be highly valuable as it will enable researches to see the wide picture of local damage that IHO-s' operations brings, influences the demand for aid itself or further compare them with benefits. Finally, analysis of long-term, which are over 10-year perspective, strategies for environmental improvement in the target areas can be made, for example, regarding biofuel vehicles and corresponding facilities for this in target areas.

Regarding System Dynamics model, it can be further extended or specified in accordance with abovementioned recommendations.

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7. Appendixes

Appendix 1. Variables and equations related to CO_2 emissions

Name of a variable	Equation	Units	Assumptions/sources
Accumulated CO2 emissions	= INTEG (CO2 per year, 0)	kg	-
CO2 per year	= CO2 emitted by the fleet	kg/year	-
CO2 emitted by the fleet	= Litres of fuel used by the fleet*CO2 emitted per litre of fuel	kg/year	European Conference of Ministers of Transport, 1998
CO2 per litre of diesel	= 2.6	kg/l	European Conference of Ministers of Transport, 1998
CO2 per litre of gasoline	= 2.3	kg/l	European Conference of Ministers of Transport, 1998
CO2 emitted per litre of fuel	= CO2 per litre of diesel * Share of diesel vehicles in the fleet + CO2 per litre of gasoline * (1 - Share of diesel vehicles in the fleet)	kg/l	Assumption: diesel and gasoline vehicles used equally; only the proportion between number of vehicles defines the average CO2 emissions
Share of diesel vehicles in the fleet	*Defined by fleet characteristics*	Dmnl[1]	Range: [0;1]

[1] Dimensionless

Appendix 2. Average consumption of fuel per 100 km transportation of 1 kg of vehicle

FUEL per KG per 100 KM (Lge/kg/100 km)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Argentina	0,0069	0,0068	0,0068	0,0068	0,0066	0,0064	0,0064	0,0062	0,0061	0,0061	0,0061	0,0061	0,0060
Australia	0,0068	0,0067	0,0064	0,0063	0,0062	0,0061	0,0060	0,0057	0,0055	0,0052	0,0052	0,0049	0,0048
Austria	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0041	0,0039	0,0039	0,0040
Belgium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0041	0,0040	0,0039	0,0039
Brazil	0,0074	0,0074	0,0074	0,0074	0,0075	0,0076	0,0073	0,0070	0,0070	0,0068	0,0068	0,0062	0,0061
Bulgaria	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0042	0,0042
Canada	0,0063	0,0062	0,0061	0,0060	0,0058	0,0056	0,0056	0,0057	0,0055	0,0052	0,0052	0,0052	0,0052
Chile	0,0063	0,0063	0,0062	0,0062	0,0063	0,0064	0,0063	0,0060	0,0059	0,0056	0,0057	0,0055	0,0055
China	0,0072	0,0071	0,0070	0,0069	0,0069	0,0069	0,0067	0,0065	0,0063	0,0059	0,0058	0,0054	0,0053
Croatia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0039	0,0040
Cyprus	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0041	0,0041
Czech Republic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0043	0,0043
Denmark	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0042	0,0041	0,0040	0,0040
Egypt	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0061	0,0061	0,0058	0,0059	0,0054	0,0054
Estonia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0044	0,0044
Finland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0042	0,0041	0,0041	0,0040
France	0,0049	0,0048	0,0047	0,0045	0,0046	0,0046	0,0044	0,0041	0,0040	0,0040	0,0039	0,0039	0,0040
Germany	0,0053	0,0053	0,0052	0,0052	0,0050	0,0049	0,0046	0,0044	0,0043	0,0042	0,0041	0,0040	0,0040
Greece	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0041	0,0040	0,0040	0,0042
Hungary	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0043	0,0044
Iceland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0040	0,0039
India	0,0068	0,0066	0,0063	0,0059	0,0060	0,0061	0,0058	0,0055	0,0056	0,0053	0,0053	0,0050	0,0049
Indonesia	0,0071	0,0071	0,0071	0,0071	0,0071	0,0071	0,0074	0,0072	0,0067	0,0066	0,0069	0,0067	0,0067
Ireland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0038	0,0038	0,0037	0,0037
Italy	0,0051	0,0051	0,0051	0,0051	0,0051	0,0051	0,0047	0,0046	0,0044	0,0044	0,0043	0,0040	0,0040
Japan	0,0065	0,0063	0,0061	0,0059	0,0059	0,0058	0,0057	0,0054	0,0052	0,0051	0,0053	0,0050	0,0050
Korea	0,0051	0,0051	0,0051	0,0051	0,0049	0,0048	0,0045	0,0042	0,0042	0,0045	0,0044	0,0042	0,0043
Latvia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0043	0,0042
Lithuania	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0042	0,0043
Luxembourg	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0040	0,0039	0,0040	0,0040
Macedonia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0047	0,0046	N/A	N/A	N/A	N/A
Malaysia	0,0075	0,0074	0,0074	0,0074	0,0071	0,0068	0,0068	0,0065	0,0063	0,0061	0,0057	0,0059	0,0058
Malta	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0044	0,0044
Mexico	0,0069	0,0068	0,0068	0,0067	0,0068	0,0069	0,0069	0,0062	0,0060	0,0058	0,0057	0,0058	0,0058
Netherlands	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0041	0,0038	0,0042	0,0041
Norway	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0039	0,0037	N/A	N/A
Peru	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0058	0,0058	0,0054	0,0053	0,0054	0,0055
Philippines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0060	0,0060	0,0060	0,0059	0,0059	0,0058
Poland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0044	0,0047
Portugal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0038	0,0037	0,0037	0,0037
Romania	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0043	0,0042
Russian Federation	0,0072	0,0071	0,0068	0,0066	0,0066	0,0066	0,0064	0,0063	0,0062	0,0060	0,0060	0,0058	0,0057
Slovakia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0043	0,0043
Slovenia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0042	0,0041
South Africa	0,0063	0,0063	0,0061	0,0060	0,0059	0,0057	0,0055	0,0054	0,0052	0,0053	0,0052	0,0050	0,0050
Spain	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0040	0,0039	0,0040	0,0040
Sweden	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0040	0,0038	0,0038	0,0038
Switzerland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,0044	0,0042	N/A	N/A
Thailand	0,0056	0,0056	0,0057	0,0058	0,0058	0,0058	0,0059	0,0052	0,0052	0,0054	0,0054	0,0050	0,0048
Turkey	0,0060	0,0058	0,0055	0,0052	0,0050	0,0049	0,0047	0,0044	0,0043	0,0041	0,0041	0,0039	0,0039
Ukraine	0,0075	0,0072	0,0068	0,0064	0,0062	0,0061	0,0059	0,0056	0,0055	0,0053	0,0049	0,0047	0,0045
United Kingdom	0,0055	0,0054	0,0053	0,0051	0,0050	0,0048	0,0046	0,0044	0,0043	0,0042	0,0040	0,0040	0,0040
United States	0,0062	0,0061	0,0060	0,0059	0,0057	0,0054	0,0054	0,0053	0,0052	0,0052	0,0051	0,0050	0,0050
GLOBAL	**0,0064**	**0,0063**	**0,0062**	**0,0061**	**0,0060**	**0,0059**	**0,0058**	**0,0056**	**0,0054**	**0,0049**	**0,0048**	**0,0046**	**0,0046**
		1%	2%	2%	1%	1%	2%	4%	3%	9%	2%	4%	0%
				2,65%	**AVERAGE ANNUAL IMPROVEMENT**								

