UNIVERSITY OF QUEBEC IN MONTREAL

A SYSTEMATIC LITERATURE REVIEW ON REMOTE LOGISTICS: EXPLORING NEW WAYS TO REDUCE FOOD INSECURITY IN NORTHERN CANADA

THESIS

SUBMITTED IN PARTIAL FULFILLMENT

[MASTERS IN OPERATIONAL MANAGEMENT]

BY

ALEXANDRA LEVESQUE

MAY 2023

UNIVERSITÉ DU QUÉBEC À MONTRÉAL

REVUE SYSTÉMATIQUE DE LITTÉRATURE SUR LA LOGISTIQUE EN RÉGIONS ÉLOIGNÉES : EXPLORER DES SOLUTION INNOVANTES POUR RÉDUIRE L'INSÉCURITÉ ALIMENTAIRE DANS LE NORD CANADIEN

MÉMOIRE

PRÉSENTÉ COMME EXIGENCE PARTIELLE

[MAÎTRISE EN GESTION DES OPÉRATIONS]

PAR

ALEXANDRA LEVESQUE

MAI 2023

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor Professor Ana María Anaya-Arenas, for her precious advice and continuous support that made this work possible. Thanks to her flexibility, we were able to make this project completely remote. Many thanks for her time and profound belief in my work and opening doors to many other opportunities.

I also wish to extend my special thanks to professor Marilène Cherkesly who convinced me to pursue a thesis while I was in her undergraduate class and for having faith in me from the beginning.

Finally, my appreciation goes out to my family and friends who encouraged and supported me through my studies.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Remote logistics is a field of study that is not yet fully covered by the academic literature. The topic is slowly starting to emerge in fields of application like humanitarian and healthcare logistics, but without covering the specific challenge of food security. Food insecurity in remote regions is significantly higher than in the rest of Canada, and that is partially due to the isolation, the long distance to travel and the lack of infrastructure in these regions. This study is the first attempt at linking the topics of logistics activities and OR/MS applications to food security factors. Through a systematic literature review of contributions on logistics in remote areas, the present paper creates a compilation of published literature on the topic and summarizes the critical findings and current practices to identify, justify and propose general applications that could be transposed to the context in Northern Canada in terms of diminishing food insecurity by improving design or distribution networks.

Keywords: *remote logistics; distribution network; network design; food insecurity; systematic literature review; Northern Canada*

RÉSUMÉ

La logistique en région éloignées est un domaine d'étude n'ayant pas encore été pleinement intégré dans la littérature académique. Le sujet commence à émerger dans des domaines d'application comme la logistique humanitaire et de la santé. Cependant, une problématique spécifique semble absente des études scientifiques surtout dans le domaine de la logistique. D'ailleurs, la sécurité alimentaire en régions très éloignées est significativement plus élevée que dans le reste du Canada. Cela s'explique en partie par l'isolement, les longues distances à parcourir et le manque d'infrastructures appropriées dans ces régions. L'étude actuelle est une première tentative afin de lier les thèmes des activités logistiques et des applications OR/MS aux facteurs de sécurité alimentaire. Grâce à une revue systématique de la littérature regroupant les contributions sur la logistique en régions éloignées, le présent article crée une compilation de la littérature publiée sur le sujet et résume les résultats critiques ainsi que les pratiques actuelles afin d'identifier, justifier et proposer des applications générales qui pourraient être transposables au contexte du Nord canadien en terme de diminution de l'insécurité alimentaire par l'amélioration des pratique de distribution ou conception de réseaux.

Mots-clés: *logistique en régions éloignées; conception de réseaux, distribution, sécurité alimentaire, revue systématique, Nord Canadien*

INTRODUCTION

Logistics in remote areas is a niche term referring to logistical activities performed to or from remote/rural areas (Asian Development Bank, 2017). A remote region can be defined as a sector located away from the main central points. Relatively similar to classic logistics system activities (fleet management, warehousing, inventory, delivery etc.), the domain is often characterized by long distances to travel and increased complexity due to infrastructure challenges. In terms of academic literature on logistics in a remote region, it is an emerging topic compared to more popular systems like urban or humanitarian logistics. In the literature, we can find some interchangeable terms for *remote* like *rural* or *hard-to-reach* regions. These terms are going to be used interchangeably in this study as well with no distinction whatsoever.

The inspiration for this work came from a health perspective and the observed challenges encountered in the Northern Communities of Canada in terms of food prices and supplies. These difficulties are the leading cause of why food insecurity is disproportionally worse in the North than everywhere else in Canada. Recent research published in 2020 for the Library of Parliament's Research Program showed that food insecurity touches up to 57% of households in Nunavut (Leblanc-Laurendeau, 2020). The extreme isolation of the Northern communities and the food security challenge are becoming serious public health issues. Even though a lot of fields, including medicine, social science and geographics are starting to look at the situation, the logistical field is lacking on that matter. I hence believe in the importance of understanding better the logistics challenges in these regions and how they can contribute to reducing the risk of food insecurity in the northern communities. Because no academic research focuses on this specific topic, we looked at similar fields of application proposing models for logistics in remote regions. The objective of the literature review is to account for the current evidence-based research in the **Operational Research and Management Sciences (OR/MS)** field for **logistics problem** applications in **remote areas** and see the **general trends** that could be applied in the remote regions of Northern Canada to diminish food insecurity. In this paper, we present a review of literature from the past 10 years in OR/MS applications in remote logistics. The methodology used is a systematic literature review that allows for a rigorous and transparent process. Therefore, it is an opportunity to enhance the most significant contributions in literature in a very structured way.

The rest of this document is organized as follows. Chapter 1 provides a rigorous description of context including a definition and overview of food security both general and specific as well as the unique characteristics of Northern regions. Chapter 2 describes logistics activities and presents the concept of remote logistics. This chapter also includes the proposed framework on how to link food security to logistics activities. Chapter 3 presents our research process and paper selection methodology. Chapter 4 reports the main findings of the search results like the bibliographical analysis. Then, chapter 5 presents the paper's trends in each identified category and the last section is a discussion and conclusion of this research.

CHAPTER 1: FOOD SECURITY AND GENERAL PRINCIPLES

"I tell my kids not to eat in the morning and have dinner instead. When they have learned not to eat in the morning, they are no longer hungry" Elder Inuit woman. -
(Ford & Beaumier, 2011)

The motivation of this chapter on the realities of food insecurity is to bring to light the challenges faced by the community and to emphasize the important role that logistics can have in tackling this issue. This section is inspired by the real case of the Canadian North and provides a detail description of context and a deep understanding of the living conditions, as it was one of my main concerns. Hence, before proposing some solutions and drawing conclusions, it is important to grasp the different factors contributing to food insecurity in this specific context.

1.1. Food insecurity

Food insecurity is a major issue worldwide and multiple attempts at diminishing hunger around the globe are made by governmental and humanitarian organizations. Therefore, Canada is not safe from this crisis. According to Statistics Canada, food insecurity affects 4.4 million Canadian individuals. Not only that this number is still on the rise, but the distribution of food insecurity is more concentrated in the North Canadian regions making the statistic jump to one in three children suffering from food insecurity (Canadian Feed the Children, 2022). This chapter will provide a general definition of food insecurity, with a deep dive into the social factors and contributors to this crisis in the specific northern regions. Then, we will take a closer look at the concept of food insecurity in remote areas in general and finally dive into the specifics of food insecurity in Arctic Canada.

Food insecurity must be understood and defined before tackling its problems in the Arctic regions. The term food security first appeared in science in 1974 at the First World Food Conference (Delisle, 1998). Evolving over the years with different definitions, the concept remains multidimensional and is viewed from multiple perspectives.

According to the official definition of the 1996 World Food Summit, food security exists when "All people, at all times have physical and economic access to sufficient nutritious and safe foods, which meet their nutritional needs and preferences, to lead an active and healthy life”.

An important aspect of the concept of food security is the fact that this notion is multidisciplinary. That is, food security is dependent on several aspects of different areas. It cannot be understood under a single pair of glasses and the possible solutions must also be multidisciplinary. It should be an incentive for different fields and disciplines to put joint efforts toward the solution of the food insecurity experienced here, in Canada. Fundamentally, food security is a basic need for health and well-being, and even for the survival of the population. However, author Delisle is careful to mention that food security is not synonymous with nutrition security. The two notions are nuanced; while nutritional security refers to the fulfillment of nutritional needs, such as vitamins, minerals, etc., food security rather refers to a more global level. Not only the quantity of food available but also the supply of these foods in sufficient and diversified quantities. Then, the development of the qualitative dimension of food security (i.e., beyond the quantity of food available) emerges. A set of three conditions must be met to be qualified as food safe.

That is, to be food secured, an individual must be able to obtain:

1. A sufficient variety of foods to meet specific requirements for various nutrients.
2. A sufficient choice for a balanced diet suitable for preventing chronic disease.
3. Appropriate information on products and their use and good healthy choices (Delisle, 1998).

1.2. Food insecurity in remote regions and the Canadian North

Remote regions are faced with contrasting context characteristics compared to urban and main centers. The level of planning difficulty is much more complicated. Not only do stakeholders have to plan for network design and distribution, but they are also faced with multiple constraints, like long-distance travel that generates high costs of transportation, hard-to-reach regions (geographical or meteorological conditions), geographical dispersion of the population and lack of appropriate infrastructures.

Therefore, when it comes to food security in the North, the difficulty is real and more present than ever, even in a highly developed country like Canada. In fact, in the Canadian North, food insecurity affects 17% of households in the Yukon and 20% of households in the Northwest Territories. However, it is most prevalent in the territory of Nunavut, where almost one in two families admit to having faced food insecurity (Banques alimentaires Canada, 2016), this insecurity is also more noticeable within indigenous households.

Regarding food insecurity, specifically in remote northern regions, key articles have demonstrated and quantified this insecurity. Moreover, the question was approached from different angles; whether it be at the level of nutritional deficiencies in children (Pirkle et al., 2014), the psychological impacts linked to the lack of nutritional security (Bradette-Laplante et al., 2020) or the testimonies of Inuit families on the means to feed their families (Ford et al., 2010), these studies prove that northern Canadian communities are in difficulty when it comes to their diet. The statistics are plentiful, but the solutions are incomplete or only focused on the symptoms of the problem. For example, food banks are trying to help, government grants are offered, or local garden initiatives are under construction, but the situation does not yet improve (Dillabough, 2016).

Despite everything, the statistics are disastrous:

- Among Nunavut, 52% of households are worried about food and 27% are frequently skipping meals. Compared to Canada where 12% of households have experienced food insecurity (Arriagada, 2017; Leblanc-Laurendeau, 2020)

- 50% of parents or guardians responding to a survey mentioned having to cut portions of their children's meals or simply skip meals. Compared to the rest of Canada, this percentage is 1% (Pirkle et al., 2014)

- 80% of respondents say they do not have enough food to eat for one day or more (Pirkle et al., 2014)

It is also important to discuss the negative impacts and repercussions on the health of the Northern population. Interviews have revealed that people have developed coping mechanisms to endure hunger. For example, Ford & Beaumier (2011a), showed through interviews that drinking coffee or tea to suppress hunger when skipping meals is common practice. Other authors, like Pirkle et al. (2014) demonstrated that this health crisis also affects nutritional biomarkers such as weight, height, and blood iron levels in children. Through assessment and interview among a cohort of children, the results show that 1/3 of these participants had a significant iron deficiency and that 19% of the children were in the lowest tercile recommended by the World Health Organization. In addition, the study mentioned that on almost *all* health indicators, Inuit scores below the national average.

From a psychological standpoint, the impact is also present. Bradette-Laplante et al. (2020) conducted a recent longitudinal study, in 2020, that assessed for the first time the effects of food insecurity on psychological distress among Inuit adolescents in Nunavik. This research has shown that food insecurity is linked to symptoms of anxiety, depression, and personality detachment over the long term and that the suicide rate among Inuit children and adolescents is 30 times higher than elsewhere in Canada (Bradette-Laplante et al., 2020). This statistic regarding food insecurity concerning depressive symptoms becomes even more concerning. That is, the food insecurity crisis in Canada's North is no longer just a health issue, it can be said to be a matter of life and death.

A recent study by Kenny et al. (2020) published an interesting systematic scoping review on the topic of the retail food sector and food insecurity among indigenous communities (worldwide). These findings are relevant for us, even if it looks at 9 different countries because it includes research conducted in remote and rural regions. The authors reviewed 139 peer-reviewed papers on the subject of food insecurity and outlined the major issues and provided a list of actions that could help. Therefore, this review allows us to base our foundation on strong reviewed evidence.

1.3 Social factors and contributors to food insecurity in North Canada

Several social elements contribute to food insecurity in these northern regions. This sub-section aims at understanding from a holistic point of view the various elements contributing to food insecurity, where there is not only one or a few factors, but many social compounds. Therefore, the health crisis is a complex and multidisciplinary issue that goes beyond food distribution and supply chain logistics. The backbone of the social climate needs to be outlined, before even tackling the issue, it is important to understand what these communities are faced with. The most frequently identified factors and contributors to food insecurity are presented below, inspired by researchers Dillabough, (2016), and Kenny et al. (2020).

- **The nutritional transition:** historically the northern communities of Quebec (Nunavik) ate only food from the land and the ocean. Thus, traditional knowledge and hunting and fishing techniques are important elements for these communities. However, nowadays a high proportion of traditional foods (especially fish) are contaminated with mercury. In the last century, communities have been forced to make a big change in the way they eat; the Western invasion shifted their traditional habits towards store-bought food options which nowadays make up the bulk of their diet. In addition, obtaining traditional foods has become more difficult for these communities, not only because of the loss of knowledge transmission but also because of the high costs of equipment and gasoline for hunting and fishing (Bradette-Laplante et al., 2020). For example, the cost of a hunting trip can amount to hundreds of dollars, or even be valued annually at $ 25,000 (Skinner et al., 2016) without even having a food guarantee (Ford et al., 2010)

- **The high price of food**: food is subject to high prices given the long distances and modes of transport required to reach its destination. Interviews with locals showed that the price of a basket of groceries for a family of four in 2008 in Igloolik was $ 551 per week. This same basket costs $ 238 in Montreal (Ford et al., 2010). In addition, the quality of the food is strongly affected by the long journeys to be travelled, resulting in not-so-fresh food that has a shorter shelf life, therefore a lot of waste.

- **Poverty and low income:** as if injustices were not enough, the cost of living in these regions is slightly higher than elsewhere in Canada and the average salary per capita is $ 20 156$ compared to 31 759$ for the rest of Canada (Ford et al., 2010).

- **Inadequate subsidies:** the government has put in place aid programs to subsidize expensive food in these areas. In addition, there are federal departments such as Health Canada, Aboriginal Affairs and Northern Development Canada which divide up responsibilities for northern food. However, there is no integration between these ministries to ensure common and coherent development, they are independent and do not work in common. There are provincial food policies as well, but programs that focus on the unique food issues in communities across Canada's Arctic are rare. The literature has shown that existing policies in Canada fall short of food security (Dillabough, 2016). Among all the initiatives to counter food insecurity in circumpolar regions, the situation does not improve.

- **The increasing rate of addiction to substances and games:** these addiction factors also contribute to food security; addiction causes people to spend their money on drugs instead of food. Often, the price of food is so expensive, drugs become a way out for these people where cocaine is cheaper than a bag of flour (Desjardins & Monderie, 2007).

- **Unconventional food price comparison:** the evaluation of the pricing of food in the Canadian North is unique to its context and groceries should not be calculated with the traditional tools used elsewhere in the country that as the National Nutritious Food Basket (NNFB). This universal tool is a food comparison benchmark that compiles a list of 67 foods to find out the acceptable price in urban centers. Even though the Revised Northern Food Basket (RNFB) is an adjusted version for food consumed in the north (remote) it is not realistic nor representative of the reality of the communities (excludes traditional food items from fishing and hunting) and is mostly constituted of non-perishable, low nutritional items (Skinner et al., 2016).

To better understand the situation and the extent of the food insecurity issue that is ongoing in remote regions of the far Canadian North, it is important to recognize all these previous facets, but also some unique context characteristics of the region itself. With a deep understanding of not only the geographical conditions but the social and cultural elements, we can start to look at the root causes of food insecurity and work towards a sustainable solution to provide a stable and reliable food network. But most importantly, this scope of work will focus on how logistics can contribute to reducing the risks. Before diving into the logistical part, the following section dives even deeper into the context definition of the Nordic geographical characteristics. Including the demographics and living conditions of the area and the description of the food system issues, all leading to food insecurity. Again, the following elements are presented to deepen the understanding of the specific regions and the unique constraints that are present.

1.4 The Impact of Geography, Life Circumstances, and Social Dynamics on Food Security

Besides the social factors discussed in the previous section, the setting of the northern regions contributes also to food insecurity.

1.4.1 The geography

The remote regions of the North consist in our study, of the far northern territories of Canada. When considering the Northern regions of the Country, they are composed of four main territories: Nunavut, the Northwest Territories, the Yukon and a part of the Quebec province, the Nunavik. Also considered Northern soil, is the Artic Archipelago which is made up of 91 islands with sparsely distributed populations and vast land. This group of regions is considered remote because of its unique characteristics which are low population density, regions far from major centers and limitations to transportation infrastructures. Appendix A presents the geographical delimitations of what we consider North Canada. As part of this project, the Far North and the Extreme North areas are taken into consideration, as they are among the most difficult to access and most problematic areas. They are indeed considered *remote.* In fact, as a neighbour of Alaska, Polar Canada faces many logistical obstacles, resulting not only from the far regions but also because of the extreme cold and isolation associated with the characteristics of the region.

1.4.2 Demographics

The Canadian North comprises almost 40% of the Canadian territory. According to Statistics Canada, the population as of 2018 was nearly 200 000 inhabitants and the majority are indigenous people (mostly Inuit). The territories of the North are then characterized by a vast region and a small population divided into different communities, very distant from each other.

1.4.3 Climate

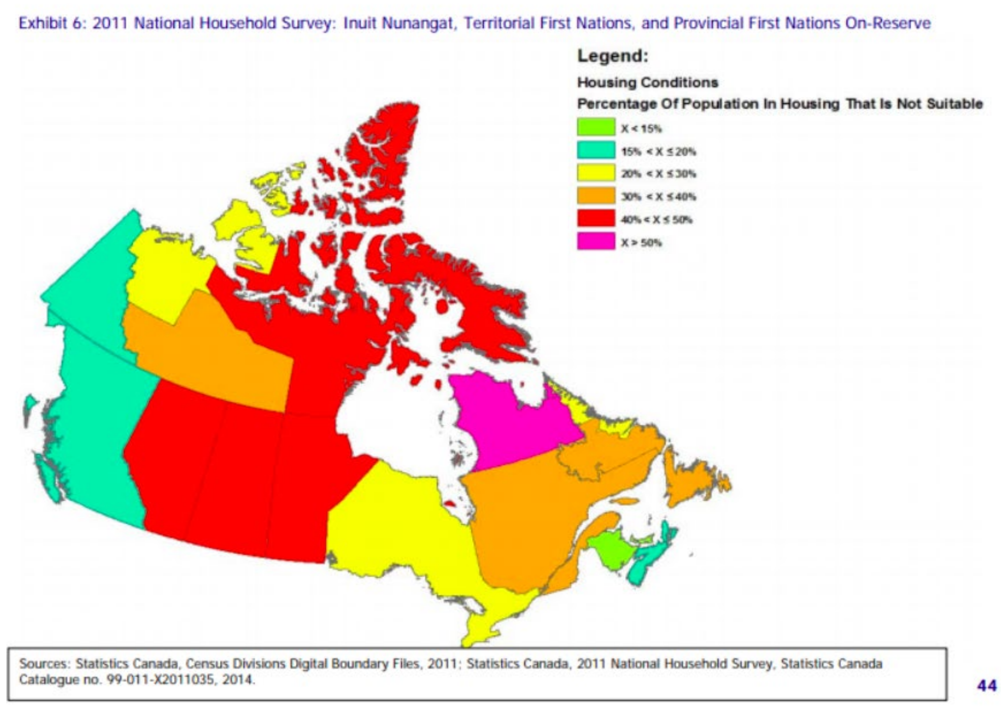
The unique context of the Canadian North is not only its remoteness and dispersed population but also the extreme climate that represents a major obstacle. The typical weather of the arctic regions results in long and freezing winters and the winter temperature ranges between -50 ° C to 0 ° C. In addition, some areas in the extreme north are permanently covered with ice. As for summer, it is short, and temperatures range from -10 ° C to 10 ° C. This warmer season then allows navigation of the seas from the end of July to the beginning of November, thus leaving less than 4 months for sea freight (Uniktour, n.d.). Although scientists predict the total melting of Arctic ice between 2030-2050, this forecast should not bias analyses at the transport level. According to researchers Giguère et al. (2017), even if these predictions are true, there will still be 1 million square km of ice in Arctic waters during the summer and, of course, there will always be ice during the winter. The melting ice presents business opportunities for transportation to these regions, and it will always remain an important component of logistics and supply management in these areas. Global warming has, on the contrary, caused difficulties in maritime transport. As an example, in 2018, the ice did not allow boats to dock at their destination on Baffin Island (Samson, 2019), causing major delays in the supply chain. It is therefore important to remember that the environment in this area is very unpredictable and not to base conclusions on the fact that the accessibility issue will resolve with ice melting.