Appendix 3. Variables and equations related to fuel consumption

Name of a variable	**Equation**	**Units**	**Assumptions/sources**
Litres of fuel used by the fleet	= Kilometres driven by the fleet*Fuel economy litres/100 km	l/year	Assuming that the driven kilometres per vehicle are equal
Litres of diesel increase per year	= 0.0016	l/year/km	Ageing effect
Litres of diesel per km per kg 2005	= 5.7e-05	l/km/kg	Technological advancement: base year 2005
Age of the fleet	= INTEG (Year increase, 0)	year	Yearly increase
Year increase	= 1	year/year	Time step
Year of vehicle purchase	*Defined by fleet characteristics*	Dmnl	Average, based on average age
Factor of local infrastructure and traffic	*Defined by the target area characteristics – External factor*	Dmnl	Comparison coefficient to global average
Fuel economy litres/100 km	= **[((**1-0.0265)^(Year of vehicle purchase-2005)**)** * **(**Litres of diesel per km per kg 2005*Share of diesel vehicles in the fleet + Litres of diesel per km per kg 2005*1.12*(1 - Share of diesel vehicles in the fleet)**)** * Average weight of the fleet + **(**Litres of diesel increase per year*1.12*(1 - Share of diesel vehicles in the fleet) + Litres of diesel increase per year*Share of diesel vehicles in the fleet**)***Age of the fleet**]***Factor of local infrastructure and traffic	l/km	Red - engine improvement; Yellow – weight-related fuel consumption; Blue – ageing effect; multiplication by 1,12 to convert estimations from diesel to gasoline

Appendix 4. Variables and equations related to fleet weight

Name of a variable	Equation	Units	Assumptions/sources
Average passenger weight	=75	kg/pers	Approximating passenger weight; based on Schoemaker (2007)
Kerb weight of car	*Defined by fleet characteristics*	kg	-
Loading of a car	*Defined by fleet characteristics*	Dmnl	Range: [0;1]
Maximum passengers of a vehicle	*Defined by fleet characteristics*	pers	Average maximum capacity of all vehicles of the fleet
Average weight of the fleet	= Kerb weight of car + Average passenger weight * Loading of a car * Maximum passengers of a vehicle	kg	Operating weight, that is transported. Assuming that a vehicle transports only passengers

Appendix 5. Variables and equations related to driven distance

Name of a variable	Equation	Units	Assumptions/sources
Average trip distance	*Defined by fleet characteristics*	km	Assuming all vehicles conduct same-distance trips
Kilometres driven by the fleet	= ("Aiding personnel-trips to be delivered" / (Loading of a car * Maximum passengers of a vehicle)) * Average trip distance	km/year	Annual mileage of the fleet

Appendix 6. Variables and equations related to fleet size

Name of a variable	**Equation**	**Units**	**Assumptions/sources**
Maximum kilometres driven by a vehicle per year	*Defined by fleet characteristics*	km/year/cars	Based on organisational logistical and operational issues
Required number of vehicles	= Kilometres driven by the fleet / Maximum kilometres driven by a vehicle per year	cars	Assuming equal distance driven annually per vehicle
Vehicles in the fleet	= INTEG (Vehicles purchased - Vehicles sold, 0)	cars	Number of vehicles in the fleet at a certain moment
Vehicles purchased	= MAX (Required number of vehicles - Vehicles in the fleet, 0) / TIME STEP	cars/year	Purchase of vehicles per year
Vehicles sold	= MAX (Vehicles in the fleet - Required number of vehicles, 0)/TIME STEP	cars/year	Sale of the vehicles per year

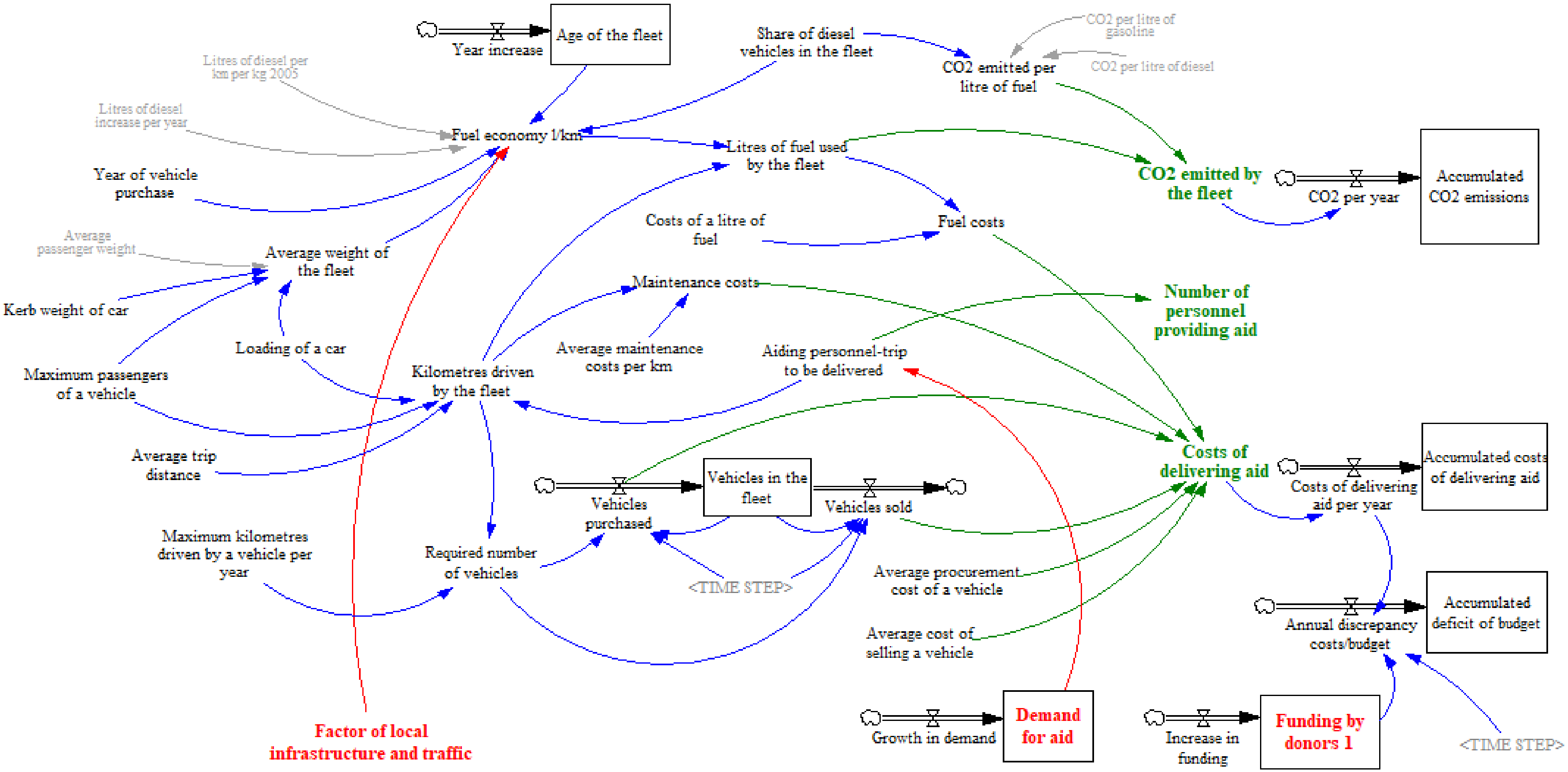
Appendix 7. Variables and equations related to fleet size

Name of a variable	**Equation**	**Units**	**Assumptions / sources**
Accumulated costs of delivering aid	= INTEG (Costs of delivering aid per year, 0)	USD	-
Costs of delivering aid per year	= Costs of delivering aid	USD/year	Overall costs per year
Costs of delivering aid	= MIN ((Fuel costs + Maintenance costs + Average procurement cost of a vehicle * Vehicles purchased - Vehicles sold * Average cost of selling a vehicle), Funding by donors)	USD/year	-
Fuel costs	= Costs of a litre of fuel * Litres of fuel used by the fleet	USD/year	-
Costs of a litre of fuel	*Defined by fleet and target area characteristics*	USD/l	Assuming constant price per litre
Maintenance costs	= Average maintenance costs per km * Kilometres driven by the fleet	USD/year	-
Average maintenance costs per km	*Defined by fleet characteristics*	USD/km	Assuming same average costs per km for all vehicle types
Average procurement cost of a vehicle	*Defined by fleet characteristics*	USD/cars	Assuming same costs of all vehicles
Average cost of selling a vehicle	*Defined by fleet characteristics*	USD/cars	Assuming same costs of all vehicles
Funding by donors	*EXTERNAL FACTOR*	USD/year	-

Appendix 8. Variables and equations related to aiding personnel-trips.

Name of a variable	**Equation**	**Units**	**Assumptions/sources**
"Aiding personnel-trip to be delivered"	*Defined by an IHO*	pers/year	Planned workload of an IHO
Number of personnel providing aid	= "Aiding personnel-trip to be delivered"	pers/year	Delivered aid by transported staff members
Demand for aid in target areas	*EXTERNAL FACTOR*	pers/year	Representation of socio-economic conditions in target areas