1.4.4 Life conditions

Life conditions in the remote north also represent a major challenge. The living environment requires improvements since multiple difficulties are present either at the social, demographical, geographical, and logistical levels, which all contribute to the poor quality of life of the population. In addition to this, there are living conditions specific to the First Nations reserves. Even if this research a priori, is regarding the issue in the food supply sector, the social obstacles in these northern regions cannot be ignored. However, the scope of the context definition will provide a general description of these conditions to help understand the importance of providing a stable, good quality and affordable food supply to these communities. Figure 1.1 shows in red the percentage of households with unacceptable living conditions (Center for the North at the

Conference Board of Canada, 2014). There is inevitably a lack of support for quality of life, be it in terms of resources, food security, health care, economic development or even government support. Therefore, these regions are in a critical situation.

Figure 1.1 – Quality of life in Canada



1.4.5 Food supply and transportation

The food sector in the North is a complicated and underserved area, characterized by a very small market with many barriers and a complex entry process, which makes it difficult to attract food container carriers. The uncompetitive and small market, with not a lot of transportation companies (Oligopoly) and a dispersed population, does not present attractive opportunities for transportation companies. Moreover, the long and costly distance to travel represents an additional disadvantage.

Not only the remoteness influences the number of carriers available, but the distance itself impacts the prices of the products to the final consumers. Indeed, a common problem encountered by the northern residents is the extremely high prices of non-expensive food. For instance, the price of 3.49 litres of orange juice in Iqaluit is $ 26.99 (Parent, 2019). Another example of food supply difficulties is inventory and sourcing management. Journalist Claudiane Samson reported the situation in Iqaluit (Nunavut), where a local grocery store reports having a lot of problems with regularity and stability in the food supply. Inventory management is complex and unpredictable, and demand must adjust to seasonal delivery. Orders are placed between March and April and are transported by boat. Usually, the first delivery arrives in July. The storage is done in the transportation containers kept outside the store. In case of a product shortage, it is urgently delivered by air, which is extremely expensive. Finally, there are additional challenges to respecting expiration dates in the food industry. Waste management in those remote areas is another extremely important aspect to be taken into consideration. An increase in foods and essential goods in the territory will generate additional packaging, and therefore additional waste. Several regions of Canada's Far North do not have a recycling program and landfills are starting to reach their maximum capacity (Samson, 2019). We must therefore be careful not to solve one problem that will cause another. Nevertheless, the size of the market or the disadvantages associated with it does not justify its lack of importance, since food is an essential resource for human survival.

1.5 Unique and restricted transportation system

As we dive deeper into the particulars of transportation in the North, it becomes evident that there are unique and restricted conditions that set it apart from other regions. The harsh climate, rugged terrain, very long distances between communities and limited infrastructure call for specialized consideration. In this chapter, we will explore how these factors have shaped the actual transportation system in the North.

1.5.1 Road transport

Restricted Road access is one of the biggest supply problems for the regions of the Far North. Appendix B presents the different regions of interest (Nunavut, Northwest Territories, Yukon) and their access to road systems. Three categories of roads are identified, namely: 1) local roads, 2) regional seasonal road access, and 3) regional all-season road access. Interestingly, Nunavut has access to only 25 local roads and none of them is regional-seasonal nor regional all-season. Therefore, **access between regions is virtually impossible**, unless you use a mode of transportation such as snowmobile or aircraft. For the Northwest Territories, access is more varied. With four local roads, 12 seasonal regional roads and 16 all-season regional roads, its set of 32 roads provide comprehensive access. Finally, the Yukon, which has a total of 15 accessible routes, has 14 which are regional all season and one which is local.

In addition, the distances between communities and regional hubs are shown as well in appendix B. For example, the Northwest Territories has 27 peripheral communities that have access to the regional road either seasonally or all season. The closest regional hub is in Yellowknife or Whitehorse and the average distance to get there is 764 km. On the Yukon side, there are 13 communities, and the closest regional hub is in Whitehorse. The average distance to be covered is then 313 km. Note that there is no regional hub for the region of Nunavut, particularly because there is no access to regional roads. Moreover, the insufficient number of roads is very problematic. Statistics Canada, (2015) states that only 1% of the Canadian road network is in the three northern territories, and the majority is unpaved. That means 40% of the Canadian country, being the vast Arctic region, is not accessible by truck (Prentice & Russel, 2009).

In addition, the icy roads currently in use not only require maintenance costs 65-70% higher than the maintenance of regular roads elsewhere in Canada. But they are also at risk because of global warming. Indeed, the icy seasonal roads will soon no longer be accessible as they will melt. This represents a major challenge for communities dependent on these roads as the only means of access to their essential food. For example, in Manitoba, more than 5,000 km of roads are ice-type and serve between 50,000 and 60,000 residents (Prentice & Russel, 2009). While the issue of accessibility and food insecurity is already critical, the situation will only get worse. Hence the urgency to take an interest in the issue and to continue to innovate in the field.

1.5.2 Air transport

To the Far North is often the only means of transportation available in winter, especially because of the ice that does not allow any other point of entry. Appendix C presents the various air infrastructures in the regions of interest. In Nunavut, there are 10 indirect flights to a regional air hub, 12 direct flights to a regional hub and two regional air transit hubs. The Northwest Territories has a total of 32 airway accesses, including two airports and nine local airports. This is the region with the most varied air access. As for the Yukon, it has 15 various air accesses, including two airports, and 11 local airports. Again, Nunavut is the least accessible territory because there are no airports (Center for the North at the Conference Board of Canada, 2014).

1.5.3 Maritime transport

The seaway, the main access route to northern regions for carriers, faces extreme weather constraints. However, a recent study by Humpert, (2018) shows that maritime traffic to the Arctic regions almost tripled between 1990-2015, mainly for resupply activities, which is encouraging for the food supply to these regions. If the traffic increases, the logistical possibilities also increase. Appendix D presents the current water transport infrastructure in the north.

Indeed, according to the study published by the researchers Mussells et al. (2017), the ice melting becomes less dynamic and more predictable, which makes it easier to navigate in these waters. Contrary to Giguère et al. (2017), who state that ice will remain a constraint, some authors are optimistic about the ice melting and opening new horizons. Only more research and time will rectify the situation. Even so, the Far North still does not have the infrastructure, such as adequate ports, to make operations efficient. To date, the investment in such a project has not been worth it for the government. However, changing climatic conditions and increasing Arctic Sea freight justify the need for infrastructure.

As we can see in this chapter, the concept, the roots, and the impact of food insecurity is highly complex and lies in a large number of domains. One cannot understand the whole context without first looking at it from the inside out, and that starts by looking at the communities themselves and their living conditions. Therefore, it needs to be tackled from different perspectives and we are aware that logistics is not "THE" solution to the problem. However, we do believe that it is a contributor to reducing some risks by increasing the food supply. Moreover, the unique feature of the North requires that logistics are planned appropriately and differ from classical commercial logistics in urban settings. The concept of remote logistics is still new, and the next chapter will go over the main principles.

CHAPTER 2: LOGISTICS ACTIVITIES AND FOOD INSECURITY

2.1 Logistics: General Concept

Food security in northern environments remains a complex issue, which is not yet fully understood. However, we believe that the holistic characteristics of logistics and OR/MS field can be a useful tool in the food security crisis.

Logistic is a broad term that encompasses multiple activities in the supply system and the movements within (i.e., manufacturing, inventory, warehouse management, distribution etc.). The principal activities of logistics are to provide a system that determines the flow of materials from their origin to their destination and every decision in between. It is to ensure that the customer is provided with the right product, in the right place, at the right time in an integrated way. Its objective is to maximize the value of a logistic system by making key decision planning, ranging, but not limited to, the decision to build a new manufacturer or a warehouse, to the scheduling of pickups and deliveries to customers.

According to Ghiani et al. (2013), the main logistics activities within a system are:

1) **Supply logistics;** upstream management including materials and component supplies
2) **Internal logistics;** material handling and storage
3) **Distribution logistics;** downstream functions after the production plant to the customers
4) **Reverse logistics;** the return of goods from the end customer back to the manufacturer or distributor, including recycling of goods.

An important notion to consider is not only the activities of the system but the management tasks associated with it. Therefore, three management phases in a logistic system and their common decisions are defined (Ghiani et al., 2013):

1) **Planning phase;** forecasting, location, supply, storage, and distribution
2) **Organizing phase;** the decision of responsibilities and tasks
3) **Control phase;** KPI measures, measuring efficiency

For this study, we specifically focus on the internal logistic activities and the flow of commodities toward customers, the last mile distribution. We are looking at the planning phase and the decisions associated with it. To be precise, we focus on the decisions regarding **location and distribution planning** because we believe that these two categories of functions are the first key aspects to achieve impact on the food supply chain in the North. Moreover, some basic questions are still unanswered (See section 2.3 Location and distribution in remote areas). These characteristics are included in our inclusion criteria for the systematic literature review. Figure 2.1 presents the scope of logistics for this research.

As discussed in Chapter 1, the difficulties are mostly explained because the area is hard to access and lacks adequate infrastructure like roads, ports, and vehicles. As well as the communities being unable to have enough food. We hence focus on the aspect of the problem of food security related to accessibility (location) and distribution for remote northern regions. We firmly believe that decisions related to facility location (how many and where to locate a supply point) or to distribution planning (routing, mode of transport etc.) can improve the food supply chain.

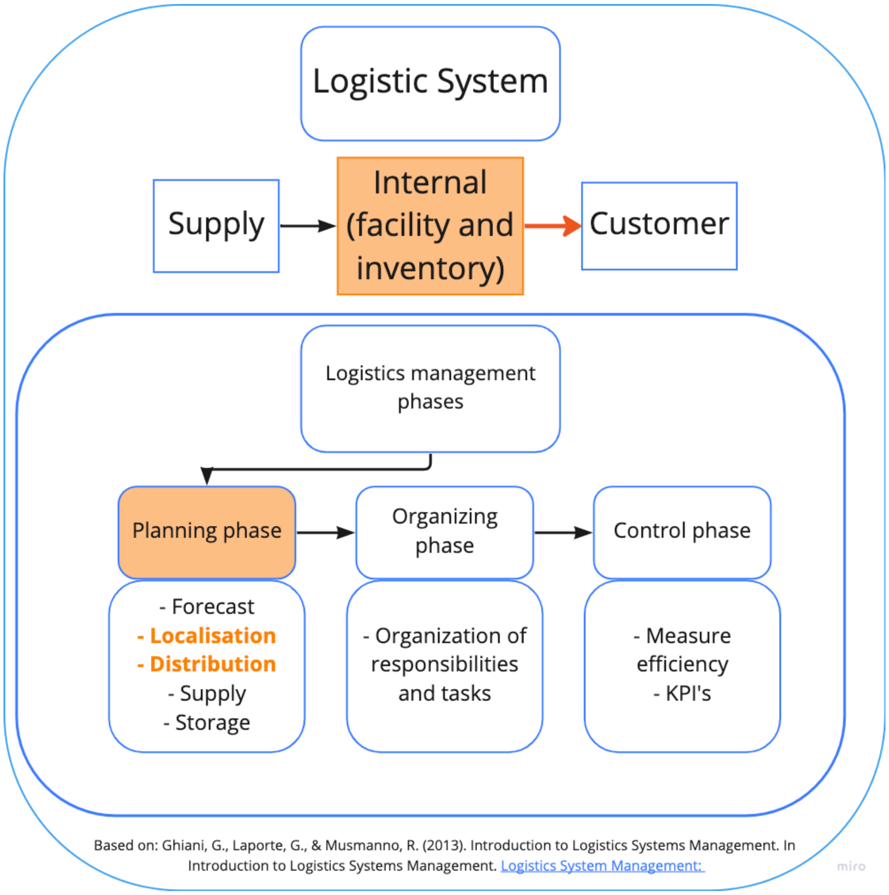


Figure 2.1- Scope of research and activities

To the best of our knowledge, this research is the first work that looks at the Northern food security crisis from a purely logistical perspective. While other activities within the supply chain could potentially impact positively the food system in the North, we are defining the scope of our contribution to two decision activities: location and distribution, as they are the first two key questions to provide the structure of the network. This will be explained in the next section.

2.2 Logistics planning phase: location and distribution activities

As for the logistics planning phase, attention must now be turned toward the location and distribution definitions to ensure a good comprehension of the two distinguished concepts.

2.2.1 Location planning definition

Location science is a well-established field and holds multiple fundamental problems that are used in operational management science (e.g., p-median problems, p-center problems, fixed-charge facility location problems etc.) (Laporte et al., 2015). Location science problems are one type of network planning problem that can be done strategically or at the tactical level. They are well documented in the operational research academia. The core of these types of problems is to decide the optimal location of a facility while satisfying the objectives of the problem (Contreras & Fernández, 2012). It is the process of establishing the geographical position of each entity in the supply chain, efficiently and optimally, to provide access to the service or the product. It is based on what the supply chain will build upon, setting important decisions like the number of facilities to open or locate, the size of the warehouses (capacity), the type and size of the fleet, the various links between entities and more. Pure location problems can exist on their own or can incorporate allocation or coverage decisions. When an allocation is considered, the model decides which facilities are used to serve what customers. Some examples of traditional problems considering allocation are the p-median and p-center ones (Contreras & Fernández, 2012). Among the location problems, there is, for example, the hub-location problem which aims at locating an intermediate point (hub) between the origin and destination nodes. The role of a hub is to serve as a transshipment point and allows the flow to be redirected to other nodes with fewer links that would be needed with direct connection (Laporte et al., 2015). One of the main advantages of the hub point is that it allows the flow to be aggregated or disaggregated and this leads to economies of scale in transportation costs. This is an interesting notion when it comes to logistics in hard-to-reach regions because such a network is characterized by high costs of transportation.

We identified the location activities as one of the main factors contributing to food security because it is considered to increase the number of service/supply points. In our case, locating additional food supply or warehouse point. The premise is that locating more accessible food supply points will reduce food insecurity by reaching a larger amount of people. This notion is supported in our framework in section 2.4.

2.2.2 Distribution planning definition

Distribution planning is the utilization of the network and the flow of commodities within. This planning activity directly affects the end customer by the measure of the level of service. Examples of decisions made with those types of problems are routing decisions and the mode of transport used.

We focused on this second type of activity because distribution decisions are closely related to location problems. When stakeholders decide to locate a facility, the next step is to connect the network with links – that comes to distribution planning (or transportation planning). Transportation would be the second most important part of a logistical system because it is often the biggest logistical cost (Ghiani et al., 2013).

Transportation/distribution planning has a direct impact on food supplies, and it directly affects the costs to the final customer (the price of food). Especially in the Northern where there are high transportation costs due to long routing distances and several difficulties related to the road network and transportation (infrastructures, routes).

2.3 Location and distribution in remote areas

Logistics in general is a well-studied and established field with lots of literature. Many tools are available to decision-makers in terms of software, decision-making support, and algorithms. In contrast, we have seen over the last years the emergence of a new concept: Remote Logistics.

Logistics in remote areas is an unfolding branch of logistics and is still poor in terms of documented studies. Compared to a more common type of logistics (procurement logistics, urban logistics, reverse logistics), the complexity of remote logistics is not yet fully integrated. In the literature, we can find some interchangeable terms for *remote* like *rural* or *hard-to-reach* regions. These terms are used interchangeably in this study as well. A simple definition of remote area is “An area far away from cities and places where most people live and are therefore difficult to get to” [Collins dictionary] and this definition suffices for the scope of this research.

Our literature review shows that in the studies, the authors do not clearly define remote logistics. However, they suggest a context definition with characteristics that are recurring among them. For example, when studying remote regions, they defined the regions as hard-to-reach or cut-off areas with often dispersed populations and constraints of time and/or distances. Additional difficulties like bad road conditions, difficult terrain and poor transportation infrastructures are present. Sometimes, more challenges are present like large intervals between orders and stock outages due to remoteness. These characteristics will guide this present research and will be included as inclusion criteria for the literature review as we look at remote logistics and possible applications in a real context (North Canada).

Remote logistic decisions include the same ones as in a regular logistic system but with additional complexity. In this present study, we restrict remote logistics to the activities previously presented in the scope of research (Figure 2.1). That means we are looking at location and distribution planning only, for remote contexts.

Location decisions in remote settings present additional challenges. For example, geographical restrictions on where to locate facilities, long-distance planning and in some cases lack of infrastructure to support operations. In remote regions, location and/or allocation problems can be used to improve accessibility by reducing travel time (or distance) to a specific facility by either (re)locating new facilities or services or providing a more efficient allocation of resources.

Distribution decisions in remote contexts usually state additional constraints. For example, the choice of mode of transportation is an important factor because many remote regions have limited route access. Especially in the north, where most of the roads are iced and not paved. The long distance to travel and the often need for multimodal planning. This is where context consideration becomes crucial in decision-making for remote logistics planning.

2.4 Our framework: Linking food insecurity and logistics activities

As it has been said, food security is a concern in multiple fields and recently we can observe a trend among authors that target food security, linked to logistics activities, geographical topics and more. The scoping review on the food sector and indigenous communities by Kenny et al. (2020), states among many contributors to food insecurity, that grocery store inaccessibility has been strongly linked to poor diet. The main barrier to food is geographical access; one study of the review proved that in northern Canada, over 90% of remote communities are serviced by only a single food retailer (Burnett et al., 2017). The grocery store's location is constantly put forward as a contribution to food security because many communities report having to shop outside their reserve, sometimes travelling very long distances (2h round trip) for food (Kenny et al., 2020). The authors also highlight the absence of **available** foods in those grocery stores with limited variety and quantities. Finally, this study provides a list of actions to enhance food accessibility, availability**,** and quality in remote indigenous people. Among the recommendations to improve the food system, they point out the need for improvement in planning the location of grocery stores, locating mobile vendors, improving the food transportation/delivery, appropriate local infrastructures, retail competition and store management practices (Kenny et al., 2020). Other initiatives have been explored like food pricing policies and multi-sector strategies to improve the food-purchasing environment.

In concordance, with the definition of food security provided earlier in Section 1.1, general pillars influencing food security in Arctic Canada were also defined by The Northern Policy Institute as accessibility, availability, supplies/stability, and utilization (Dillabough, 2016).

Power, (2007) used the recurring notions of accessibility and availability regarding food insecurity in Northern Canada specifically. The study proposed a conceptualization of food security for the Aboriginal context and argues that the previous public health definition of food security is not suited for the typic Aboriginal context. The authors urge the importance of taking into consideration the unique characteristics of northern communities when planning food distribution like food harvesting, sharing and consumption that goes above the food security of individual Canadian households. This paper defines the accessibility notion as the reliability to access important traditional food as well as market food. In terms of availability, it is linked to environmental contamination of traditional food and the climate change impact on the ecosystems that affect overall availability, supply, and safety so that the population should be able to access sufficient and safe traditional and market food. The author also argued that the northern context has an even greater impact on these pillars, because of the challenges on traditional food practices, cultural practices, unique geographic and climate restrictions and more.

To better understand the specific contributors to food security, Ford & Beaumier (2011a) proposed a more precise conceptual framework that encompasses the local determinants that contribute to food insecurity in Inuit communities. The authors present a multi-method study of combined interviews and focus groups to identify the elements encountered by families touched by food insecurity. From that, some local determinants are identified like food accessibility, budgeting, food quality, affordability, availability, knowledge, education regarding nutrition and more. Again, there we can find the recurring terms of accessibility and availability.