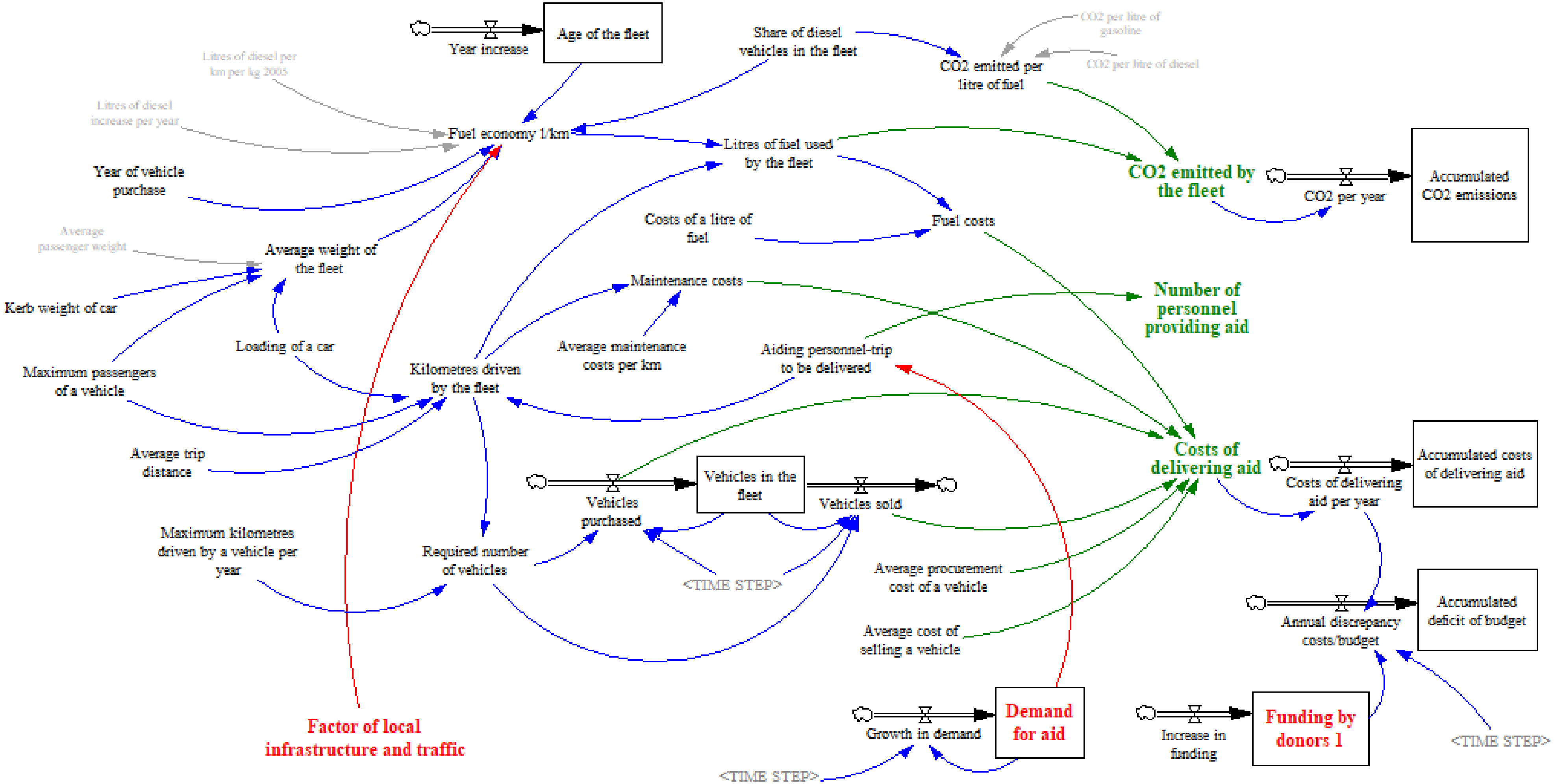
Appendix 9. Model used for testing Scenario 1 and Scenario 3



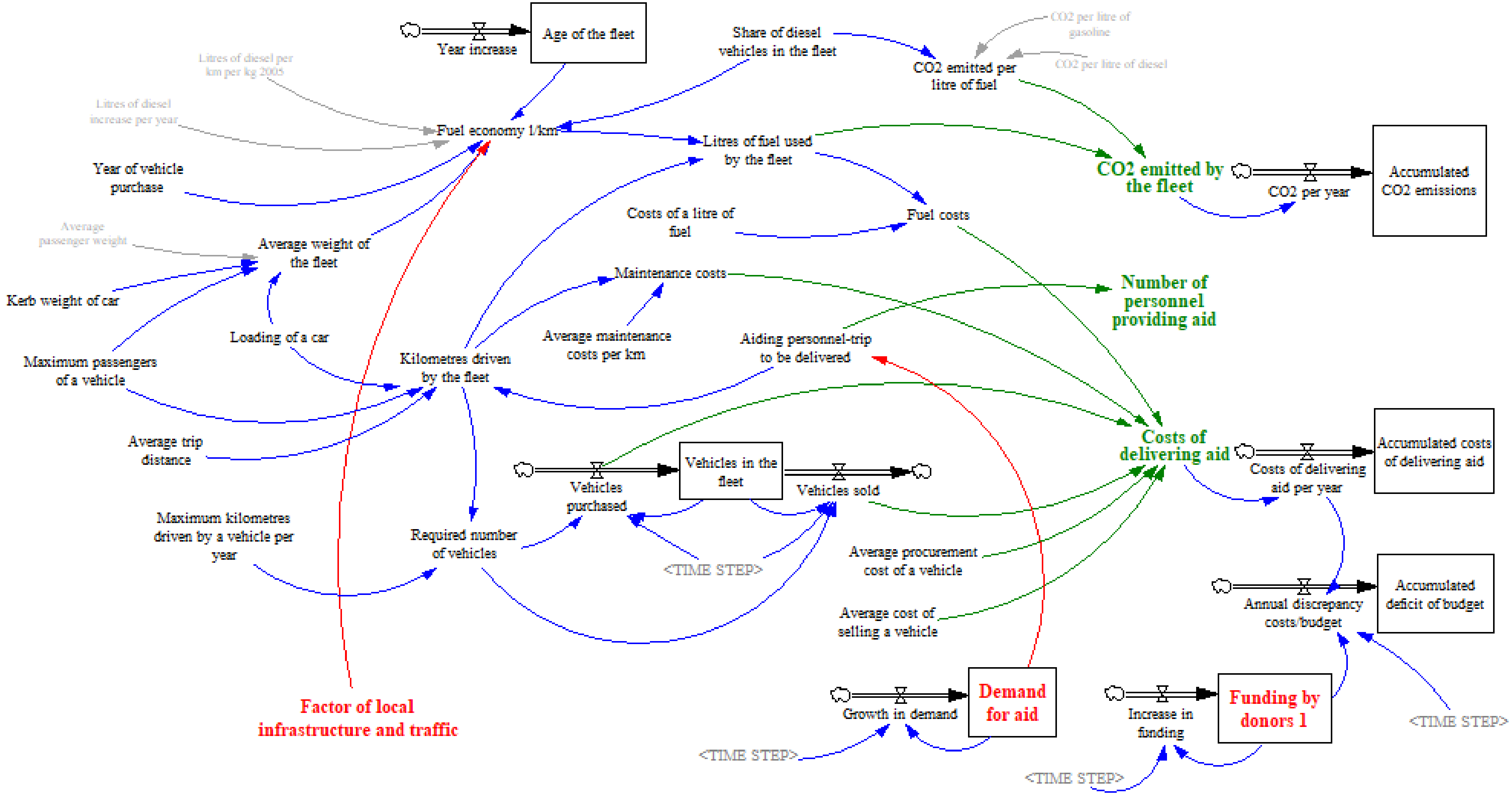
Appendix 10. Equations and new variables for scenario analysis (Scenario 1 and 3)

Variable	**Unit**	**Equation**
Demand for aid	pers	= INTEG (Growth in demand, **'Assumed average annual number of person-trips' from Table 3 per region'*)*
Growth in demand	pers/year	= 0,18 * **'Assumed average annual number of person-trips' from Table 3 per region'**
Funding by donors	USD	= INTEG (Increase in funding, **' Average annual costs' from Table 3 per region**)
Increase in funding	USD/year	Scenario 1: = 0,18 * **' Average annual costs' from Table 3 per region** Scenario 3: = 0,09 * **' Average annual costs' from Table 3 per region**
Accumulated deficit of budget	USD	= INTEG ("Annual discrepancy costs/budget", 0)
"Annual discrepancy costs/budget"	USD/year	= Costs of delivering aid per year - Funding by donors /TIME STEP

Appendix 11. Model used for testing Scenario 2



Appendix 12. Model used for testing Scenario 4.