As we can see, several authors have agreed on several food security pillars. We hence propose that there is a strong link between the concepts of accessibility and availability and the logistics problems of location and distribution decisions that are worth studying. Gregory et al. (2005) defined three relevant dimensions of food insecurity within a food system: food access, food availability and food quality (Figure 2.2). This figure proposes a framework with dynamic interactions between the bio-geophysical and human environment that leads to a food system that supports food security. That system includes interaction between the production, processing, distribution, preparation, and consumption of food. The most interesting part of this article is the link that is made between the main dimensions (food **availability, accessibility**) and the actual key concepts of the logistics field (allocation and distribution).

Figure 2.2 – Elements within a food system by (Gregory et al., 2015)

According to Figure 2.2, the first dimension of a food system is food ***accessibility*** which is defined as the ability of individuals to access adequate resources. Access is linked to concepts of affordability (prices of products and costs of travelling to reach them), allocation (how the resources are assigned in the network), or preference of products (traditional food preferences, fresh foods products or other personal preferences).

Secondly, food ***availability*** refers to assure that sufficient food is in the hands of the population, how to assure that the food logistic network meets the demand, with sufficient production at the source, efficient and equitable distribution, and options of exchange, food sharing and exchange among the population. The authors also include the dimension of food quality as a third influence. However, because the elements influencing food quality (nutritional value, social value, and food security) are apart from our focus on internal logistics management concepts and are more external elements, we will not tackle them. Also, the scope of this research draws the boundaries to the planning of location and distribution activities, the notion of quality is not explored, as well as the other sub-categories within food access and food availability (i.e., affordability, preferences, production, and exchange).

The elements presented above are the leading ground of our conceptual framework, guided by the following question: *What are the main elements of OR/MS and logistics that can contribute to improving food accessibility and availability (i.e. improving food security)?*

Figure 2.3 represents the framework of this study. On the left side, we can see the factors influencing food security proposed by Ford & Beaumier (2011b). Note that the elements of food availability and accessibility have been developed in more detail to include the dimensions proposed earlier in figure 2.2, by Gregory et al. (2005). Then, on the right side are the activities of a logistic system from Ghiani et al. (2013) with clear highlights (in orange) of the scope we will focus on. Finally, our research question and its objective lie at the intersection of these two concepts to solidify and link the theories, for which the systematic literature review will provide a better understanding.

From these studies, we strongly believe that OR/MS and the planning phase activities can be useful tools to increase two factors of food security: 1) Food accessibility and 2) Food availability. To develop our hypothesis, we will review scientific contributions in logistics network planning and see if a such link can be done. More precisely, we will use a systematic literature review (chapter 3) process to review and analyzes the logistical activities of network and distribution planning to establish the link between the two fields of research (health and logistics).

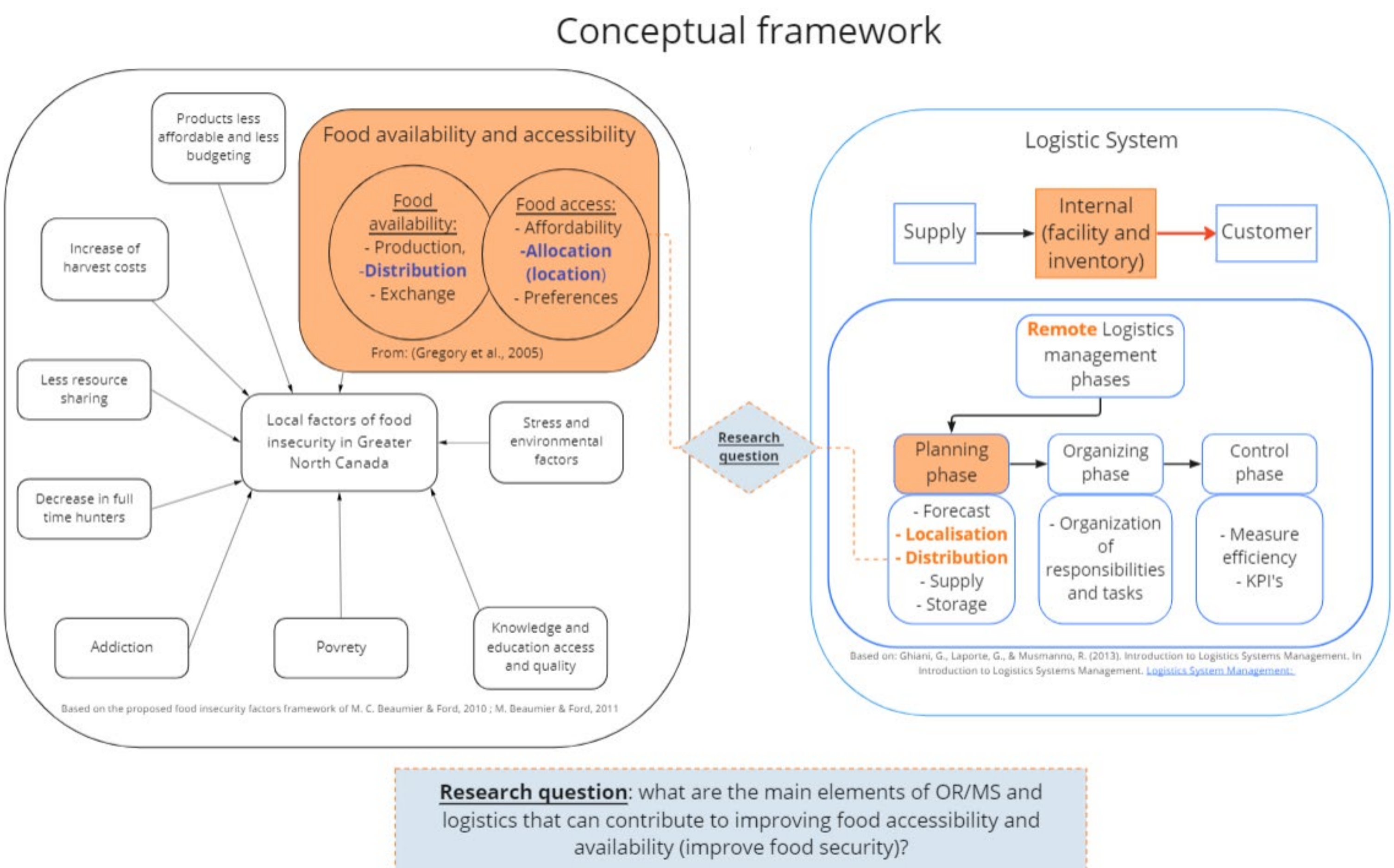


Figure 2.3 - Conceptual framework

CHAPTER 3: SYSTEMATIC LITERATURE REVIEW METHODOLOGY

A systematic literature review is a common methodology traditionally used in medicine and social sciences. It is now being more and more used in the OR/MS field. It is a well-established tool to build frameworks, develop theories and provide insights into certain logistics practices (Durach et al., 2021) and improve the contribution expected from a "traditional" review methodology (Chee Yew Wong, 2021).

As remote logistics is a new concept, it deserves to be reviewed systematically. We chose to do a systematic literature review (SLR) because it is known to be the gold standard among reviews. It provides a thorough, systematic, transparent, and reproducible approach (Snyder, 2019). We used the well-documented approaches and guidelines of (Gough et al., 2017; Snyder, 2019; Tranfield et al., 2003) to be as thorough as possible. However, some may argue that the downsides of a systematic review include bias in the selection of papers due to human selection and or misleading if data are not used properly (Yuan Y & Hunt, 2009). To minimize the bias during this research, we made sure that the screening process was applied to a sample of papers by two members of the research team, independently.

This review follows the good practices also proposed by Durach et al. (2021). The authors proposed four specific ways to synthesize literature in OR/MS field. We position our research as an inductive theory-building approach. Mainly because the process allows us to identify themes, patterns, and relationships as well as an understanding of a topic. The process is iterative and is most suitable for subjects that are in growth and demanding an exploratory picture, like this present review on remote logistics.

This paper will provide a methodological systematic literature review surrounding the location-allocation and the distribution networks currently used in remote areas, with contributions that could be applied to increasing food accessibility and/or availability and improving food security in remote regions. Our SLR follows the general structure proposed by the general framework of (Figure 3.1), by Gough et al. (2017).

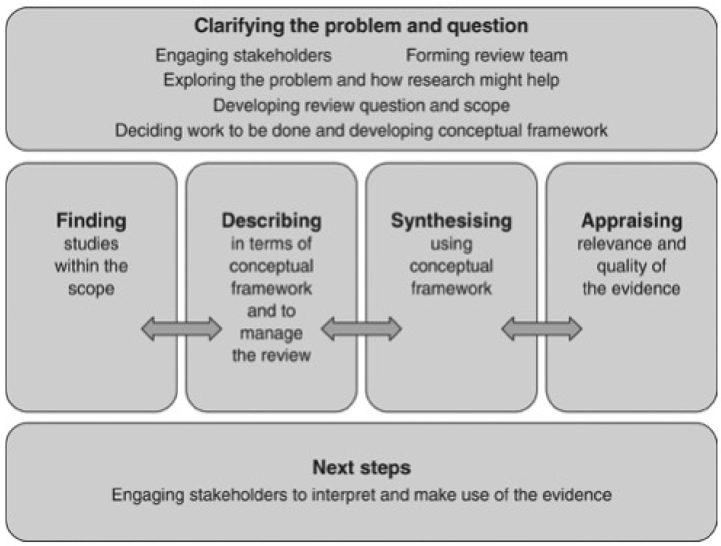


Figure 3.1 - Systematic Literature Review Process

The first step of the review is to clarify the problem, defining the boundaries by exploring the topic and defining how the research can contribute to the field (Section 3.1). Then, we entered the phase of finding the studies to review. This process was iterative and included the definition of search queries, inclusion and exclusion criteria and a thorough screening process (Section 3.2). Finally, the synthesizing and analyzing of the literature was the most time-consuming task, but the main contribution of this paper. This section is included in chapter 4 along with bibliographical information of the papers. The main findings and analytical part of the literature are presented in chapter 5 and the appraising of the reviewed papers will be completed and discussed in chapter 6.

3.1 Clarifying the problem and question

Chapters 1 and 2 prove that food insecurity is a real health crisis and is faced with many challenges. However, we think that the planning activities of logistics management can have a positive impact on the matter, by improving accessibility and availability. Hence, the objective of the literature review is to account for the current evidence-based research in the Operational Research and Management Sciences field for location or distribution problems that are applied to or can be transposable to remote areas. This will allow us to see the general trends that could be applied in the remote regions of Northern Canada to diminish food insecurity.

This objective is threefold:

1. To create a **compilation** of published literature regarding logistics network design and distribution in general remote areas

2. To **analyze and present** the critical findings and current practices about logistics optimization in remote areas

3. To **identify, justify and hence propose** general learnings in the logistics optimization field that could be transposable in the context of remote areas of Northern Canada.

3.2 Finding the studies

Once the research question has been defined and the objective set, the search process is established and then launched. Four distinct steps were followed for finding the studies: i) defining the keywords and search queries, ii) defining the inclusion and exclusion criteria, iii) launching the search in databases, and iv) applying the screening process.

i. Keywords and Search Queries

The search queries were defined based on the following conceptual map (Table 3.1) combining key concepts and words of initial brainstorming. A preliminary search was performed on Scopus testing the initial keywords and exploring grounds. As the first process, we included a concept for keywords of Northern Canada (e.g., Arctic, North Canada, Northern region…). However, this concept generated no results, due to the unexplored topic in logistics. We then had to broaden the search by eliminating some keywords and looking at general remote areas. A total of 14 different queries were generated (Table 3.2). From these, we identified five primary queries (highlighted in yellow) that included most of the identified keywords, with some adjustments to suit each database. The librarian's experience played a crucial role in selecting the final five queries and the fact that some queries generated very limited and sometimes zero results helped us in the selection.

Table 3.1 - Initial Concept Keywords

Concept 1	Concept 2
Supply chain	Remote areas
Supply chain	Remote area*
Supply network*	""Rural area*""
Logistic*	Rural
Supply	Remote
Procurement	
Food procurement	
Cargo	
Shipping	
Delivery	
Order*	
Transport*	
Mode*	
Distribution	
Distribution network*	

Deriving from the above, queries were defined and adapted to the different databases to obtain a broader search. The highlighted queries are the retained ones for conducting the research (Table 3.2).

Table 3.2 - Defined Search Queries

Query #	**Search query generated**
1	(supply OR logistic* OR procurement OR deliver* OR "network design" OR sourcing OR order* OR transport* OR "reverse logistic" OR "last mile" OR distribut*) AND (isolated OR rural* OR remote*) AND NOT("urban transport*" OR "urban traffic" OR "interurban" OR "inventor" OR "information* flow" OR "financial flow")
2	(supply OR logistic* OR procurement OR deliver* OR "network design" OR sourcing OR order* OR transport* OR "reverse logistic" OR "last mile" OR distribut* OR mathematic*) AND (isolated OR rural* OR remote*) AND NOT("urban transport*" OR "urban traffic" OR "interurban" OR "inventor" OR "information* flow" OR "financial flow")
3	("rural network" OR "operational research" OR supply OR logistic* OR "physical distribution" OR procurement OR deliver* OR "network design" OR "mathematical model" OR "routing problem" OR "transportation problem" OR sourcing OR order* OR transport* OR "reverse logistic" OR "last mile" OR distribut* OR humanitarian OR disaster) AND (isolated OR rural* OR remote*) AND NOT("urban transport*" OR "urban traffic" OR "interurban" OR "inventor" OR "information* flow" OR "financial flow")
4	("operational research" OR logistic* OR distribution OR "network design" OR "mathematical model" OR "routing problem" OR "transportation problem" OR transport* OR "reverse logistic" OR humanitarian OR disaster) AND (isolated OR rural* OR "remote region") NOT (data OR tourism OR urban transport OR urban traffic OR interurban OR sustainable OR inventory OR "information flow" OR financial)
5	("rural network" OR "operational research" OR supply OR logistic* OR "physical distribution" OR procurement OR deliver* OR "network design" OR "mathematical model" OR "routing problem" OR "transportation problem" OR sourcing OR order* OR transport* OR "reverse logistic" OR "last mile" OR distribut* OR humanitarian OR disaster) AND (isolated OR rural* OR remote*)
6	(("operational AND research" OR supply OR logistic* OR distribution OR procurement OR deliver* OR "network AND design" OR "mathematical AND model" OR "routing AND problem" OR "transportation AND problem" OR sourcing OR order* OR "reverse AND logistic" OR "last AND mile") AND ((humanitarian OR disaster) OR (isolated OR rural* OR remote*))
7	(("operational AND research" OR supply OR logistic* OR distribution OR procurement OR deliver* OR "network AND design" OR "mathematical AND model" OR "routing AND problem" OR "transportation AND problem" OR sourcing OR order* OR "reverse AND logistic" OR "last AND mile") AND ((humanitarian OR disaster) OR (isolated OR rural* OR remote*))
8	("operational research" OR logistic* OR distribution OR deliver* OR "network design" OR "mathematical model" OR routing OR transport* OR sourcing OR order* OR "reverse logistic" OR "last mile") AND ((humanitarian OR disaster) OR (isolated OR rural* OR remote*))
9	("operational research" OR logistic* OR distribution OR deliver* OR "network design" OR "mathematical model" OR routing OR transport* OR sourcing OR order* OR "reverse logistic" OR "last mile") AND (humanitarian OR disaster OR isolated OR rural* OR remote*)
10	("rural AND network*" OR mathematical OR "physical AND distribution" OR "last AND mile" OR "operational AND research" OR "humanitarian AND logistic" OR "disaster") AND (rural OR underserve* OR remote OR "hard AND to AND reach")
11	{network design} AND {remote area} AND logistic
12	("routing AND planning" OR distribution OR tsp OR algorithm OR transport* OR humanitarian OR emergency OR disaster) AND (remote OR "hard AND to AND reach" OR rural OR isolated
13	(supply OR logistic* OR {physical distribution} OR {network design} OR {mathematical model} OR {routing problem} OR {optimization problem} OR {transportation problem} OR transport* OR {reverse logistic} OR {last mile} OR distribution) AND ({humanitarian logistic} OR "disaster AND planning" OR {emergency response}) AND (isolated OR {rural area} OR {remote area})
14	((routing OR transportation OR {mathematical model} OR optimization OR distrbution) AND ({isolated area} OR {rural area} OR {remote area}))

Three databases were selected to cover the OR/MS and business aspects of our problem and be as effective and exhaustive as possible. First, *Scopus* which is a multidisciplinary database, then *ABI/Inform Global* and *Business Source Complete* which are more business-oriented databases. The three databases complete each other and provide different results and academic journals.

ii. Inclusion and exclusion criteria

Once the previous queries were launched in the databases, the screening process starts to select the papers included in the review. Therefore, it is necessary to define a clear set of inclusion and exclusion criteria (I&E). To select a study for the review, it must satisfy all the inclusion criteria and none of the exclusion criteria. The inclusion and exclusion criteria need to be clear and precise to facilitate the screening. This review was limited to a 10-year time frame, to focus on a first instance on the most recent studies and the current practices, as this is a new emergent topic in literature. Is is targetting academic and reviewed publications only (in English), to insure we had peer-reviewed publications and elimitate conference papers.

Then, in terms of the topic of research, we allowed papers that were not exclusive to the OR/MS field but needed to include an optimization model. Topics like the design or network structure, planning of supply or physical distribution of products, location problems, and transportation and routing problems are great examples. It could include applications related to the industry, healthcare, humanitarian/disaster, geography, the public sector, and others.

Moreover, the papers need to correspond to specific remote context characteristics that are either applied to or transposable to remote areas. Because of the lack of a generally agreed definition for remote logistics, we looked at another closely related domain to inspire our definition and suitable characteristics. One of the most recurring domains across our search results is applications in humanitarian logistics.

That is: « [Humanitarian Logistics] is the efficient and cost-effective planning, implementation and control of the flow and storage of goods/materials and the related information from the point of origin to the point of destination to alleviate **the suffering of vulnerable people** » (Thomas & Kopczak, 2005). We think that the definition of humanitarian logistics by these authors sets a great parallel and can be transposed to the food security crisis in a remote context because they share the same purpose. We hence analyzed common features in humanitarian logistics and propose in Table 3.3 a parallel of key characteristics proposed in the literature between the humanitarian and the remote logistics context.

Table 3.3 - Humanitarian and remote logistics parallel

Characteristics	*Humanitarian logistics*	*Remote logistics*
Hard-to-reach regions	Destruction of roads	Long distance, geographical restrictions
Lack of infrastructures	Damaged or improper access to infrastructure	Inadequate or lack of infrastructure
Lack of resources	Emergency supplies	Infrequent deliveries, expensive end products
Dispersed population	Evacuation and refugees	Distant communities over vast territories
Social aspects	Suffering and injury/deaths	Equity among people
Dynamicity of the problem	Unpredictable demand, uncertainty in nature	Seasons and weather reliant

*Inspired by Nikbakhsh & Zanjirani Farahani (2011).

Among the six aspects in the context of humanitarian logistics, we believe that four of them are the main aspects that define a remote logistics setting and are the most aligned with the context of northern Canada presented in Chapter 1. The four key aspects of our context are a hard-to-reach region, high transportation costs, poor or non-existing infrastructure, and high geographical dispersion. Table 3.4 extend on the four characteristics of remote regions and how they are defined as inclusion criteria for this research. A paper needs to mention, relate or approach *at least one* of them. As we started from a context definition based on the Canadian North, we want our literature to be transposable to such context.

Table 3.4 - Remote characteristics

1. **Hard-to-reach regions or underserved areas (remote):** a paper will fit in this category either if it is explicitly qualified as remote or if it is perceived as hard to reach. The hard-to-reach aspect can be because of distance, geographical difficulties (steep mountains, gravel roads etc.) or seen as underserved because of poverty, humanitarian disaster or other limiting factors.
2. **High cost of transportation or products:** this refers to the higher-than-average logistical costs related to transportation or delivery. Specifically, the high costs associated with long-distance or long-haul travel.
3. **Poor or non-existent infrastructures:** this is the lack of general transport infrastructures. It can be poor, damaged, or non-existent roads, rail tracks, port or airport related.
4. **Geographical dispersion:** this involves the spatial arrangement in a large, vast region with few populations or that a great distance separates one another. It can also include dispersed suppliers.