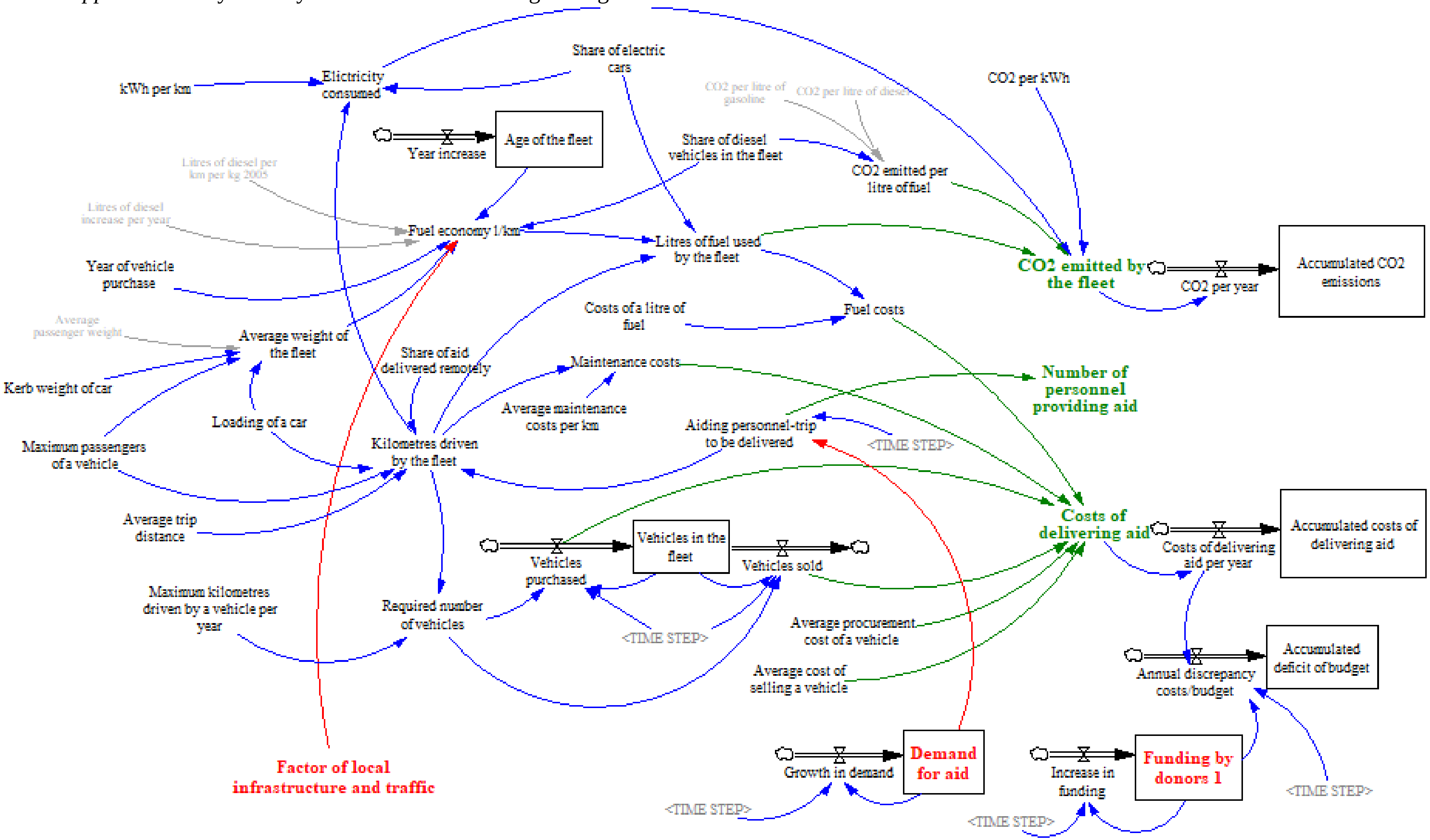
Appendix 13. Equations and new variables for scenario analysis (Scenario 2 and 4)

Variable	Unit	Equation
Demand for aid	pers	= INTEG (Growth in demand, **'Assumed average annual number of person-trips' from Table 3 per region*)*
Growth in demand	pers/year	Demand for aid*0,18/TIME STEP
Funding by donors	USD	= INTEG (Increase in funding, **' Average annual costs' from Table 3 per region**)
Increase in funding	USD/year	Scenario 2: = 0,09 * **' Average annual costs' from Table 3 per region** Scenario 4: = 0.09 * **' Average annual costs' from Table 3 per region** + STEP (Funding by donors 1/TIME STEP*0.3,2025)
Factor of local infrastructure and traffic	Dmnl	Scenario 2: = **Estimation from Figure 3 per region** + RAMP (0.01, 2020, 2030) Scenario 4: = **Estimation from Figure 3 per region* + RAMP (0.01, 2020, 2024) + RAMP (-0.02, 2025, 2030)

Appendix 14. Number of electric charging stations per country

Country	Number of electric charging stations	Possibility of the strategic option 3	Source
Afghanistan	1	No	Electromaps.com
Central African Republic	0	No	Electromaps.com
D.R. Congo	1	No	Electromaps.com
Iraq	4	No	Electromaps.com
Jordan	15 (in Aman)	Yes (electricity from gas)	Chargemap.com
Kenya	5 (big cities) – already can use	No	DW.com
Mali	2	No	Electromaps.com
Nigeria	12 (in Lagos)	Yes (electricity from gas)	Chargemap.com
South Sudan	0	No	Chargemap.com