As for the exclusion criteria, a paper was automatically rejected if it was under another logistical activity than planning for location network or distribution (reminder of activities in Figure 2.1). Also, contexts like urban logistics or rail planning were rejected because of the lack of similarities to our remote definition. For example, we also exclude papers related to inventory management, information or financial flow, the internet of things and other literature reviews.

The following I&E criteria were validated and tested over a set of four preliminary papers that were known to be pertinent to our search from known authors (Anaya-Arenas et al., 2018; Anuar et al., 2021; Cherkesly et al., 2019; Dufour et al., 2018). This allowed us to validate the I&E criteria, our comprehension and application of them, to ensure that the selected papers will fulfill the objective of the review. From these preliminary papers, three were retained and respected our inclusion criteria and one was eliminated because it was a literature review/survey (Anuar et al., 2021).

We are aware that there are some interesting projects and documentation in the grey literature, but we wanted to evaluate the OR/MS contribution in a first instance and limit ourselves to the practical aspects. Even though several government reports and white papers, issued from the grey literature, were used for the context definition, the search for the SLR was limited to scientific papers only.

Table 3.5 - Inclusion and exclusion criteria applied (I&E)

<table>
<tr><th>Inclusion criteria</th><th>Exclusion criteria</th></tr>
<tr><td>- 10-year time frame
- Academic publication
- Peer reviewed
- English
- Must include a logistic decision-making problem (location, allocation, network design, transportation) tackled by OR/MS techniques (mathematical programming, simulation etc.)</td><td rowspan="2">⊗ Urban transportation
⊗ Inter-urban logistics
⊗ Rail planification
⊗ Inventory management only
⊗ Information or financial flow
⊗ IoT application
⊗ Literature reviews
⊗ And all other activities of OR/MS that do not apply to the definition of the problem</td></tr>
<tr><td>At least one of these criteria must also apply:

- Design or network structure
- Planning of supply, transportation, or distribution problems
- Delivery planning
- Location-allocation problems
- Return or reverse logistics
- As much for inbound or outbound
- Single or multi-echelon
- Either inbound or outbound flow

The above must also have at least one transposable characteristic of remote in North Canada previously defined

1. Hard to reach or remote region
2. High costs of transportation (reflected on the product)
3. Lack of infrastructures
4. Dispersed population</td></tr>
</table>

iii. Launching the search

After the initial search on our sample of four papers and the I&E validated, the search was launched in full, in all three databases with our five queries. All searches were documented in a very thorough Excel table. Each of the three queries was launched in each database (3) for a total of 10 search queries plus an exploratory search independently in Scopus, all between 01/08/2021 and 08/11/2021. The search provided a total of 3738 results to screen. The following Table 3.6 shows the queries launched and the results obtained.

iv. Screening process and coding

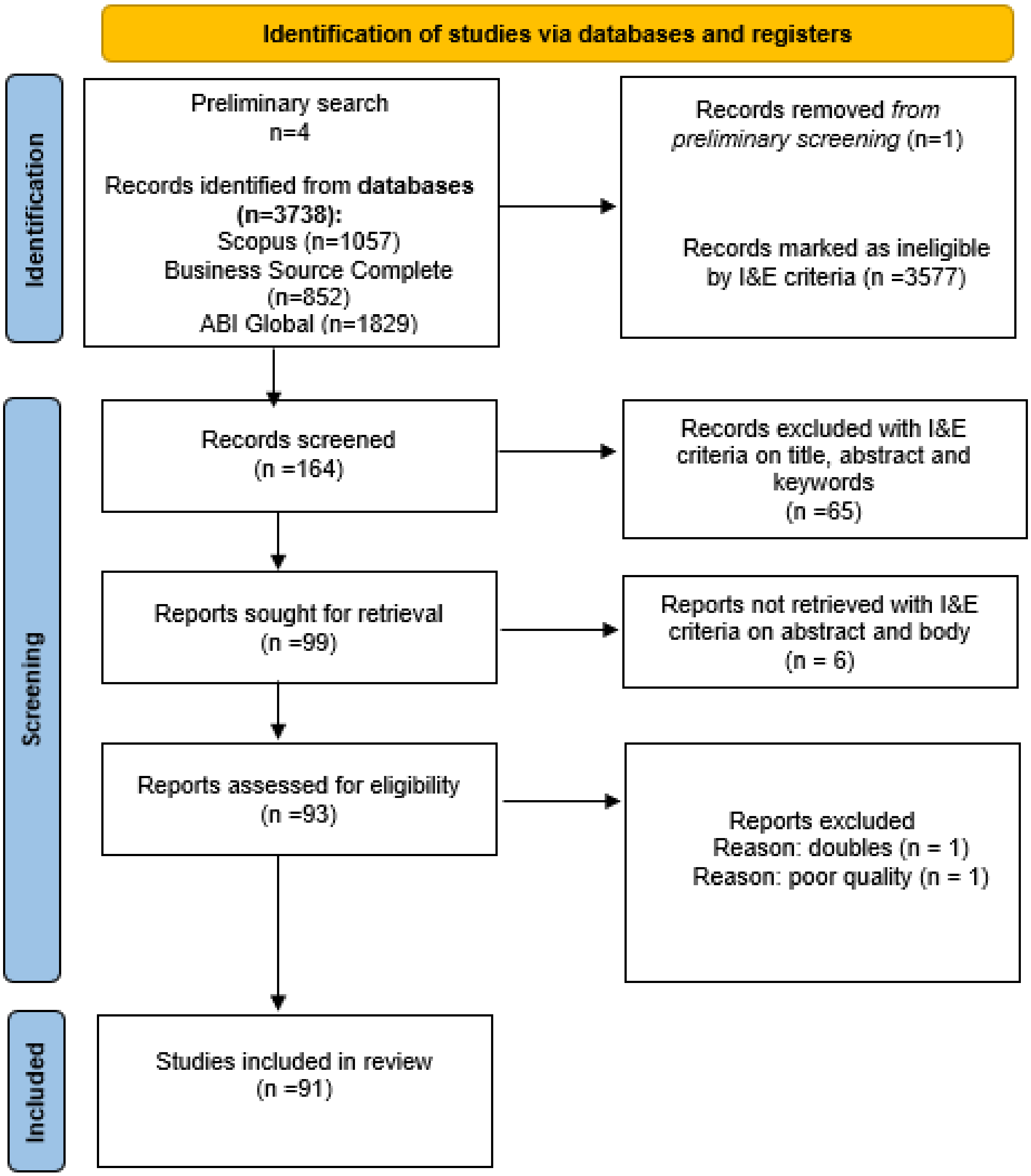
The screening process was applied multiple times at different degrees. Initially, our literature was composed of four preliminary papers in addition to the queries. Once the process was validated and tested on a sample, the full search queries produced 3738 results over 3 databases.

The first time a query was launched, the inclusion and exclusion criteria were applied only to the title and keywords as quick screening (n=3738), which led to 164 potential papers. We retained papers that had words such as "location planning", "Distribution of emergency supplies", and "Optimization of hub selection or coverage" and eliminated those such as "Evaluate rural fatalities", "Optimization of reinforced composite in rural construction", ''Diet in the rural region'', "E-commerce", "Smart farming" and/or ''Energy supply''. Then, those retained papers (n=164) were screened for a second time with the same criteria extended now to title, abstract and keywords (when available). This left us with 99 papers to screen in depth. This third screening stage was extended to the body of literature (main sections: problem definition, methodology, resolution method, conclusion) and allowed us to validate both the objective of the paper, the fact that an optimization model was proposed and the context that can be applied or transpose to a remote region. We eliminated the papers that covered the systemic literature review, urban context, rail planification and any other exclusion criteria that were missed in the first screening due to the prior application only on title and abstract. This process reduced the retained articles to 91, with the elimination of one double and one for poor quality. To illustrate the screening process, a PRISMA Flow Diagram is used in Figure 3.2.

Table 3.6 - Screening Process Tracking (search resultls)

Search #	Query ID	Title / search query	Date searched	Database	Results number
1	2	(supply OR logistic* OR procurement OR deliver* OR "network design" OR sourcing OR order* OR transport* OR "reverse logistic" OR "last mile" OR distribut* OR mathematic*) AND (isolated OR rural* OR remote*) AND NOT("urban transport*" OR "urban traffic" OR "interurban" OR "inventor" OR "information* flow" OR "financial flow")	05-08-2021	Scopus	416
2	3	("rural network" OR "operational research" OR supply OR logistic* OR "physical distribution" OR procurement OR deliver* OR "network design" OR "mathematical model" OR "routing problem" OR "transportation problem" OR sourcing OR order* OR transport* OR "reverse logistic" OR "last mile" OR distribut* OR humanitarian OR disaster) AND (isolated OR rural* OR remote*) AND NOT("urban transport*" OR "urban traffic" OR "interurban" OR "inventor" OR "information* flow" OR "financial flow")	12-10-2021	Scopus	1
3	4	("operational research" OR logistic* OR distribution OR "network design" OR "mathematical model" OR "routing problem" OR "transportation problem" OR transport* OR "reverse logistic" OR humanitarian OR disaster) AND (isolated OR rural* OR "remote region") NOT (data OR tourism OR urban transport OR urban traffic OR interurban OR sustainable OR inventory OR "information flow" OR financial)	08-11-2021	ABI/inform Global	867
4	13	(supply OR logistic* OR {physical distribution} OR {network design} OR {mathematical model} OR {routing problem} OR {optimization problem} OR {transportation problem} OR transport* OR {reverse logistic} OR {last mile} OR distribution) AND ({humanitarian logistic} OR "disaster AND planning" OR {emergency response}) AND (isolated OR {rural area} OR {remote area})	12-10-2021	Scopus	52
5	14	((routing OR transportation OR {mathematical model} OR optimization OR distrbution) AND ({isolated area} OR {rural area} OR {remote area}))	12-10-2021	Scopus	588
6	13	(supply OR logistic* OR "physical distribution" OR "network design" OR "mathematical model" OR "routing problem" OR "optimization problem" OR "transportation problem" OR transport* OR "reverse logistic" OR "last mile" OR distribution) AND (("humanitarian logistic" OR "disaster" OR "emergency response") AND (isolated OR "rural area" OR "remote area")	29-11-2021	ABI/inform Global	286
7	14	((routing OR transportation OR "mathematical model" OR optimization) AND ("isolated area" OR "rural area" OR "remote area"))	29-11-2021	ABI/inform Global	676
8	3	("rural network" OR "operational research" OR supply OR logistic* OR "physical distribution" OR procurement OR deliver* OR "network design" OR "mathematical model" OR "routing problem" OR "transportation problem" OR sourcing OR order* OR transport* OR "reverse logistic" OR "last mile" OR distribut* OR humanitarian OR disaster) AND (isolated OR rural* OR remote*) AND NOT("urban transport*" OR "urban traffic" OR "interurban" OR "inventor" OR "information* flow" OR "financial flow")	13-10-2021	Business Source Complete	447
9	13	(supply OR logistic* OR {physical distribution} OR {network design} OR {mathematical model} OR {routing problem} OR {optimization problem} OR {transportation problem} OR transport* OR {reverse logistic} OR {last mile} OR distribution) AND ({humanitarian logistic} OR "disaster AND planning" OR {emergency response}) AND (isolated OR {rural area} OR {remote area})	08-11-2021	Business Source Complete	13
10	14	((routing OR transportation OR {mathematical model} OR optimization OR distribution) AND ({isolated area} OR {rural area} OR {remote area}))	08-11-2021	Business Source Complete	392
TOTAL					**3 738**

Figure 3.2 - PRISMA Flow Diagram



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

One interesting finding during the screening process was the misleading titles of some articles for our scope of research. For example, during the third screening some papers still made it through the process because of titles like "GIS and Optimization: Potential Benefits for Emergency Facility Location in Humanitarian Logistics" (Rodríguez-Espíndola et al., 2016). Now this paper was a priori very promising, but when looking at the whole body and main contribution, it was out of our scope. The authors use geographic cartography modelling, which is very technical, and geoscience based, which is hard for us to comment on the topic. Therefore, it didn't have an OR/MS model or tool that was used for the contribution, and it was excluded. Other articles like Rau & Vega (2012) included the notion of accessibility in a specific way as a ratio measure between supply and demand location points. However, they didn't fit with the I&E criteria defined because there is no logistical contribution to the paper, so they had to be excluded as well. Other authors Tomek & Liburd (2020) skipped our first and second screenings because of the title "Sustainable Accessibility in rural destination: a public transport network approach". However, when reading in full, the contribution is specifically done in the field of public transportation planning. In the end, we ended up excluding six papers that originally failed the process because of the criteria being only applied to the title, abstract and keyword. The results among different domains and technicality prove just how pluri-disciplinary these terms can be and how often they are used interchangeably among domains (e.g., accessibility, optimization, network).

Now that all the papers are screened there are 91 articles left that fit all the inclusion and exclusion criteria. To manage all the information and data contained in these articles, a classification and coding system was put in place (the following Figure 3.3). Additionally, Appendix E presents examples of these files. For each paper, the following coding process was applied. First, a synthesis file was created to aggregate the information of the paper to have all the information in one place and to quickly navigate through them. Secondly, a mathematical model data file was created, collecting in a specific way the main aspects of the optimization model proposed in the paper (objective function, specific constraints). Finally, an Excel file was created, coding the specifics of each contribution (example in Appendix E). The details of coding are explained in the next section.

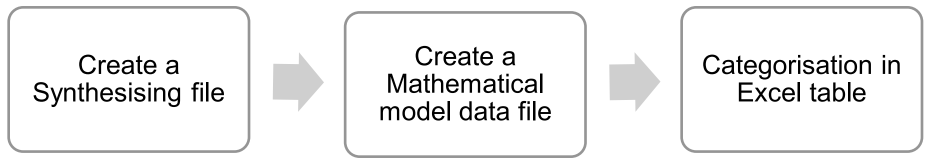


Figure 3.3 - Coding system

3.3 Categories and classification

The 91 papers were classified in a table and many categories were defined to extract as much information as possible. A total of 15 categories were analyzed. The first category refers to the bibliographical data of the paper (i.e., year and publishing journal, the journal's discipline, country of authors, etc.). The second main category involves the type of logistic problem (i.e., network planning, distribution planning or other related). In addition, we analyzed the context of the application or the field of the contribution (humanitarian, healthcare, or industrial logistics) and the relevant characteristics, like the type of networks, number of echelons and number of entities. Another category was different between the objective functions of the model and the type of constraints applied (categories, units of constraints, etc.). Finally, the papers were also coded according to the resolution method (i.e., heuristic approach or exact method) and the instances solved (case study or artificial data instances)

The categories are the base of the synthesis of the literature in the following chapters. They're the leading thread of our analysis. Chapter 4 presents the general trends of the retrieved literature, including bibliographical information and common categories to all papers. Then, chapter 5 is the main findings and the analysis of the literature. This section is divided into three main themes: 5.1 Accessibility and location problems, 5.2 Availability in terms of distribution planning and 5.3 Combined location-distribution problems in remote regions.

CHAPTER 4: GENERAL TRENDS

General trends can be observed in terms of published literature in remote areas. This section presents the bibliographical findings (i.e., year of publication, country studied…), problem categories and general characteristics.

4.1 Bibliographical findings

As we can see in the following figure, the topic of logistics in rural regions is in constant growth since 2011. Ranging from three to six publications a year between 2011-2017, a considerable increase is noted in 2018 with 16 papers published. Since then, the annual research has been around 12-18 papers a year, which is more than double the yearly publications on the topic of remote logistics.

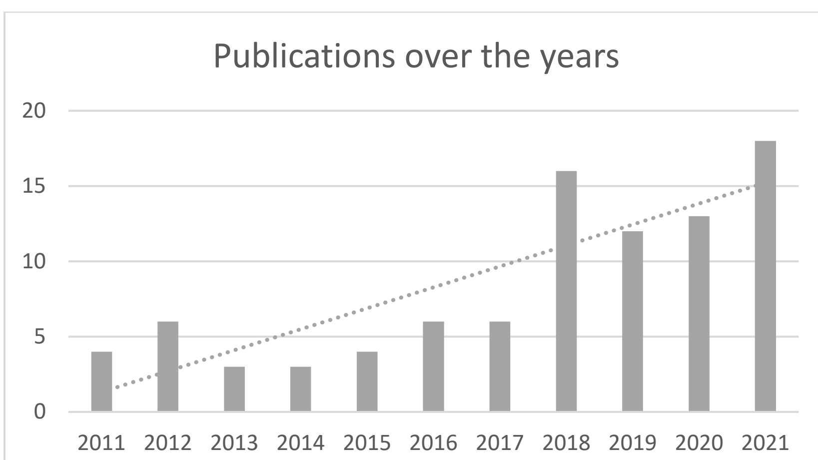


Figure 4.1 - Year of published papers

However, the domain of application of the studies varies and is more prominent in the healthcare branch. As for the distribution of the journal discipline, most of the papers studied here are in the OR/MS field. The following Figure 4.2 shows the discipline of journals in which the papers were published.

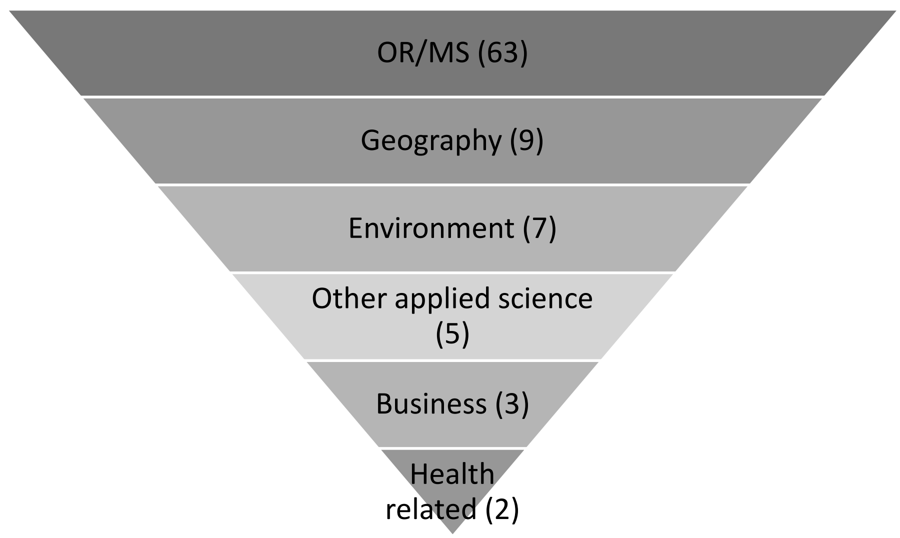


Figure 4.2 - Discipline of journals

Whereas the author's affiliation is mainly to the United States (22%) and China (18%), the rest is varying between 30 other countries.

We also observed that 79% of the contribution was tested over a real case study and only 21% of the papers used artificial data to test their model. Moreover, the region or country studied in the case study was computed, finding that 12% of the papers are applied to a real case in the United States and 9% in China. The remaining were applied to over 33 countries. Instinctively, when thinking of remote regions, we often think of extreme places like Greenland, Alaska, northernmost Canada, Australia, or remote regions in Africa or Latin America. However, the results of our literature review showed that the application or case study of the papers is more concentrated around either The United States, Europe, and Asia (which ironically are among the largest economies in the world).

Two reasons can explain this finding. First, we are studying a new topic in academia, which means that logistics in remote areas and the definition we attributed to it in terms of remoteness more specific to the North, is poorly documented. Secondly, to compensate for this issue, we looked at similar problems that are more documented, which as humanitarian logistics. Also, according to Wallemacq (2018), natural disasters occur more often in Asia than in others which is why authors are more prone to study humanitarian logistics in these locations.

The following Figure 4.3 illustrates the distribution of literature around the world in terms of the country studied. The red pins show the concentration of countries' studies, where between 4-11 papers were published. Among them, we count study cases from the United States (11), China (8), Iran (5) and Turkey (4). The pink pins represent the countries where only 2-3 papers studied the region (Taiwan, Chile, Canada, Germany etc.). Over 35 countries were studied in the literature, and 17 countries had only one publication for their specific country – not shown on the map.

Figure 4.3 - Country studied in the literature

Finally, Figure 4.5 demonstrates the continents being generally known to be the most at risk for disaster (Asia, Middle East, and South America). In fact, among these prone-to-disaster continents, we found that the most studied continents in terms of logistics in remote areas (according to our criteria) were also Asia, the Middle East and America. That is to be expected because we included in the definition of remote areas in the characteristic keywords like cut-off regions or services caused by a disaster event. That reflects well our findings mostly in humanitarian applications.

Figure 4.4 - Location prone to disasters follows the trend of publications studied in remote logistics (source: [Which country has the worst geographical disadvantage? - Quora](#))

4.2 Problem type and characteristics

All papers selected were read in-depth and analyzed. According to our review objective and the inclusion/exclusion criteria defined earlier, we were able to identify eight main categories to classify the literature within two main axes:

1) Type of logistic problems

We decided to classify first, the main group of papers according to the logistic problem studied as it has distinguished decision structure and temporal length and to align our analysis process to the principles of accessibility and availability. In terms of a logistical problem, there are two main categories identified: network planning and distribution planning.

On one side, network planning is a broader term that encompasses location planning and allocation decisions. These problems take decisions on the structure of the logistic network itself: where to locate, how many facilities to locate, the size of the network, how to assign clients or beneficiaries to the service facilities, and so on, to improve the access to the service or product of interest. On the other side, distribution planning focuses on the routing and transportation among the networks, how to assure that the products will be available to customers (or users) in an efficient and fast way, linking the distribution problems to the notion of availability. It covers an analysis of capacity, transportation mode, distribution time, and more.

The two logistic problems type differ not only in terms of decisions but also in terms of problem characteristics and constraints. These fundamental differences are why they deserve to be analyzed in separate categories (i.e., location problems vs routing problems). Most papers studied location planning problems (46%) with a close second for distribution problems (38%).

Finally, it is not rare that the two types of problems (location and routing) are combined, and we found more than 15% of papers that covers an integrated problem. Integrated decisions are a more realistic representation of a supply chain. We can think for example of a classical network design (i.e., fixed-cost transportation problem) (Contreras & Fernández, 2012). It is nowadays argued that the decisions of location and distribution cannot be made independently. An important contribution of (Maranzana, 1964) made this statement clear proving that “ignoring transportation costs when making location decisions may lead to suboptimal solutions for a system as a whole” (Saldanha-da-Gama, 2022).

2) Application context

Inside each logistical problem, we were able to identify and group papers by the application field they covered, namely: if the problem solves an industrial or public sector case, a healthcare logistic problem or a humanitarian case. Note that industrial and public sector field was combined due to the lack of papers in it and the similarities among the domain (similar problem definition, constraints etc.), compared to healthcare and humanitarian where the context differs with a sense of urgency, death tolls, equity notion, non-profits organizations etc.

The application context is also rooted in the particularities of the contribution and how it can be extended or applied to the remote logistics context for food security. Meaning that the context of application can be broad, but if it shares some transposable contribution (presented in our I&E criteria), it can be useful for us. For example, the distribution in the humanitarian context (rescue equipment) shares the characteristic of high-weight, high-volume products that could be compared to food products of the same size. So far, it doesn't matter so much in what field of application the contribution was made, as long as it shares some transposable characteristics that come from our inclusion criteria of Table 3.4.

The overall portion of literature tackling an industrial/public sector topic represents (33%) of the review. The decisions in these settings are often under a deterministic environment with straightforward constraints. In this group, papers often link the decisions with the notion of accessibility and availability in terms of the distance to travel (for example: how many schools to locate, location-allocation for recycling programs etc.). The aim is to increase service in a stable environment. Contrarily, when looking at humanitarian applications (47% of all contributions), the notion of urgency becomes more dominant in the model (e.g., death tolls measure, suffering measure) and contributions usually aim at diminishing the suffering after a disaster or bringing survival kits fast for survival. The accessibility and availability are hence disrupted by the said disaster, and it became interesting that contributions reflect this challenge in the constraints of the model like infrastructures damages, blocked roads, and increased demand, but rarely in the objective function. Finally, the healthcare application represents a small portion of the literature (20%) but couldn't be ignored. The decisions of medication deliveries and mobile clinics are some examples that are interesting to see for remote areas because of the increased challenge of the long distance between the point of service. Our results showed that the healthcare contributions are the ones that had a clearer and more accurate representation of the remote challenges (as we understand it in the context of food security). For instance, remote challenges are strictly due to the geographic areas, long travel time, difficulty of access and/or lack of infrastructure. In contrast to the humanitarian field where these components are in majority and only present when a disaster occurs, and not in the normal course of activities (temporary location decisions). In healthcare in remote areas settings, authors often model their objective as a coverage notion with time limits. This reflects well with our context of the north when we want to bring as much food as possible to everyone with time restriction for food spoilage. Munir et al. (2020) presented agent-based modelling to improve point of health coverage under a location-allocation model. They stated as the objective "Healthcare for all" is an integral mandate to achieve social equity, how about we translate it to "Food for all" as part of this study?

Hence, we can see that the literature needs to be classified according to its type of logistical problem but also by the domain of application because of the different types of decisions that are taken in each subcategory. Also, most of the data used in the studies were real data from a case study, which is interesting if we want to look at practical applications. The following Table 4.1 summarizes the authors by type of problems and domain of application.

These two axes will be the leading thread for the analysis section. Moreover, our analysis will relate the streams to the notion of food accessibility and availability as the framework proposed. The following chapter will go into the specifics of each category identified in the literature and their characteristics and identify the main trends among the researchers.

Table 4.1 – Papers by axes: type of problem and domain of application

91	Location planning (42)	Distribution planning (35)	Combined location distribution (14)
Industrial and public sector (30)	(Araya-Cordova et al., 2021), (Araya F. et al., 2012), (Amarilies et al., 2020), (Anwar et al., 2018), (Chen Y. et al., 2021), (Dharmadhikari & Farahmand, 2019), (Frank et al., 2021), (Grubesic et al., 2013), (Mejía et al., 2021), (Pan et al., 2020), (Schlogl et al., 2019), (Shreshta et al., 2014), (Tîtu et al., 2015) (Vazifeh et al., 2021) **N=14**	(Cooper et al., 2021), (Es Yurek & Ozmutlu, 2018), (Feng, 2020), (H. Chen et al., 2018), (Liu, 2020), (Miranda et al., 2015), (Molenbruch et al., 2021), (Munawar et al., 2021), (Pacheco et al., 2013), (Rabbani et al., 2016), (X. Jiang et al., 2014), (Xu et al., 2020), (Yang et al., 2020) **N=13**	(Cubillos & Wøhlk, 2021), (Gu & Wallace, 2021), (Mommens et al., 2021) **N=3**
Healthcare (18)	(Berg et al., 2019), (Bo-Cheng et al., 2016), (Chaovalitwongse et al., 2017), (EunSu Lee, 2021, (Jánošíková et al., 2021), (Klein et al., 2020), (Luo et al., 2017), (Mosayebi et al., 2020), (Munir et al., 2020), (Reuter-Oppermann et al., 2019), (Thorsen & McGarvey, 2018), (Van Barneveld et al., 2018), **N=12**	(Clarke et al., 2017), (Gupta, 2017), (Parvin Hoda et al., 2018), (Salman et al., 2021) **N=4**	(Cherkesly et al., 2019), (VonAchen et al., 2016) **N=2**

Humanitarian (43)	(Anaya-Arenas et al., 2018), (A. Y. Chen & Yu, 2016), (Bozorgi-Amiri et al., 2012), (Campbell & Jones, 2011), (Chauhan et al., 2019), (Dufour et al., 2017), (Geng et al., 2021), (Görmez et al., 2011), (Hong et al., 2012), (Khayal et al., 2015), (Loree & Aros-Vera, 2018), (Pochan et al., 2020), (Rawls et al., 2012), (Rezapour et al., 2018), (Saeidan et al., 2018), (Zhang J.H. et al., 2012) **N=16**	(Baidya et al., 2019), (Chowdhury et al., 2018), (Escribano Macias et al., 2020a), (Ferrer et al., 2018), (Gao et al., 2020), (Holguin-Veras et al., 2013), (Jiang J. et al., 2017), (Kasaei et Salman, 2016), (Khare et al., 2021), (Maghfiroh et al., 2018), (Nadi et al. 2017), (Nagasawa et al., 2021), (Park et al., 2018), (Rabta et al., 2018), (Shin et al., 2019), (Sopha et al., 2019), (Xavier et al., 2021), (Zhang G. et al., 2021) **N = 18**	(Afshar & Haghani, 2012), (Alinaghian & Goli, 2017), (Davis et al., 2014), (Davoodi & Goli, 2019), (Han et al.,2011), (Escribano Macias, et al., 2020b), (Pérez-Rodríguez & Holguín-Veras, 2016), (Tirkolaee et al., 2020), (Y. H. Lin et al., 2012) **N=9**

CHAPTER 5: FINDINGS ON REMOTE LOGISTICS IN OR/MS

This chapter presents the first results of the literature analysis. As explained before, our results could be organized into nine main groups, according to the axis of the logistic problem and application field (Table 4.1). This chapter will present the main findings of the contributions of each one of the nine groups. We will first analyze the results of the three application fields in the location-allocation problems, as contributions to accessibility measures (Section 5.1). Afterwards, we will look at how network utilization can improve food availability in the distribution model (Section 5.2) and this in the three subcategories of the application field as well. Finally, section 5.3 presents combined location-distribution problems in remote regions and goes over problems that have integrated decisions (location, routing and/or other logistics problems). As a reminder, the remote logistic scope is extended to keywords that share characteristics like regions considered ‘’Hard-to-reach’’ by context definition, ‘’Difficult to access’’ often due to infrastructure destruction (followed by a disaster), ‘’Long distance’’ or ‘’Dispersed population’’ because of the distance between the point of interests. Generally speaking, in our research, the domain of application of industrial, public sector and healthcare do define the area of study as remote itself. However, when it comes to the humanitarian sector, the notion is more ambiguous for us. We decided to include humanitarian contexts because they share remote characteristics (Table 3.3), especially with accessibility features (destruction of roads, impossible to reach an area, lack of adequate infrastructures etc.)

Each contribution of the review was analyzed in depth, according to the code defined in Section 3.3. The goal of the coding process was to extract as much information as possible to determine possible links between contributions. In each section, and subsection, the main findings of our analysis will be presented, and the relevant characteristics of each contribution are summarized in a table at the end of each group.

Regardless of the group, the following six keys and general characteristics are reported in a table:

1) **Data Modelling is** used to reflect if the authors consider a problem with data under a deterministic or a stochastic environment.
2) **Problem Characteristics** refer to sub-elements of the modelling approach like the Objective Function proposed (minimization, maximization or multi), what is included in that function (element of costs, distance, coverage etc.), as well as if there is a capacity limit to the model or the type of constraints modelled (quantity, size, number of locations, etc.).
3) **The type of Product** in the study case will show the flow that is modelled in each contribution (people, relief packages, medicine, general goods etc.).
4) **Resolution Method** will show how the optimization problem is solved (either with an exact algorithm, with a heuristic or with only the commercial solver).
5) **Tested Over** will show if the authors used real collected data (e.g., past disaster data, current data from a region) or artificial data.
6) **Size instances** will report the characteristics of the hardest instance that was solved, to evaluate the extent of the study case and the network studied and its potential application to other cases.

5. What do the terms accessibility and availability refer to in terms of OR/MS?

Accessibility and availability are essential concepts in OR/MS. This research seeks to explore the connection and their relevance to location and distribution problems. Each concept is explored by these concepts, but also by their domain of application (either industrial, healthcare or humanitarian).

5.1 Accessibility in remote regions and location problems

Accessibility is measured by the possibility of access to geographic proximity. Statistics Canada defines remoteness accessibility in remote communities as the proximity to all population centers that can be reached within a reasonable amount of time, set as 150 minutes for Canada (Alasia et al., 2017). It is also an important and recurring notion when it comes to remote logistics. Our search results show that this subject is usually sought after in location decisions. Indeed, over the years, some accessibility measures have been developed by authors in OR/MS field and applied in different contributions to network planning and facility location problems. It can be defined as the indication of ease in reaching certain relevant opportunities; like a service or purchased goods, measured by travel time, and weighted by the attractiveness of the opportunity (Frank et al., 2021). It can be measured by the maximum required distance or time to reach or get a service. We can see how the concept of accessibility translates into location-allocation problems when the objectives often minimize total travel time, total distance to travel and the spatial interactions among the entities of networks. The definition of accessibility remains the same whether in a remote context or not, it reflects the challenges of access to a certain point of service often explained by the location being too far or too hard to reach.

Therefore, location problems can be formulated as optimization problems in the literature they represented 45% of the papers. Those problems present generally, key decisions to be made in the number of facilities, modelling environment, homogeneity of commodity, number of echelons, interactions between facilities etc. Elements that can contribute to increased accessibility among a network.

Our search results show an increase in the overall literature for location planning in remote areas all domains of application combined. Figure 5.1 illustrates the evolution of location/network planning research in hard-to-reach regions over the years. A couple of publications were made in early 2011-2012 (3-4) with a drop in 2013 and 2014. After 2017 we see a big increase and constant growth in publications jumping from 1 publication in 2017 to 8 in 2021. A big increase means location planning in a remote area is developing. This aligns with the current trend seen in general location problems, which has had a strong development over the past 10 years due to the increase of new technology, a fast economy and an increased in environmental issues (Saldanha-da-Gama, 2022).

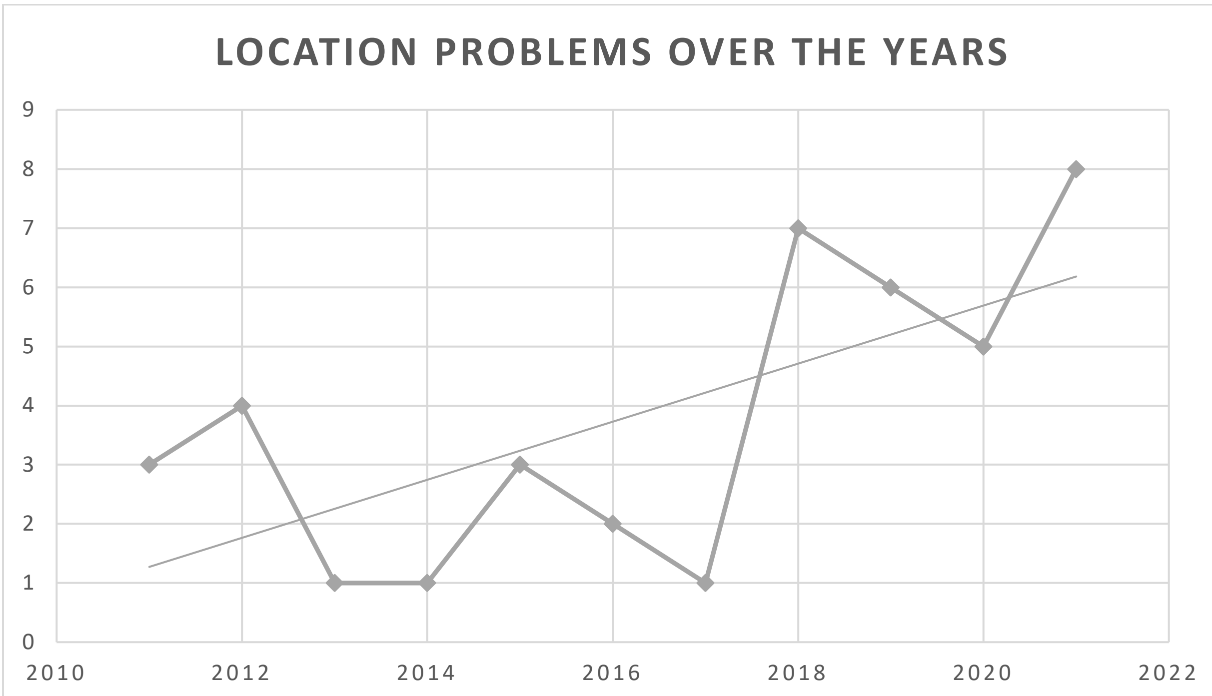


Figure 5.1 - Evolution of Network Planning over the years

When looking at the evolution of literature not only by year of publication but by the domain of application (industrial and public sector, healthcare, humanitarian) in Figure 5.2, we can see that the Industrial sector has seen an increase in literature since 2017 (orange line). This domain of application ranged between 0-1 publication a year since 2011, jumping to 5 publications in 2021. That could potentially be linked to the increased interest of companies to exploit resources in remote regions and explore more optimal network planning in those regions. As for the healthcare field (yellow line), the growth is more constant and stable, but our results showed publications only after 2014, with an increase ranging between one to three publications a year since then. For the humanitarian domain of application (green line), the trend is more sporadic. A big portion of literature (3) in 2011, and 2012, followed by a drop between 2013-2017 and regrowth in 2018 with 4 publications, with a final drop in 2020-2021.

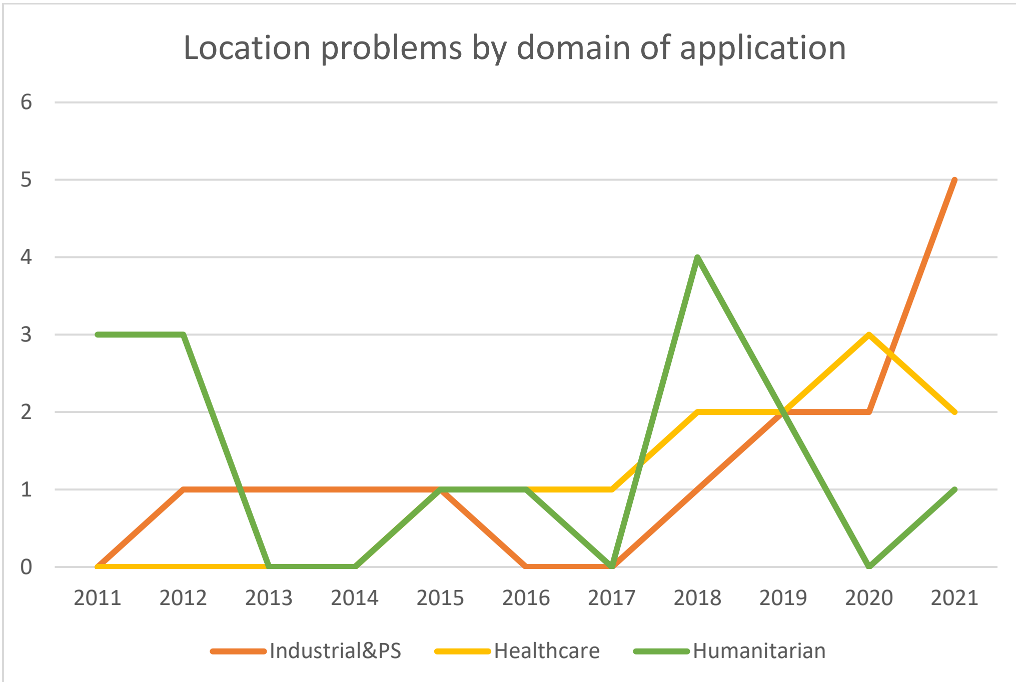


Figure 5.2 -Publication by domain of application (location problems)

5.1.1 Location problems in industrial and public sectors

As mentioned earlier, the category of industrial and public sector is combined because of the similarities in the objectives (Min costs) and problem definition (deterministic environment). Among the 14 papers on location planning in the industrial and public sectors, only five of them were purely for industry settings (Dharmadhikari & Farahmand, 2019; Mejia et al., 2021; Titu et al., 2015; Vazifeh et al., 2021; Pan et al., 2020) and were all revolving around food products.

Moreover, half of the papers propose a classic single-echelon network (only one link between entities) where the service or distribution facilities are located in an optimal way to reach the final customers. Over 10 papers, proposed a two-echelon facility location problem and one a three-echelon, minimizing not only the access time to customers or final users but also the procurement and supply time to distribution centers.

The papers target accessibility mostly in their objective function when the goal is to improve accessibility through different proxies. For example, (Dharmadhikari & Farahmand, 2019; Anwar et al., 2018; Araya et al., 2012) use a standard minimization of costs when setting up and using their networks (food, waste, and school services). On their side, Pan et al. (2020) seek minimization of distance to travel by drones in food distribution, Grubesic et al. (2013) and Amarilies et al. (2020) seek to maximize the service level of covered demand. Frank et al. (2021) and Araya-Córdova et al. (2021) proposed an objective function that aims at maximizing the probability of adopting a recycling program to determine the best combination between increasing new resources our redistributing the existing ones. They measure the average probability of the adoption program by a logistic regression model based on historical municipal variables. In addition, a common objective in the industrial setting is profit maximization which is used exclusively by two papers in the domain of food distribution (Mejía et al., 2021) and biomass products (Vazifeh et al., 2021).