Appendix 15. System Dynamics model for testing strategies



Appendix 16. Additional or adjusted variables and equations for testing of strategy regarding electric vehicles

Variable	**Unit**	**Equation**
kWh per km	kWh/km	= 0.2
Share of electric cars	Dmnl	*Defined by strategy*
Electricity consumed	kWh/year	= Kilometres driven by the fleet*Share of electric cars*kWh per km
CO2 per kWh	kg/kWh	= 0.2
Litres of fuel used by the fleet	l/year	= Kilometres driven by the fleet*"Fuel economy l/km"*(1-Share of electric cars)
CO2 emitted by the fleet	kg/year	= Litres of fuel used by the fleet*CO2 emitted per litre of fuel+Electricity consumed*CO2 per kWh

Appendix 17. Additional or adjusted variables and equations for testing of strategy regarding remote aid delivery

Variable	**Unit**	**Equation**
Share of aid delivered remotely	Dmnl	*Defined by strategy*
Kilometres driven by the fleet	Km/year	= ("Aiding personnel-trip to be delivered"/(Loading of a car*Maximum passengers of a vehicle))*Average trip distance*(1-Share of aid delivered remotely)

Appendix 18. Initial settings/base case (Jordan)

Variable	**Setting**
Age of the fleet (initial value)	7
Share of diesel vehicles in the fleet	0,38
Year of vehicle purchase	2013
Kerb weight of car	1500
Maximum passengers of a vehicle	5,1
Loading of a car	0,3
Average trip distance	20
Factor of local infrastructure and traffic	1,227
Average maintenance costs per km	0,06
Costs of litre of fuel	1,04
Average procurement cost of a vehicle	18 256
Average cost of selling a vehicle	9 000
Demand for aid (initial value)	80 686
Funding by donors (initial value)	350 288
Maximum km driven per car per year	11 102
Vehicles in the fleet (initial value)	95

Appendix 19. Outcomes of model simulations for testing of strategies

Strategy	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Base case (no change)	Required aid delivered within budget; CO_2 accumulated: 5 708 tonnes	Cumulative deficit of budget 6 mln USD by 2030; CO_2 accumulated: 7 841 tonnes	Cumulative deficit of budget 1,5 mln USD by 2030; CO_2 accumulated: 5 708 tonnes	Cumulative deficit of budget 3,6 mln USD by 2030; CO_2 accumulated: 7 489 tonnes
Loading of a car 0,1	Cumulative deficit of budget 16 mln USD by 2030; CO_2 accumulated: 16 483 tonnes	Cumulative deficit of budget 31 mln USD by 2030; CO_2 accumulated: 22 649 tonnes	Cumulative deficit of budget 17 mln USD by 2030; CO_2 accumulated: 16 483 tonnes	Cumulative deficit of budget 28 mln USD by 2030; CO_2 accumulated: 21 633 tonnes
Loading of a car 0,25	Cumulative deficit of budget 1,7 mln USD by 2030; CO_2 accumulated: 6 785 tonnes	Cumulative deficit of budget 8 mln USD by 2030; CO_2 accumulated: 9 322 tonnes	Cumulative deficit of budget 3 mln USD by 2030; CO_2 accumulated: 6 785 tonnes	Cumulative deficit of budget 6 mln USD by 2030; CO_2 accumulated: 8 904 tonnes
Loading of a car 0,5	2,8 mln USD saved cumulatively by 2030; CO_2 accumulated: 3 553 tonnes	Cumulative deficit of budget 1,3 mln USD by 2030; CO_2 accumulated: 4 879 tonnes	1,4 mln USD saved cumulatively by 2030; CO_2 accumulated: 3 553 tonnes	1 mln USD saved cumulatively by 2030; CO_2 accumulated: 4 661 tonnes

Loading of a car 0,75	4,2 mln USD saved cumulatively by 2030; CO2 accumulated: 2 476 tonnes	1 mln USD saved cumulatively by 2030; CO2 accumulated: 3 398 tonnes	2,8 mln USD saved cumulatively by 2030; CO2 accumulated: 2 476 tonnes	3,2 mln USD saved cumulatively by 2030; CO2 accumulated: 3 246 tonnes
Loading of a car 1	4,9 mln USD saved cumulatively by 2030; CO2 accumulated: 1 937 tonnes	2,1 mln USD saved cumulatively by 2030; CO2 accumulated: 2 656 tonnes	3,5 mln USD saved cumulatively by 2030; CO2 accumulated: 1 937 tonnes	4,4 mln USD saved cumulatively by 2030; CO2 accumulated: 2 539 tonnes
Average trip distance 15 km	1,7 mln USD saved cumulatively by 2030; CO2 accumulated: 4 281 tonnes	Cumulative deficit of budget 3 mln USD by 2030; CO2 accumulated: 5 881 tonnes	Required aid delivered within budget; CO2 accumulated: 4 281 tonnes	Cumulative deficit of budget 0,7 mln USD by 2030; CO2 accumulated: 5 881 tonnes
Average trip distance 20 km = **Base case**	Required aid delivered within budget; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 6 mln USD by 2030; CO2 accumulated: 7 841 tonnes	Cumulative deficit of budget 1,5 mln USD by 2030; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 3,6 mln USD by 2030; CO2 accumulated: 7 489 tonnes
Average trip distance 25 km	Cumulative deficit of budget 2,1 mln USD by 2030; CO2 accumulated: 7 135 tonnes	Cumulative deficit of budget 9 mln USD by 2030; CO2 accumulated: 9 801 tonnes	Cumulative deficit of budget 3,5 mln USD by 2030; CO2 accumulated: 7 135 tonnes	Cumulative deficit of budget 6,7 mln USD by 2030; CO2 accumulated: 9 361 tonnes