All these proxies can be somehow related to improving accessibility, as the notion of distance to reach the facility is included. On the other side, Frank et al. (2021) is the only paper in the group to define a specific measure for accessibility. The authors propose to locate a set of mobility hubs, maximizing the accessibility to travel places for rural public transportation and minimizing the total distance to a set of clusters (named point of interest). To do so, they measured accessibility as the average ratio of travelling by car vs travelling by public transport multiplied by workplace-accessibility connection with travel volumes. This contribution helps to validate our hypothesis and framework in section 2.4 that accessibility in rural areas can be improved by location-allocation problems in objective functions mathematical models.

As for the data modelling environment, most papers are under a deterministic environment, which is to be expected because the context application is strategic and forecasted with "certainty" to a high level of aggregation. That is to say, we can find two types of objective functions in the location-allocation problems studied and all are single objectives, except for one (Vazifeh et al., 2021). The more common type of function is the minimization of costs, and the second one is the maximization of profits or demand satisfaction. Another interesting author modelled the objective function as the maximization of accessibility. They gave for example that: if the travel time by car is 15 minutes and the travel time by the best feasible publicly available travel itinerary by public transportation and/or on-demand modes is 60 min, the accessibility of this connection equals 25%. This latter contribution helps to validate our hypothesis and framework in section 2.4, that accessibility in rural areas can be improved by location-allocation problems in objective functions mathematical models. The location problems in our results have all capacity constraints fixed explicitly in the mathematical model. They restrict either the capacity in the inventory levels (Amarilies et al., 2020; Anwar et al., 2018; Frank et al., 2021; Mejía et al., 2021; Vazifeh et al., 2021), in the settings of the network budget (Araya et al., 2012; Frank et al., 2021) or on the transportation of flow (Mejía et al., 2021; Pan et al., 2020).

Products in the network include waste products (Araya-Cordova et al., 2021; Amarilies et al., 2020; Anwar et al., 2018; Chen et al., 2021), foods (Mejía et al., 2021; Dharmadhikari & Farahmand, 2019; Titu et al., 2015), biomass products (Vazifeh et al., 2021) or transportation of people (Araya et al., 2012; Frank et al., 2021). These products are usually high in weight and volume which is interesting and transposable to our context application in remote Canada for food insecurity. Finally, all the models in this group solve a real case, but one. This means that the logistic problems presented are rooted in reality and practical challenges, in rural and hard-to-reach areas around the world. The cases range from size instances of 6-1830 supply points and 3-38650 demand nodes.

Finally, the majority of models are solved using exact algorithms and commercial solvers, while only five proposed a heuristic method. Two authors proposed simulation techniques to solve an optimization problem. Tîtu et al. (2015) used ARENA as a discrete simulation modelling to evaluate the possibility of entity aggregation and policy modification and Schlögl et al. (2019) used an Agent-Based Simulation to visualize and solve the model. The remote aspect of this category lies mainly in the remote/rural regions (stated in the description) or the long distance to travel between points.

For example, Chen Y. et al. (2021) propose a multi-objective FLP problem that considers the road upgrading of either staying the same or the construction of new roads for the waste system stations in rural areas. Similarly, Shrestha et al. (2014) present also a multi-objective problem for the network configuration of rural roads and decide on the choice of road updates (what material is used in hilly regions) to maximize the coverage of the population. This type of technical contribution is interesting in remote northern regions where roads are complicated, not paved and sometimes not present. Here the model includes to consideration of constructing new roads versus the status quo for waste product collection. These kinds of arbitrary decisions are important to consider not only from a logistical point of view but from a financial one.

Table 5.1 - Location problems in the industrial and public sectors

Authors	Data modelling	Type of decisions	Problem characteristics				Products		Resolution method	Tested over	Size instances		
N=14		**Location of**	**Objective function**	**What is included**	**Capacity limits**	**Allocation**	**Type of product**	**Weigh and volume**		**Real or Art.**	**Supply nodes**	**Potential sites**	**Demand nodes**
(Amarilies et al., 2020)	Determinist	Waste collection	Max	Demand	Yes	No	Waste Product	High	Heuristic	R	10	26	120
(Anwar et al., 2018)	Determinist	Waste collection	Min	Costs	Yes	Yes	Waste Product	High	Exact	R		2-30	28
(Araya et al., 2012)	Determinist	Schools	Min	Costs	Yes	Yes	People	High	Heuristic	R	-	694	26021
(Araya-Córdova et al., 2021)	Stochastic	Recycling stations	Max	Probability	No	Yes	Waste product	High	Exact	R	128	-	345
(Chen Y. et al., 2021)	Determinist	Waste collection	Max/Min	Sum of min distance/Costs	No	Yes	Waste products	High	Heuristic	R	100	6	38650
(Dharmadhikari & Farahmand, 2019)	Determinist	Pilers	Min	Costs	Yes	Yes	Food	High	Exact	R	100+	37	100+
(Frank et al., 2021)	Determinist	Hubs	Max	Accessibility	Yes	Yes	Public transport	High	Exact	R	1830	24	50
(Grubesic et al., 2013)	Determinist	Airports	Max	Demand	Yes	No	Air transport	High	Exact	R	107	-	-
(Mejía et al., 2021)	Determinist	Hubs	Max	Profits	Yes	No	Food	High	Heuristic	R	100+	30	5

(Pan et al., 2020)	Determinist	Hubs	Min	Distance	No	No	Food	Light	Heuristic	A	-	10	30
(Schlogl et al., 2019)	Stochastic	Road upgrade	Min	Costs	Yes	Yes	People	High	Simulation	R	-	-	12
(Shrestha et al., 2014)	Determinist	Road upgrade	Max/Min	Coverage/Costs	Yes- surface types	No	People	High	Exact	R	24	-	219
(Tîtu et al., 2015)	Determinist	Food logistic components (collection, sorting, baling)	NA	NA	Yes	Yes	Food	High	Simulation	R	3	1	1
(Vazifeh et al., 2021)	Determinist	Hubs	Max/min	Profits and costs	Yes	No	Biomass Product	High	Solver	R	6	2	3

5.1.2 Location problems in healthcare

Access is also a main concern in the healthcare system. In general, people living in remote areas have limited access to healthcare and cannot afford access to health costs (Chaovalitwongse et al., 2017. Physical accessibility (or spatial accessibility) is about the provision of the service and how efficiently the location can be reached. It has also been shown that accessibility is the most important factor in maintaining a healthy population in terms of the efficacy of the healthcare system (Munir et al., 2020). This section will present the articles studying network planning and location problems in the context of healthcare for non-emergency facilities. Table 5.2 present the column's classification when it comes to location in healthcare and includes similar categories as the previous section (i.e., Data modelling, Type of decision, Problem characteristics, Product transported in the network, Resolution method, Real case applications, Case instance). However, an additional column is present as **Technology used** because it was observed that sometimes authors rely on specific technological tools to support the decision process.

The papers reviewed here (12) can be separated into two categories: ambulance location (4) or point of healthcare location (8). When it comes to ambulance planning, the objective is always to maximize the coverage (by service level, maximum service time, and demand served). Other than presenting general, (classic) reallocation of ambulances models, that could be also applied in remote regions, this chunk of literature does not bring new or specific contributions in terms of logistics in remote areas.

As for the point of healthcare location papers, they include the location of hospitals, clinics, dialysis facilities or defibrillators stations. Most of the problems are the location-allocation types that include a decision for the allocation of resources (assignment) on a single echelon network. Most of the paper is prepared in a deterministic environment and includes some coverage notions. However, even if they are all single objectives, they differ in terms of functions and goals. For example, Munir et al. (2020) and Reuter-Oppermann et al. (2019) presented the location of points of healthcare services to maximize the weighted sum of covered demand (demand point with a facility open in less than a 25-minute ratio). On their side, Thorsen & McGarvey (2018) decide on the length of stay of mobile clinics at each population to maximize the number of patients served.

Whereas, Bo-Cheng et al. (2016), aimed at increased coverage by presenting a multi-criterion two-step floating catchment area with Bayesian analysis. Four papers aimed at a minimization objective (time, distance, or costs) (Chaovalitwongse et al., 2017; Klein et al., 2020; Luo et al., 2017; Mosayebi et al., 2020). The maximal covering problems are well established in the healthcare field and follow the primary concerns of providing healthcare for everyone, even more so in rural areas. In addition, most problems include capacity limits on the located facility (unit capacity) but also include a capacity on a time limit modelled as a tolerance time or a waiting time to access the service.

Finally, the accessibility notion being one of the priority concerns in remote healthcare is not proportionally represented in the present literature. Again, the notion is omnipresent in the papers but tackled indirectly with the objective function of coverage maximization. Only two authors directly tackled the accessibility issue in their location-allocation models (Munir et al., 2020; Luo et al., 2017), by incorporating it into the objective function. But even here, they differ in their approaches.

Munir et al. (2020) analyzed inadequacies and equity issues in physical access to healthcare services in remote regions. They developed an Agent-Based Simulation approach to the location-allocation of new healthcare points to increase healthcare services accessible to the community. The authors conclude that healthcare is often limited by connectivity, accessibility, and equity issues in rural regions, which is consistent with our framework that location problems can improve accessibility. Whereas Luo et al. (2017) presented an accessibility measurement based on: proximity (measured by travel time) and equality of care. The authors formulated a two-step optimization method that incorporates the sequential decision-making of a patient in choosing a health facility. For the first time, the ratio determines the best location based on the accessibility (distance proximity) of the closest point. The second step adjusts the capacities of the facility for minimal inequality in accessibility (matching the supply to the demand).

These authors showed that patients value travel time (or distance) from the point of service as the most important criterion and then consider the quality of care or waiting time as a second indicator. Concretely, they measured spatial accessibility and defined it as “The convenience for residents at a given location to overcome the spatial impedance to obtain a service provided at a facility”. The authors argued that the simple measure of proximity (travel time) does not include the decision that a patient might choose more than one hospital, nor does it take into consideration the competition among patients for healthcare services. That is why they proposed the 2-step index measure of accessibility as their main contribution. The refined 2-step floating catchment area method links the accessibility index to the decision of the patient - see Appendix F. With this accessibility index, a higher value corresponds to better accessibility. This was used to map the region according to their accessibility measure using the ArcGIS toolkit.

When it comes to healthcare accessibility there is the question of social equity, and the main goal is to provide adequate access to everyone. In Munir et al. (2020), accessibility was measured as a generated road network dataset concerning travel time using the ArcGIS toolkit and agent-based modelling simulation. The objective function is coverage maximization to provide healthcare for all populations. Similarly, Luo et al. (2017) tackled equity in their accessibility index measurement by insuring care proximity and minimal inequity, but their objective function is incorporated as a multi-objective including not only minimization of accessibility but travel distance and the number of facilities located. That means they aimed at balancing supply and demand and minimizing the distance for the most remote user. Service fulfillment is often the primary optimization objective in healthcare applications (Vidal et al., 2019), and that is reflected in the literature’s objective function to maximize coverage/demand (66%).

The location problems in our results for healthcare applications in our results have all capacity constraints fixed explicitly in the mathematical model. They restrict the capacity of the located facility (size/quantity/volume) in 67% of papers. In 75% of the papers reviewed in the group, authors also fix constraints on a time limit. For example, setting up a maximal time of response for performance indication (van Barneveld et al., 2018). Travel time becomes a sensitive notion when locating healthcare because the patient must have access to care in a reasonable matter of time to avoid consequences (sometimes modelled as a coverage problem). Also, Thorsen & McGarvey (2018) include in their restriction a limit of disparity using a parameter that can be adjusted by managers. When that parameter is zero, the total number of patients served at a location is forced to equal the percentage of the under-served population residing in the same location.

Products are mostly people in the network and service. That is to be expected because it is in the healthcare sector where the demand is pulled from the patients (people) and supply is provided from the healthcare point (service). Only Bo-Cheng et al. (2016) looked at an actual medical product and it was for the location of automated external defibrillators. What is interesting from these problems for our context definition of food security in remote North is rather the network planning and strategic decisions for the location of a facility (i.e., warehouse, food supply point) than the products themselves.

All the models in this group solve real data cases. This means that the logistic problems presented are rooted in reality and practical challenges, in rural or hard-to-reach areas around the world. The cases range from size instances of 5-60 supply points and 9-6135 for demand nodes. Finally, 8 papers were solved using an exact algorithm often supported by a geolocation tool, with the majority (5) providing a new formulation to an existing method as their contribution. Again, only two authors used Agent-Based simulation (Jánošíková et al., 2021; Munir et al., 2020) as a resolution method. The remote aspect is present in those papers as a characteristic of “hard-to-reach”, which can be reflected in the articles as purely rural areas with the difficulty of access to healthcare or long distance to travel to get it.

Table 5.2- Location problems in the healthcare sector

Authors	Data modelling	Type of decisions	Problem characteristics				Products		Resolution method	Tested over	Size instances			Technology used	
N=12		Location of …	Objective function	What is included	Capacity limits	Allocation	Type of product	Weight or Volume			Supply entity	Potential sites	Demand		
(Berg et al.,2019)	Determinist	Ambulances	Max	Coverage	No + time limits	Yes	People	High	Exact	R	13	1979	1472	No	-
(Bo-Cheng et al., 2016)	Stochastic	Defibrillators	Max	Coverage	Yes + time limits	Yes	Defibrillators	Light	Exact	R	51	476	6135	Yes	ArcGIS for data processing
(Chaovalitwongse et al., 2015)	Determinist	Mobile clinic	Min	Costs	Yes	Yes	Service	NA	Exact	R	11	-	9	Yes	Computer information system (support decision)
(EunSu Lee, 2021)	Determinist	Ambulances	Max	Coverage	No + time limits	No	People	High	Exact	R	-	100+	1993	Yes	GIS for data collection
(Jánošíková et al., 2021)	Stochastic	Ambulances	Min/Max	Time/Coverage	Yes + time limits	Yes	People	High	Simulation	R	-	273	211	Yes	LandScan database: model spatial

															distribution of patients
(Klein et al., 2020)	Determinist	Dialysis facilities	Min	Time	Yes + time limits	Yes	Service	NA	Heuristic	R	-	100	45	No	-
(Luo et al., 2017)	Stochastic	Hospitals	Min	Distance (accessibility)	Yes + time limits	Yes	Service	NA	Exact	R	44	3	647	No	-
(Mosayebi et al., 2020)	Determinist	Hospitals	Min	Costs	Yes	Yes	Service	NA	Exact	R	-	13	30	No	-
(Munir et al., 2020)	Determinist	Hospitals	Max	Coverage (accessibility)	Yes + time limits	Yes	Service	NA	Simulation	R	5	13	11	Yes	ArcGIS base for coverage area analysis
(Reuter-Oppermann et al., 2019)	Determinist	Clinics	Max	Coverage	No + time limits	Yes	Service	NA	Exact	R	60	4	21	Yes	Google Distance Matrix API (distance matrix)
(Thorsen & McGarvey, 2018)	Determinist	Mobile and fixed clinics	Max	Demand	No	No	Service	NA	Exact	R	-	9	43	Yes	GIS ArcMap data generation
(Van Barneveld et al., 2018	Stochastic	Ambulances	Max	Coverage	Yes + time limits	No	People	High	Heuristic	R	18	12	162	No	-

5.1.3 Location problems in humanitarian

Humanitarian logistics is the application with the biggest number of papers in our results (overall 41 papers), which can be easily explained by the "hard to reach" or "remote" aspect of the area, forced by the disaster. We can find here a location problem in an area that in regular conditions might not be considered remote, but because of the event of a disaster, the disruptions encountered are imposing new accessibility restrictions and constraints to this area that make it remote. The most frequent remote characteristics in a humanitarian disaster are either the region has been cut off by the disaster, and it is now hard to reach or there is a disruption in the network infrastructures or services which makes it poor and inefficient. Humanitarian logistics operations are made under uncertainty and the source of this uncertainty is dependent on the specific disaster to occur (Saldanha-da-Gama, 2022).

To look at the literature in this category we kept the same previous classification columns and added one for the disaster phase studied (preparation, response, recovery of mitigation). For example, when the context is in the prevention or anticipation of a disaster and the urgency is not as present, the mitigation and preparedness phase is modelled as network design problems with more strategic and tactical planning, rather than operational. Most articles under location problems in the humanitarian field (13/15) are under the preparedness-mitigation disaster cycle phase. The following table presents the different author's contributions regarding location problems in the humanitarian context. The review shows that 10 out of 15 papers are classic FLPs, locating a relief facility. Whether it is a shelter, supplies or distribution center, they all have the same mission: to alleviate the adverse effects of a disaster and to provide emergency care and supplies to the victims. Other location of the facility includes charging drone stations (Chauhan et al., 2019) or a warehouse for stocking supplies (Geng et al., 2021). Whereas 60% solve the model using a heuristic method. Most of the time, authors include some allocation decisions among their models and the network is constituted of a single echelon most of the time. Contrarily, when choosing a multi-echelon, the middle link is a distribution center between the supply and demand point. The problems are almost equally distributed among a deterministic (6) and stochastic (9) environment. This comes as a surprise because to capture the reality and uncertainty of a natural disaster stochastic modelling would be more appropriate, even if more complex. The objective functions for the models are single-objective minimization of costs (60%) and other minimization objectives (time, multi-objective; distance, damages, penalty). Here, Pochan et al. (2020) use a two-level hierarchical model with weighted demand travel time as their objective. Saeidian et al. (2018) suggested a location-allocation problem using a multi-criteria approach that takes into consideration parameters like land use, area, distance, population, slope, and instance from the road. These kinds of technical aspects are interesting when looking at a unique context like northern Canada (ice roads, no pavement etc.). In the latest, the method used was a clustering approach with a GIS analysis tools to choose the site's initial conditions.

Table 5.3 presents only the multiple **costs** included in the objective function. The notion of costs in a humanitarian setting is much larger and broader than in industrial logistics. It is more like an umbrella term including multiple elements like penalty costs of unsatisfied demand (deprivation or shortage), construction costs including placement or set-up costs, operational costs (rent, storage, procurement), transportation costs (logistics, shipment, delivery) and human suffering costs. Human suffering costs* is a notion present in (Geng et al., 2021; Loree & Aros-Vera, 2018) where the authors measure either the victim's suffering perception or the valuation of human life (put a monetary value to it).