Kerb weight 150 kg (& Maximum seats 2 & Procurement costs 1300 USD + full renewal)	1,5 mln USD saved cumulatively by 2030; CO2 accumulated: 4 443 tonnes	Cumulative deficit of budget 2 mln USD by 2030; CO2 accumulated: 6 229 tonnes	Required aid delivered within budget; CO2 accumulated: 4 443 tonnes	Required aid delivered within budget; CO2 accumulated: 5 929 tonnes
Kerb weight 900 kg (& Maximum seats 4 & procurement costs 12 400 USD)	Required aid delivered within budget; CO2 accumulated: 4 621 tonnes	Cumulative deficit of budget 5,4 mln USD by 2030; CO2 accumulated: 6 380 tonnes	Cumulative deficit of budget 1,5 mln USD by 2030; CO2 accumulated: 4 621 tonnes	Cumulative deficit of budget 3 mln USD by 2030; CO2 accumulated: 6 088 tonnes
Kerb weight 1550 kg = Base case	Required aid delivered within budget; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 6 mln USD by 2030; CO2 accumulated: 7 841 tonnes	Cumulative deficit of budget 1,5 mln USD by 2030; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 3,6 mln USD by 2030; CO2 accumulated: 7 489 tonnes
Kerb weight 2400 kg (& Maximum seats 7 & Procurement costs 20 000 USD)	0,4 mln USD saved cumulatively by 2030; CO2 accumulated: 5 664 tonnes	Cumulative deficit of budget 4,7 mln USD by 2030; CO2 accumulated: 7 761 tonnes	Cumulative deficit of budget 1 mln USD by 2030; CO2 accumulated: 5 664 tonnes	Cumulative deficit of budget 2,3 mln USD by 2030; CO2 accumulated: 7 416 tonnes
Kerb weight 3150 kg (& Maximum seats 12 & 22 000 USD)	2,2 mln USD saved cumulatively by 2030; CO2 accumulated: 3 584 tonnes	Cumulative deficit of budget 1,5 mln USD by 2030;	0,8 mln USD saved cumulatively by 2030; CO2 accumulated: 3 584 tonnes	0,7 mln USD saved cumulatively by 2030CO2 accumulated: 4 691 tonnes

		CO2 accumulated: 4 908 tonnes		
Year of purchase 2005	Cumulative deficit of budget 0,9 mln USD by 2030; CO2 accumulated: 7 567 tonnes	Cumulative deficit of budget 7 mln USD by 2030; CO2 accumulated: 10 370 tonnes	Cumulative deficit of budget 2,3 mln USD by 2030; CO2 accumulated: 7 567 tonnes	Cumulative deficit of budget 4,6 mln USD by 2030; CO2 accumulated: 9 910 tonnes
Year of purchase 2010	Required aid delivered within budget; CO2 accumulated: 6 378 tonnes	Cumulative deficit of budget 6,3 mln USD by 2030; CO2 accumulated: 8 753 tonnes	Cumulative deficit of budget 1,8 mln USD by 2030; CO2 accumulated: 6 378 tonnes	Cumulative deficit of budget 4 mln USD by 2030; CO2 accumulated: 8 362 tonnes
Year of purchase 2015	Required aid delivered within budget; CO2 accumulated: 5 278 tonnes	Cumulative deficit of budget 5,7 mln USD by 2030; CO2 accumulated: 7 255 tonnes	Cumulative deficit of budget 1,3 mln USD by 2030; CO2 accumulated: 5 278 tonnes	Cumulative deficit of budget 3,4 mln USD by 2030; CO2 accumulated: 6 929 tonnes
Year of purchase 2020	Required aid delivered within budget; CO2 accumulated: 4 255 tonnes	Cumulative deficit of budget 5,9 mln USD by 2030; CO2 accumulated: 5 862 tonnes	Cumulative deficit of budget 1,7 mln USD by 2030; CO2 accumulated: 4 255 tonnes	Cumulative deficit of budget 3,7 mln USD by 2030; CO2 accumulated: 5 597 tonnes

Electric vehicles 0 = **Base case**	Required aid delivered within budget; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 6 mln USD by 2030; CO2 accumulated: 7 841 tonnes	Cumulative deficit of budget 1,5 mln USD by 2030; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 3,6 mln USD by 2030; CO2 accumulated: 7 489 tonnes
Electric vehicles 0,25 (& Procurement costs 21 000 USD)	Required aid delivered within budget; CO2 accumulated: 4 472 tonnes	Cumulative deficit of budget 6,5 mln USD by 2030; CO2 accumulated: 6 123 tonnes	Cumulative deficit of budget 1,9 mln USD by 2030; CO2 accumulated: 4 472 tonnes	Cumulative deficit of budget 4,3 mln USD by 2030; CO2 accumulated: 5 865 tonnes
Electric vehicles 0,5 (& Procurement costs 25 000 USD)	Cumulative deficit `of budget 1 mln USD by 2030; CO2 accumulated: 3 236 tonnes	Cumulative deficit of budget 7,6 mln USD by 2030; CO2 accumulated: 4 417 tonnes	Cumulative deficit of budget 2,5 mln USD by 2030; CO2 accumulated: 3 236 tonnes	Cumulative deficit of budget 5 mln USD by 2030; CO2 accumulated: 4 241 tonnes
Electric vehicles 0,75 (& Procurement costs 28 000 USD)	Cumulative deficit of budget 1,5 mln USD by 2030; CO2 accumulated: 1 999 tonnes	Cumulative deficit of budget 8,3 mln USD by 2030; CO2 accumulated: 2 704 tonnes	Cumulative deficit of budget 2,9 mln USD by 2030; CO2 accumulated: 1 999 tonnes	Cumulative deficit of budget 6 mln USD by 2030; CO2 accumulated: 2 617 tonnes
Remote aid 0 = **Base case**	Required aid delivered within budget; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 6 mln USD by 2030; CO2 accumulated: 7 841 tonnes	Cumulative deficit of budget 1,5 mln USD by 2030; CO2 accumulated: 5 708 tonnes	Cumulative deficit of budget 3,6 mln USD by 2030; CO2 accumulated: 7 489 tonnes

Remote aid 0,1	0,7 mln USD saved cumulatively by 2030; CO_2 accumulated: 5 137 tonnes	Cumulative deficit of budget 5 mln USD by 2030; CO_2 accumulated: 7 051 tonnes	Cumulative deficit of budget 0,8 mln USD by 2030; CO_2 accumulated: 5 137 tonnes	Cumulative deficit of budget 2,4 mln USD by 2030; CO_2 accumulated: 6 740 tonnes
Remote aid 0,2	1,4 mln USD saved cumulatively by 2030; CO_2 accumulated: 4 567 tonnes	Cumulative deficit of budget 3,6 mln USD by 2030; CO_2 accumulated: 6 273 tonnes	Required aid delivered within budget; CO_2 accumulated: 4 567 tonnes	Cumulative deficit of budget 1,3 mln USD by 2030; CO_2 accumulated: 5 991 tonnes
Remote aid 0,3	2,1 mln USD saved cumulatively by 2030; CO_2 accumulated: 3 996 tonnes	Cumulative deficit of budget 2,4 mln USD by 2030; CO_2 accumulated: 5 488 tonnes	0,7 mln USD saved cumulatively by 2030; CO_2 accumulated: 3 996 tonnes	Required aid delivered within budget; CO_2 accumulated: 5 243 tonnes
Remote aid 0,4	2,8 mln USD saved cumulatively by 2030; CO_2 accumulated: 3 425 tonnes	Cumulative deficit of budget 1,2 mln USD by 2030; CO_2 accumulated: 4 704 tonnes	1,4 mln USD saved cumulatively by 2030; CO_2 accumulated: 3 425 tonnes	1 mln USD saved cumulatively by 2030; CO_2 accumulated: 4 494 tonnes
Remote aid 0,5	3,6 mln USD saved cumulatively by 2030; CO_2 accumulated: 2 854 tonnes	Required aid delivered within budget; CO_2 accumulated: 3 920 tonnes	2,9 mln USD saved cumulatively by 2030; CO_2 accumulated: 2 854 tonnes	2,2 mln USD saved cumulatively by 2030; CO_2 accumulated: 3 745 tonnes

Appendix 20. CO2 emissions resulting from change in loading of a vehicle (colour marked meeting the budgetary constraints; light-green row: 20-25% change of parameter);

	Scenario 1	Scenario 3	Scenario 4	Scenario 2	Delta CO2	Delta loading
Loading of a car 0,1	16483	16483	21633	22649	189%	-0,2
Loading of a car 0,25	6785	6785	8904	9322	19%	-0,05
Base case (0,3)	5708	5708	7489	7841	-	0,00
Loading of a car 0,5	3553	3553	4661	4879	-38%	0,20
Loading of a car 0,75	2476	2476	3246	3398	-57%	0,45
Loading of a car 1	1937	1937	2539	2656	-66%	0,70

Appendix 21. CO2 emissions resulting from change in average trip distance (colour marked meeting the budgetary constraints; light-green row: 20-25% change of parameter)

	Scenario 1	Scenario 3	Scenario 4	Scenario 2	Delta CO2	Delta trip
Average trip distance 25 km	7 135	7 135	9 361	9 801	25%	5 km
Average trip distance 20 km = Base case	5708	5708	7 489	7 841	-	-
Average trip distance 15 km	4 281	4 281	5 881	5 881	-25%	- 5km

Appendix 22. CO_2 emissions resulting from change in weight of the fleet (colour marked meeting the budgetary constraints; light-green row: 20-25% change of parameter)

	Scenario 1	Scenario 3	Scenario 4	Scenario 2	Delta CO2	Delta kg
Kerb weight 150 kg (& Maximum seats 2 & Procurement costs 1300 USD + full renewal)	4443	4443	5929	6229	-22%	- 1400 kg
Kerb weight 900 kg (& Maximum seats 4 & procurement costs 12 400 USD)	4621	4621	6088	6380	-19%	- 650 kg
Kerb weight 1550 kg = Base case	5708	5708	7489	7841	-	-
Kerb weight 2400 kg (& Maximum seats 7 & Procurement costs 20 000 USD)	5664	5664	7416	7761	-1%	850 kg
Kerb weight 3150 kg (& Maximum seats 12 & 22 000 USD)	3584	3584	4691	4908	-37%	1600 kg

Appendix 23. CO_2 emissions resulting from change in age of the fleet (colour marked meeting the budgetary constraints; light-green row: 20-25% change of parameter)

	Scenario 1	Scenario 3	Scenario 4	Scenario 2	Delta CO2	Delta years
Year of purchase 2005 (age 15)	7567	7568	9 910	10370	33%	-8
Year of purchase 2010 (age 10)	6 378	6 378	8 362	8753	12%	-3
2013 = Base case (age 7)	5708	5708	7489	7841	-	-
Year of purchase 2015 (age 5)	5278	5 279	6 929	7255	-8%	2
Year of purchase 2020 (age 0)	4 255	4 255	5 597	5862	-25%	7

Appendix 23. CO2 emissions resulting from change in share of electric vehicles in the fleet (colour marked meeting the budgetary constraints; light-green row: 20-25% change of parameter)

	Scenario 1	Scenario 3	Scenario 4	Scenario 2	Delta CO2	Delta share EV
Electric vehicles 0 = Base case	5708	5708	7489	7841	-	-
Electric vehicles 0,25 (& Procurement costs 21 000 USD)	4 472	4 472	5 865	6123	-22%	0,25
Electric vehicles 0,5 (& Procurement costs 25 000 USD)	3 236	3 236	4 241	4417	-43%	5
Electric vehicles 0,75 (& Procurement costs 28 000 USD)	1 999	1 999	2 617	2704	-65%	0,75

Appendix 24. CO2 emissions resulting from change in share of aid delivered remotely (colour marked meeting the budgetary constraints; light-green row: 20-25% change of parameter)

	Scenario 1	Scenario 3	Scenario 4	Scenario 2	Delta CO2	Delta share remote aid
Remote aid 0 = Base case	5708	5708	7489	7841	-	-
Remote aid 0,1	5 137	5 137	6 740	7 051	-10%	0,1
Remote aid 0,2	4 567	4 567	5 991	6273	-20%	0,2
Remote aid 0,3	3 996	3 996	5 243	5488	-30%	0,3
Remote aid 0,4	3425	3 426	4 494	4704	-40%	0,4
Remote aid 0,5	2 854	2 854	3 745	3920	-50%	0,5