Table 5.3 - Notion of Cost in Objective Function

Papers including the costs in their O.F.	Penalty costs of unsatisfied demand	Construction costs	Operational costs	Transportation costs	Human suffering costs*
(Anaya-Arenas et al., 2018)	X				
(A. Y. Chen & Yu, 2016)		X	X	X	
(Bozorgi-Amiri et al., 2012)	X	X	X	X	
(Campbell & Jones, 2011)	X	X	X	X	
(Geng et al., 2021)	X	X	X	X	X
(Hong et al., 2012)				X	
(Khayal et al., 2015)	X	X		X	
(Loree & Aros-Vera, 2018)	X	X		X	X
(Rawls & Turnquist, 2012)			X	X	
(Yenice & Samanlioglu, 2020)	X				
(J. H. Zhang et al., 2012)			X		

Table 5.4- Location problems in the humanitarian sector

Authors	Data modelling	Type of decisions	Problem characteristics				Products		Resolution method-	Tested over	Size instances			Technology	How technology is used	Disaster phase-
N=15		Location of*	O.F.	What is included	Capacity limits	Allocation	Type of product	Weigh and volume			Supply	Potential sites	Demand			
(Anaya-Arenas et al., 2018)	Determinist	FRC	Min	Unsatisfied demand, time and gap	Yes	Yes	Rescue equipment	High	Heuristic	R	-	-	6	No	-	Preparedness
(A. Y. Chen & Yu, 2016)	Determinist	TRC	Min	Costs	Yes	No	Healthcare services	NA	Heuristic	R	20	5	10828	No	-	Response
(Bozorgi-Amiri et al., 2012)	Stochastic	FRC	Min	Costs	Yes	Yes	Rescue equipment	High	Heuristic	A	9	18	25	No	-	Preparedness
(Campbell & Jones, 2011)	Stochastic	FRC	Min	Costs	No	Yes	Rescue equipment	High	Heuristic	R	4	-	100	No	-	Preparedness
(Chauhan et al., 2019)	Determinist	D	Max	Demand	Yes + battery energy	Yes	Package	Light	Heuristic	R	-	104	122	No	-	Preparedness
(Geng et al., 2021)	Determinist	W	Min	Costs	Yes	Yes	Rescue equipment	High	Heuristic	R	-	10	11	No	-	Preparedness
(Görmez et al., 2011)	Determinist	FRC and TRC	Min	Multi (distance and number of sites)	Yes	Yes	Rescue equipment	High	Exact	R	-	40	964	Yes	Data generation GIS	Preparedness

(Hong et al., 2012)	Stochastic	FRC	Min	Costs	Yes	No	Rescue equipment	High	Exact	R	5	20	20	No	-	Preparedness
(Khayal et al., 2015)	Determinist	TRC	Min	Costs	Yes	Yes	Rescue equipment	High	Exact	A	10	4	15	No	-	Preparedness
(Loree & Aros-Vera, 2018)	Stochastic	FRC	Min	Costs	Yes + time	Yes	Rescue equipment	High	Heuristic	A	-	20	100	No	-	Preparedness
(Pochan et al., 2020)	Stochastic	FRC	Min	Time	Yes + time	Yes	Rescue equipment	High	Heuristic	R	-	132	350406	Yes	Analysis and data generation	Preparedness
(Rawls & Turnquist, 2012)	Stochastic	FRC	Min	Costs	Yes	Yes	Rescue equipment	High	Exact	R	16	50	30	No	-	Preparedness
(Rezapour et al., 2018)	Stochastic	FRC	Max	Survivors	Yes + Time	Yes	Rescue equipment	High	Exact	R	50	-	1100	No	-	Response
(Saeidian et al., 2018)	Stochastic	FRC	Max/Min	Multi (Land use, Area, Distance, Slope)	Yes	Yes	Rescue equipment	High	Heuristic	R	-	150	39	Yes	GIS Analysis tool	Preparedness
(Yenice & Samanlioglu, 2020)	Stochastic	FRC and TRC	Min	Multi (distance, damage and penalty)	Yes	Yes	Rescue equipment	High	Exact	R	21	100	1920	Yes	Arcview GIS and geographical database (generate data)	Preparedness

*Location of Temporary relief center (TRC), Fixed Relief Center (FRC), Drone station (D), Warehouse (W), Distribution center (DC)

5.2 Availability in terms of distribution planning

Food availability is another important component of food systems. It refers to the quality of being able to obtain a certain product or service (Oxford Languages, 2022). In the case of food security, the difference between accessibility and availability is that the first notion is about geographic proximity (possibility to access/reach the location) whereas, availability seeks that once you reach the destination, the products will be available. The two concepts are complementary to each other to provide food security. Therefore, once the food network is established through a location-allocation decision, to provide food accessibility, the delivery and transportation of products need to be stable and efficient to provide food availability leading to distribution problems.

Distribution planning (DP) is another main category of a logistical problem. It is an important notion in supply chain management that aims at planning the flow, deciding the shipments, and finally (at an operational level) deciding the best routes to deliver to the entire network. The mathematical model usually takes decisions on the movement of resources in the network. A common problem among many is the classic Vehicle Routing Problem (VRP) model, which originated in 1959 by Dantzig and Ramser. This problem consists of planning a set of routes (contrasting with the Traveling Salesman Problem which plans a single route to multiple nodes). Generally, distribution problems are assuming the network configuration is established. A broad definition of this activity is proposed as “a systematic approach to ensure that the process encompassing the delivery of goods to different distribution centers is done properly keeping in mind which goods are to be supplied in what quantity at what location in the desired time” (MBA Skool team, 2016).

Our results show that the literature on DP in remote areas has been emerging rather constantly over the past last 10 years as seen in the following Figure 5.3.

It goes with the evidence that overall routing problems have dramatically evolved over the past 20 years, mainly because of its economic interest and advantage for transportation companies (Vidal et al., 2019). Remote logistics being complex and a new topic, it makes sense that practitioners and researchers are starting to look at ways to optimize the planning in the distribution of goods in that context of remoteness. Having no publication specific to our queries between 2011-2012. Then, ranging between 1-2 publications in earlier years 2013-2016, with a steep increase in 2018 of 8 publications. Finally, a small drop in 2019 to range between 4-8 publications a year since then.

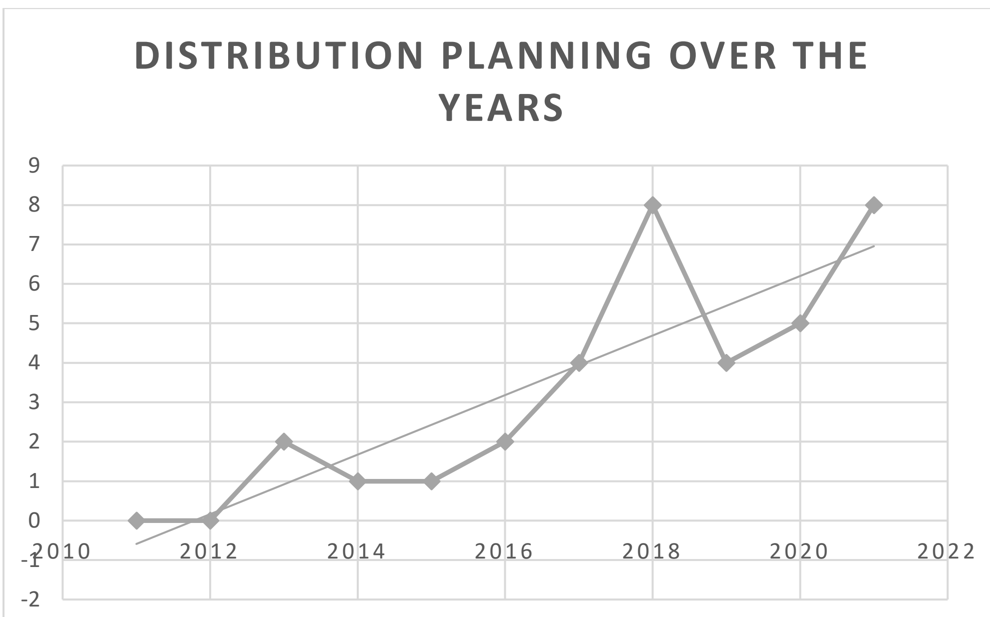


Figure 5.3- Distribution planning over the years

Now looking at the evolution trend in the domain of application. The industrial sector (orange line) was rather stable between 2011 and 2017 with less or equal to 1 publication a year on the topic of interest. Then, they increased in 2018 to 2 publications with a bigger increase in 2020 to 4 publications. As for the Healthcare context (yellow line), it is the less active field in terms of distribution planning in remote areas. With no publication from 2011-2016, it saw an increase in 2017 to 2 publications but then dropped back to 0-1. For the humanitarian domain (green line) the trend saw a significant rise in 2018 reaching its peak of 5 publications that year. Since then, it dropped between 1-4 publications a year.

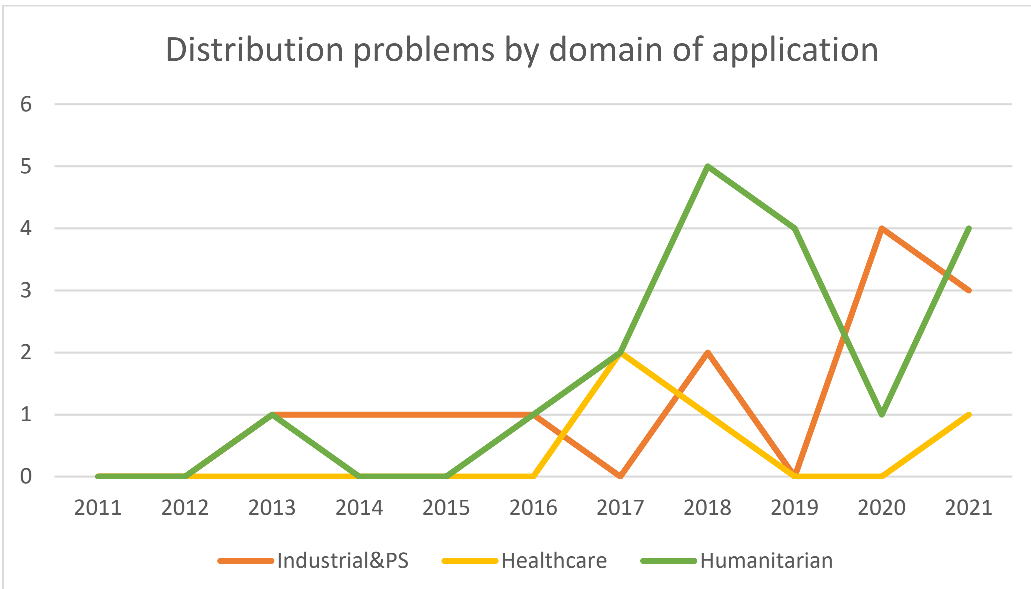


Figure 5.4 - Publications by the domain of application (distribution planning)

The results for distribution problems have been divided into the same three groups of the operational sector identified: industrial and public sector, healthcare, and humanitarian. However, because a distribution problem differs from a location one, the table and characteristics analyzed were adapted consequently. We kept the columns of Data modelling, Problem characteristics (O.F, capacity limits, echelons), Product type, Resolution method, Tested over real or artificial data and

Size instance, with the same significance. Moreover, we added a column on the Transportation mode used: whether it was vehicles (includes trucks, cars), drones, vehicle-drone combined, trains, airplanes, boats or multi-modal. Finally, a classification for the Fleet indicates if the model considers a heterogeneous or homogeneous fleet (in the specific mode used). As general findings, the choice of transportation mode preferred is ground vehicles (51% trucks) with a homogeneous fleet, driving on paved roads, with no consideration of terrain aspects. Surprisingly, not a lot of mention of terrain difficulty when authors present the mode of transport even though we're in a context of remote and hard-to-reach regions. For example, no special analysis is made for hard-to-reach regions in mountains, deserts, Arctic, or Nordic conditions which could impact the choice of mode of transport. Unfortunately, geographical terrain is taken into consideration partially in three papers (Park S. et al., 2018; Munawar S. H. et al., 2021; Nadi A. et al., 2017) that proposed to make a terrain assessment via drones to better access the area but don't adapt the model or mode of transportation for specific terrain aspects.

5.2.1 Distribution problems in industrial and public sectors

The first category contains the distribution problems among the industrial and public sectors like police routing, military, public transportation, waste transportation or general goods and e-commerce distribution. 13 papers fit into this category. Because distribution problems are generally difficult to solve and complex, it is not a surprise that most papers are modelled with deterministic data (84%), under a single echelon (84%) with a homogeneous vehicle fleet (76%) in a single commodity environment. Even though these characteristics are not usually close to reality, which is often more dynamic with a multi-period, multi-commodity qualities, they allow authors to set a better problem for fast and optimal solutions preferred by stakeholders.

Among the distribution planning literature, routing problems are more prominent. Here, in the industrial and public sectors, many authors used the VRP to base their study and usually agree on the definition of it (11 out of 13). In general terms, the definition problem consists of designing a set of routes to minimize the total distance travelled to visit a set of geographically dispersed locations (customers) or the minimization of costs of routing. A total load of a vehicle (i.e., the sum of all the goods that it delivers in a single route) must be within its capacity (Pacheco et al., 2013).

In contrast, only Es Yurek & Ozmutlu (2018) tackled the distribution problem in an industrial setting as a Traveling Salesman Problem (TSP), which consists of a single vehicle travelling a single route to visit multiple nodes. The TSP is less realistic in remote applications because of the extremely long distance to travel and distant nodes. Relying on a single vehicle (one driver) to do the whole route is harder, explaining why this modelling is not very present in a remote context. A useful aspect that is becoming present in recent contributions is the use of drones in distribution planning. (Es Yurek & Ozmutlu, 2018; Munawar et al., 2021; Xu et al., 2020 and Yang et al., 2020) use the combination of vehicles and drones as a mode of transport. The role of the drone is to complement the truck in the operations by its ability to access difficult terrain. The drone is here used for assessment of terrain (in bushfires management or threatening military environment) and rarely for the delivery itself in the four papers. The planning of the routes is then made based on the information gathered by the drone assessment.

The objective function often refers to the minimization of transportation costs (61%), also presented as the minimization of total distance value (in costs). This objective aligns with the industrial domain of application where transportation companies aim at reducing their operational/routing costs. Some capacity constraints are applied on units and volume, but also on time (waiting time of truck and time of the longest route). Only Liu, (2020) aimed at profit maximization for industrial products.

The type of products transported is often high-weight-high-volume (77%) and varies between the movement of people, foods, and industrial products. One author; Munawar et al. (2021) focused on light-weight-low-volume relief items transported by drones. In this part of the literature, authors tested their model on real cases 61% of the time, with instances size ranging from 5-12087 points. The resolution method used is mostly heuristic (69%), with one author; Cooper et al. (2021), using simulation with system dynamics for resolution. The remote aspect is present in these papers by the context definition applied directly in remote/rural areas for the majority. Even though the term accessibility was linked to location problems (Section 5.1) it was encountered here by Cooper et al. (2021), as they aim at maximizing accessibility. However, they define it in a more qualitative way referring to food market access (distance, travel times and costs, as well as road accessibility and quality) and don't dive deeper into the concept. The contribution provides rather a position market aggregation for the region with multiple scenario possibilities.

Availability is not presented as a clear concept in this portion of distribution planning literature, nor is it reflected in the objective function. However, some statements are worth mentioning. As presented in chapter 2, availability refers to the product being available at a pre-established accessible location. Hence, we can say that product distribution contributes to the availability, by bringing the commodities to demand nodes in an appropriate, acceptable way. For example, (Yang et al., 2020; Es Yurek & Ozmutlu, 2018) proposed a delivery service, which can result in high availability by increasing the frequency and time of the deliveries. Whereas (H. Chen et al., 2018; Yang et al., 2020) mentioned a good routing model that can reduce the cost of the final distributed service/product substantially. Also, Cooper et al. (2021) aim at an aggregation model (aggregate quantities between markets) to increase fresh food availability, by insuring equitable distribution.

However, the study focuses more on the positioning and flow in the market between farmers and customers. While using Simulation as a resolution method, it doesn’t tackle the availability notion in a clear, specific way. Finally, all the finding for this section is presented in Table 5.5.

Table 5.5 - Distribution planning problems in the industrial and public sectors

Authors N=13	Data modelling	Problem characteristics						Products		Resolution method	Tested over	Size instances
		Objective function	What is included	Capacity limits	Echelons	Transport mode	Fleet	Product Type	Product weight			
(Cooper et al., 2021)	Determinist	Max	Multi (affordability, accessibility, and profit)	Units, temperature	Single	Vehicle	Homogeneous	Food	High	Simulation	R	12087
(Es Yurek & Ozmutlu, 2018)	Determinist	Min	Waiting time	Units, Battery life	Single	Vehicle-drone	Homo(each)	NA	Light/high	Heuristic	A	20
(Feng, 2020)	Determinist	Min	Multi (costs and distance)	Weight, distance	Single	Vehicle	Homo	Food	High	Heuristic	R	30
(H. Chen et al., 2018)	Determinist	Min	Distance	Time	Single	Vehicle	Hetero	People	High	Heuristic	R	5
(Liu, 2020)	Determinist	Max	Profits	Units, time	Multi (3)	Vehicle	Homo	Industrial products	NA	Heuristic	A	80
(Miranda et al., 2015)	Determinist	Min	Costs	Time, volume	Single	Vehicle	Homo	Household waste	High	Exact	R	33
(Molenbruch et al., 2021)	Determinist	Min	Costs	Time, units	Multi (2)	Vehicle	Hetero	People	High	Heuristic	A	80
(Munawar et al., 2021)	Determinist	Min	Costs	Battery life, weight	Single	Vehicle-drone	Homo	Relief aids	Light	Heuristic	R	80
(Pacheco et al., 2013)	Determinist	Min	Multi (distance/time)	Units, time	Single	Vehicle	Homo	People	High	Heuristic	R	57
(Rabbani et al., 2016)	Stochastic	Min	Costs	Units	Single	Vehicle	Homo	NA	High	Heuristic	A	NA
(X. Jiang et al., 2014)	Determinist	Min	Costs	Units, time	Single	Vehicle	Homo	People	High	Heuristic	R	28
(Xu et al., 2020)	Stochastic	Min	Costs	Time, level, units	Single	Drone	Homo	NA	NA	Exact	A	8
(Yang et al., 2020)	Determinist	Min	Costs	Units and volume	Single	Vehicle-drone	Hetero	Industrial products	High	Exact	R	115

5.2.2 Distribution problems in healthcare

Our results have shown that in healthcare operations, the routing and distribution problems are negligible. Surprisingly, in distribution problems in healthcare in remote regions, there are only four papers. For this section, three papers aim cost minimization of routing with constraints applied on the capacity of quantity transported using homogeneous vehicles. One paper proposed a multi-objective function with maximum coverage while minimizing the number of sites and distance to travel.

Clarke et al. (2017) proposed a capacitated VRP with synchronized pick-ups and drop-offs between medication delivery and supervision. Similarly, Gupta (2017) proposed a determinist vaccine delivery model that determined the optimal size of the order and Parvin Hoda et al. (2018) a stochastic distribution problem for medication to be distributed near key locations so they are available when needed and to reduce shortages. Only one paper (Salman et al., 2021) approached distribution planning in the healthcare category as mobile clinic routing. This latest model utilizes available resources more efficiently and ensures the availability of healthcare services in rural areas using call record data to identify the demand for service.

75% of the papers were modelled under a deterministic environment, while all were tested over real case data with instances ranging from 7-291 nodes, and 50% used a heuristic resolution method versus an exact one. The routing models are for a single echelon with only a homogeneous fleet and the mode of transportation varies of vehicles (3) and combined truck-drone (1). The distribution models transported medical products of both high and low sizes (vaccines) and one provided service only (Salman et al., 2021). Constraints are present in the models mostly on vehicle capacity (units) but also restrictions are applied on time, for the time frame of deliveries and frequencies.

Availability is again discrete in the literature and not taken into consideration in the mathematical model. Therefore, the authors mention the notion as a qualitative argument. In Gupta (2017), the concept is mentioned as the proposed mathematical model will increase the availability of medicine at a minimum cost. In the same line of thought, Parvin Hoda et al. (2018) mention the increased resource availability to reduce shortages. Finally, Salman et al. (2021) ensure efficient resource utilization to ensure the availability of service in rural areas.

It is however rare the low number of papers resulting from our search. One might think that transportation problems concerning the supply of medicine and equipment are an important challenge in remote regions, but no contributive approach to the problem. Moreover, in the general context of healthcare, routing is usually present in the planning of home healthcare, mobile clinics, and vaccination campaigns. Even though these problems could be easily applied in remote regions, no contribution was found. One explanation can be that often healthcare in remote areas translates into a humanitarian response because of the nature of the problem being more urgent and often resulting from a post-disaster context.

The following Table 5.6 summarizes the characteristics of distribution problems in remote healthcare.

Table 5.6 Distribution problems in healthcare sector

Authors N=4	Data modelling	Problem characteristics						Products		Resolution method	Tested over	Size instances
		Objective function	**What is included**	**Capacity limits**	**Echelons**	**Transport mode**	**Type of fleet**	**Product Type**	**Product weight**			
(Clarke et al., 2017)	Determinist	Min	Costs	Time and capacity	Single	Vehicle-drone	Homo(each)	Medical products and people	High	Heuristic	R	41
(Gupta, 2017)	Determinist	Min	Costs	Quantity	Single	Vehicle	Homo	Medical products	Light	Exact	R	3
(Parvin Hoda et al., 2018)	Stochastic	Min	Costs	Quantity	Multi (3)	Vehicle	Homo	Medical products	High	Heuristic	R	291
(Salman et al., 2021)	Determinist	Max/min	Multi (coverage, sites and distance)	Distance and frequencies	Single	Mobile clinics	Homo	Healthcare service	NA	Exact	R	7

5.2.3 Distribution problems in humanitarian

Contrary to healthcare distribution planning, distribution problems in the humanitarian setting are a well-studied topic and over the past years, the Emergency Management sector has been in effervescence. In this review of remote applications, the literature on humanitarian transportation includes a total of 18 papers. Just like the papers on location planning under the humanitarian context, the ones presented here are also considered remote applications because of being geographically distant from main centers or because of the nature of the problem that generates a remote environment (i.e., destruction of key infrastructures, blocked roads, inaccessibility because of dangerous terrain). Most of the papers specifically target last-mile delivery. Therefore, because last-mile problems are full of uncertainty and typically have many scenarios, a common way to solve this type of problem is to perform multiple scenario analyses (Khare et al., 2021), which is the case for most articles in this section.

Almost all papers consider vehicle routing problems (VRPs) with or without a terrain assessment component. Only two authors proposed TSPs: Park et al. (2018) proposed a TSP for route optimization, therefore allowing a single vehicle for the route, and Ryosuke et al. (2021) proposed multiple travelling salesman problems (planning multiple tasks/routes for multiple drones that are solved individually). Most of the literature in this category is modelled under a deterministic environment (72%) which simplifies the modelling properties but used real case studies (66%). The objective function varies between total travel time minimization (33%), total routing costs minimization (22%) and other minimization functions (death tolls, social costs) or maximization (profits, demand, safety factor and accessibility (travel time measured). The profit maximization of G. Zhang et al., (2021) constitutes a truck-and-drone problem that serves zones selectively with the goal of maximum profit, which relaxes the common assumption that all sites must be visited. a visit presents a profit value. This was interesting modelling in terms of humanitarian contribution, where profits are not a common objective. While 61% of the literature used heuristic resolution methods, 28% chose an exact method and only 11% used another method like a commercial solver or simulation tool. In the humanitarian literature studied here, we start to see a more prominent inclusion of **humane** characteristics like human suffering and distribution fairness. Recalling the human suffering costs in humanitarian location problems of section 5.1.3, the trend is continuing in this domain of application exclusively.

When it comes to non-profit organizations, they often have an obligation toward the customer, therefore providing equitable service (Vidal et al., 2019). Table 5.7 summarizes the papers including some of these equity and survival notions. When measuring human suffering, it is possible to include welfare economic concepts into mathematical models like in Holguín-Veras et al. (2013). When focusing more on the fairness concept, it is more demand-driven and relies mostly on satisfying demand measures.

Table 5.7 - Humane characteristics in the model

Notion	Authors	How it is presented
Human suffering	(Holguín-Veras et al., 2013)	Measured in objective function as Penalty cost of unsatisfied demand; social cost to provide even level of service to every node.
Equity and fairness	(Escribano Macias, et al., 2020; Ferrer et al., 2018; J. Jiang et al., 2017; Sopha et al., 2019)	An additional objective formulation for proportional distribution by measuring the difference in demand satisfaction; Equity in deviation of satisfying demand; Fairness considered in the time dimensions by minimizing the difference in material demand urgency degree; Coordination strategies using scenario analysis to provide fairness.
Safety measure	(Baidya & Bera, 2019; Ferrer et al., 2018)	Safety constraints (road conditions, hilly regions). The objective function to maximize safety factor; refers to expected losses due to assaults of a convoy
Survival function	(Nadi & Edrisi, 2017)	The survival function is measured as the arrival of teams on site. The percentage of survivors is decreasing exponentially after a determined period. Goal to minimize death tolls

In this category, when looking at the availability in terms of distribution planning, we can see that it often translates as a goal for the authors. For example, to increase the availability of rescue operations and equipment, availabilities of supplies to demand, reducing uncertainties in satisfaction of demand. Whereas this objective is mostly qualitative in nature and more of a result from the other principal objectives (like minimization of response time or costs) than explicitly included in the mathematical formulation itself. However, the authors talk about the availability notion in their research, and they are often nuanced in their definitions. For example, (G. Zhang et al., 2021; Park et al., 2018) mentioned that they aim at providing a systematic method of terrain assessment (combined truck-drone) that can be used by humanitarian agencies to observe transportation network availability (road availability, if blocked or not) after a disaster. Where, (J. Jiang et al., 2017; Sopha et al., 2019) presented the concept as the more general availability of supplies at location points. Finally, Chowdhury et al. (2018) proposed a GIS-based transport network that aims at integrating the existing transport system and selecting the shortest routes, to offer the flexibility of ensuring the continuous availability of transport services in remote regions when an emergency arises.

From another point of view, the network in this section is 61% of the time a single-echelon but with a good number of papers being a multi-echelon system (39%), mostly two-levels. The type of product distributed in the network is a single commodity (72%) between high-weight/high-volume rescue equipment or low-weight/low-volume medical products – size varies a lot between papers. Two authors provide networks that transport multi-commodities of medical products and people combined. The type of fleet is often homogeneous (78%), but the mode of transportation varies a lot.

We can observe a distinction between the mode of transportation used in the different problems. Some authors are studying the traditional distribution mode using ground vehicle transportation whereas other others focus on air distribution (mostly using drones). When looking at articles that exclusively model a routing problem using **ground transportation**, this refers most of the time to trucks with a certain load capacity with a mix of either a homogeneous (5 papers) or heterogeneous (3 papers) fleet. In vehicle transportation, the products transported are medical products and rescue equipment with the objective function of urgency that translates into minimization of response or operational time. When it comes to **air transportation**, authors use drones as their mode of choice, except for Xavier et al. (2021) using helicopters. The difference when using a drone as the primary mode of distribution is that the capacity in terms of weight and volume is significantly reduced compared to trucks. Even though they all differ in terms of the objective function (from minimization of distance, costs, or time), they all have capacity constraints and additional restrictions applied on the battery life of the drones and need to consider shorter trips and recharging options.

When it comes to a combination of **air and ground transportation**, capacities in units, tend to vary depending on what specific type of fleet is used. There is a mix of vehicle-drone, helicopter-vehicle, or train-plane combinations. When authors combined ground vehicles with drones (Nadi & Edrisi, 2017; G. Zhang et al., 2021) the drones are used for the assessment of terrain equipped with a camera as input generation before the vehicle deliveries are made. Whereas when using *drones only* the papers are equally distributed between last-mile drone delivery (Escribano Macias, Angeloudis, et al., 2020; Rabta et al., 2018) or using the drones for assessment and surveying to assist decisions in distribution planning (Escribano Macias, Goldbeck, et al., 2020; Park et al., 2018; Ryosuke et al., 2021).

Table 5.8 - - Distribution problems in the humanitarian sector

Authors N=18	Data modelling	Problem characteristic						Product		Resolution method	Tested over	Size instance
		Objective function	What is included	Capacity limits	Echelons	Transport mode	Type of fleet	Product Type	Product weight			
(Baidya & Bera, 2019)	Stochastic	Max	Safety factor	Capacity, safety	Multi (4)	Train and cargo flight	Hetero	Rescue equipment	High	Exact	R	3
(Chowdhury et al., 2018)	Determinist	Max	Accessibility	-	Multi (3)	Vehicle, pedestrian and boats	Hetero	People	High	Exact	R	338
(Escribano Macias, Goldbeck, et al., 2020)	Stochastic	Min	Costs	Battery life, weight	Single	Drone	Homo	Rescue equipment	Light	Heuristic	R	13
(Ferrer et al., 2018)	Determinist	Max/min	Equity, priority, reliability, security/time, costs	Capacity	Multi (2)	Vehicle	Hetero	Medical products	Light	Heuristic	R	38
(Gao et al., 2020)	Determinist	Min	Time	Battery life, weight	Single	Vehicle-drone	Homo (each)	Rescue equipment	Light	Heuristic	A	100
(Holguín-Veras et al., 2013)	Determinist	Min	Costs	Budget, level of service	Single	Vehicle	Homo	Rescue equipment	High	Heuristic	A	20
(J. Jiang et al., 2017)	Determinist	Max/min	Efficiency/demand difference	Time, capacity	Single	Vehicle	Homo	Rescue equipment	High	Exact	R	12
(Kasaei & Salman, 2016)	Determinist	Min	Time	Accessibility (roads), capacity	Single	Vehicle	Homo	Not applicable	NA	Heuristic	R	20
(Khare et al., 2021)	Determinist	Max/min	Demand/costs	Time	Multi (3)	Helicopters-mules	Homo	Medical products	Light	Heuristic	R	116

(Maghfiroh & Hanaoka, 2018)	Stochastic	Min	Time	Time, capacity	Single	Vehicle	Hetero	Rescue equipment	High	Heuristic	R	199
(Nadi & Edrisi, 2017)	Stochastic	Min	Deaths	Time, capacity	Multi (2)	Vehicle-helicopters	Homo(each)	Rescue equipment	High	Exact	R	28
(Park et al., 2018)	Determinist	Min	Reception rate	Time	Multi (4)	Drone	Homo	People	NA	Heuristic	A	100
(Rabta et al., 2018)	Determinist	Min	Costs (measured by distance)	Time, capacity, priority	Single	Drone	Homo	Medical products	Light	Solver	A	5
(Ryosuke et al., 2021)	Determinist	Min	Distance variation	-	Single	Drone	Homo	NA	Light	Heuristic	A	10
(Shin et al., 2019)	Determinist	Min	Time	Time	Single	Vehicle	Homo	Medical products and people	Light and high	Heuristic	A	17
(Sopha et al., 2019)	Stochastic	NA	NA	Distance, capacity	Multi (2)	Vehicle	Homo	Rescue equipment	High	Simulation	R	1130
(Xavier et al., 2021)	Determinist	Min	Time	Time, capacity	Single	Helicopters	Homo	Medical products and people	Light and high	Heuristic	R	25
(G. Zhang et al., 2021)	Determinist	Max	Profits	Battery life, speed, time	Single	Vehicle-drone	Homogeneous (each)	NA	NA	Exact	R	100

5.3 Combined location-distribution problems in remote regions

Location and distribution problems were presented as two district categories in the previous sections. It is now clear that network design is the preliminary decision to be made for a distribution network. Literature has also shown that the location-allocation decisions of *where* to locate facilities and the spatial organization of entities are directly related to the increased accessibility of goods or services. Therefore, the distribution decisions on routing and *how* the flow within this network should be established have been linked to increased availability in terms of being able to obtain said product/service (Contreras & Fernández, 2012). Because the decision on location and distribution are interrelated, it is not a surprise that some authors decided to integrate both aspects into their models. Our results through those 15 papers presented an integrated model and most of them (66%) are in a humanitarian response context. These integrated articles and their characteristics are presented in Table 5.9. The categories of the columns are similar to the previous sections, with an additional aspect on the mix between the decisions made (location, allocation, routing, covering, scheduling) and the way the decisions were taken; simultaneously or sequential. Then, a column presents what type of facility is located (fixed or temporary). Only five papers (33%) presented the problem using a stochastic data setting, which again, might increase the complexity of the problem, but is much closer to reality. The rest chose a deterministic modelling environment.

One motivation behind integrated problems is the ability to simultaneously combine the decisions and allow central operation planning that can eliminate delays in those decisions making. Most of the papers simultaneously take an integrated decision instead of sequentially. In a remote context, one major drawback is that the demand points are very distant from the supply, resulting in long travel distances for vehicles. One of the main findings of Y. H. Lin et al. (2012) was that adding alternative support facilities or re-configuring existing facilities may produce some gains in efficiency and accessibility. Linking here once again the notion of location problems to accessibility. 40% of papers chose to locate temporary facilities to relieve the pressure on the network rather than fixed points. This is explained because these are under humanitarian and disaster contexts, where it makes sense to choose temporary locations instead of fixed ones, because of the sporadic demand and lower installment costs.

The network design is constituted of a single echelon 53% of the time and a multi-echelon structure 47% of the time, mostly 2 levels. The fleet is mostly homogeneous (53%) but sometimes presented as heterogeneous. The mode of transportation is a single mode (66%). The network is mainly single- products, often rescue equipment, because the domain of application is mostly humanitarian. But there is also the movement of medical products (1), people (3) or recycling products (2), with one paper offering medical services. Overall, the commodities are high-weight and high volume in quantities transported.

The objective function for this portion of the literature is total cost minimization focused (53%) including transportation costs, distance travelled or time associated costs and penalty costs (social cost of not meeting demand). The other objective varied between time (20%) and distance (13%) minimization. Authors (Afshar & Haghani, 2012; Han et al., 2011) proposed to minimize weighted unsatisfied demand to avoid penalty, whereas Cubillos & Wøhlk (2021) proposed to maximize the demand covered but as a multi-objective, that minimizes the tour length simultaneously. These conflicting objectives are attained not by a single optimal solution, but by a trade-off combination with the weighted method.

Constraints are applied to the mathematical models as general capacity limits (of vehicles, facilities, stocking etc.). Some restrictions are related to time notion, either on the time taken for deliveries or for the time of hours worked by staff. In Davis et al. (2014), the model is formulated with a work-week limitation to provide a delivery schedule. Whereas Gu & Wallace (2021) use clustering of the demand for different peak hours to allocate the water-taxis schedule.

Interestingly, Davis et al. (2014) proposed a model that takes into consideration food spoilage by adding a time-based constraint to the model. Therefore, perishable food constraints become even more relevant in remote contexts because of longer travelled routes. In this study, the authors conclude that it can be challenging to provide regular ad frequent deliveries in rural areas and accessibility is limited because of distance, therefore their goal was to increase food access by using more food delivery points. Other than this study, there are very few articles focusing on food product deliveries and including the perishable notion.

In terms of accessibility and availability, the studies are vague on that matter. No consideration is taken in the mathematical models, but arguments are made that a more efficient allocation and utilization of the network will increase access to resources (Tirkolaee et al., 2020). Also, Escribano Macias, et al. (2020) propose a drone utilization method that allows an increase in accessibility by assessing the terrain first (network accessibility) and Y. H. Lin et al. (2012) based their research on the finding that adding alternative support facilities or re-configuring existing facilities may produce some gains in efficiency and accessibility.

Finally, 86% of the papers used real study cases with instances size ranging between 3-5000 demand nodes. The resolution method used was evenly distributed between the heuristic method (53%) and the exact method (40%), with one paper (Mommens et al., 2021) using an agent-based simulation tool to evaluate the delivery to homes or collection points configuration.

Table 5.9- Combined location-distribution problems in remote areas

Authors N=15	**Problem characteristics**											**Products**		**Resolution method**	**Tested over**	**S inst**
	Decisions on		**Type of facility**	**Domain of application**	**Data Modelling**	**Objective function**	**What is included**	**Capacity limits**	**Echelons**	**Transport mode**	**Type of fleet**	**Product Type**	**Product weight**			
(Afshar & Haghani, 2012)	**Location-routing**	Integrated simultaneously	Temporary	Humanitarian	Determinist	Min	Unsatisfied demand	Capacity	Multi (more than 4)	Vehicles but model allows multiple modes	Hetero	Rescue equipment	High	Exact	R	20
(Alinaghian & Goli, 2017)	**Location-allocation-routing**	Integrated simultaneously	Temporary	Humanitarian	Stochastic	Min	Time	Capacity, total time	Single	Vehicle	Homo	Medical	High	Heuristic	A	11
(Cherkesly et al., 2019)	**Location-routing-covering**	Integrated 2 steps	Fixed	Healthcare	Determinist	Min	Costs	Time	Single	Motorbikes	Homo	People	High	Exact	R	3
(Cubillos & Wøhlk, 2021)	**Location-routing**	Integrated simultaneously	Fixed	Recycling	Determinist	Max/min	Distance/demand	Distance	Single	Vehicle	Hetero	Recycling products	High	Heuristic	R	20
(Davis et al., 2014)	**Location-allocation-routing**	Integrated 2 steps	Fixed	Food banks	Determinist	Min	Sites, distance	Vehicle, food spoilage, working hours	Multi (3)	Vehicle	Homo	Foods	High	Exact	R	28

(Davoodi & Goli, 2019)	**Location-allocation-routing**	Integrated partitioning	Temporary	Humanitarian	Determinist	Min	Waiting time	Vehicle capacity	Single	Vehicle	Hetero	Rescue equipment	High	Heuristic	R	21
(Dufour et al.,2017)	**Location-distribution**	Integrated 2 steps	Fixed	Humanitarian	Stochastic	Min	Costs	Yes + on product type	Multi (2)	Multi (boat, rail, air, trucks)	Hetero	Rescue equipment	High	Heuristic	R	500
(Gu & Wallace, 2021)	**Location-allocation-routing**	Integrated simultaneously	Temporary	Transportation	Determinist	Min	Costs	Working hours	Multi (2)	Boat	Homo	People	High	Exact	R	5
(Han et al., 2011)	**Location-allocation-routing-scheduling**	Integrated simultaneously	Temporary	Humanitarian	Stochastic	Min	Distance, unsatisfied demand	Capacity	Single	Vehicle	Homo	Rescue equipment	High	Heuristic	A	18
(Y. H. Lin et al., 2012)	**Location-routing**	Integrated 2 steps	Temporary	Humanitarian	Determinist	Min	Costs	Capacity, distance, time	Multi (2)	Vehicle	Homo	Rescue equipment	High	Heuristic	R	15
(Escribano Macias, et al., 2020b)	**Location-routing**	Integrated simultaneously	Fixed	Humanitarian	Stochastic	Min	Costs	Battery life, capacity	Single	Drone	Homo	Rescue equipment	Low	Heuristic	R	13

(Mommens et al., 2021)	**Network configuration-routing**	NA	Fixed	General	Determinist	Min	Costs	Capacity, emissions levels	Multi (3)	Vehicle	Hetero	General	High	Simulation	R	50
(Pérez-Rodríguez & Holguín-Veras, 2016)	**Inventory-allocation-routing**	Integrated simultaneously	NA	Humanitarian	Determinist	Min	Costs	Capacity	Single	Vehicle	Homo	Recycling products	High	Heuristic	R	10
(Tirkolaee et al., 2020)	**Allocation-scheduling**	Integrated simultaneously	NA	Humanitarian	Stochastic	Min	Time, delay	Priority levels	Single	Vehicle	Hetero	People	High	Exact	R	6
(VonAchen et al., 2016)	**Location-routing**	Integrated simultaneously	Fixed	Healthcare	Determinist	Min	Sites, costs	Capacity	Multi (2)	Pedestrian and bikes	Hetero	Medical service	NA	Exact	R	55

CHAPTER 6: DISCUSSION

The literature review allowed us to see the major contributions in terms of logistics in remote areas. One of the main observations is that the concept of remote logistics is new in the scientific literature, especially for regions like the North of Canada. The lack of specific scientific research on logistics in remote areas in the context of food distribution (food security) is the motivation to propose a systematic literature review to establish the current state of the art and identify the next research steps to follow. We were able to use the known literature on general logistics in remote regions to make some links to our context of the application. We noticed that logistics in a humanitarian setting were very similar in terms of identified characteristics to remote logistics in Northern Canada Table 3.3. The general applications, all domains included, were considered for this study because of their transposability characteristics. That was explained by the broad definition of 'remote' that allows for attributes like 'hard-to-reach', 'difficulty of access', 'lack of infrastructure' and 'dispersed population, all included as inclusion criteria in the initial search.

Our framework in Figure 2.3 proposed an existing link between factors of food insecurity and logistics activities. More so, the direct influence of *accessibility* and *availability* is an indicator that logistics have an important impact. This study states that OR/MS concepts like Network Planning and Distribution Planning can directly influence the notion of food security by the intermediate relationship to accessibility and availability notions.

One major observation is the lack of uniformity in the definition of these terms (availability and accessibility) and practice, they are used interchangeably. Accessibility is more present in the reviewed literature than the availability notion. Based on the dimensions of food security of (Gregory et al., 2005), we are the first, to our knowledge, to attempt at providing a clear distinction between the two notions in terms of the type of logistical problems. It is clear to us that ***accessibility is the possibility to access and reach a certain location that offers a product/service*** whereas ***availability is to obtain through network utilization (routing) of the said product/service at a pre-established location.***

To classify and analyze the literature, we divided the articles according to the type of logistical problems. Three main categories were identified: location-allocation problems, distribution problems and combined problems. Then, sub-categories were proposed with our second axis of analysis that made the distinction between the domain of application (industrial and public sector, healthcare, and humanitarian setting).

Among the reviewed literature on location problems, very few authors raised the question of hub location for improving accessibility. Only (Frank et al., 2021; Mejía et al., 2021; Pan et al., 2020; Vazifeh et al., 2021) did so. However, that question deserved more attention because one of the drawbacks of remote regions is the long distance between supply-demand nodes. Therefore, it would make sense to segment the network into shorter travels (hub/temporary facility) to cut down the distance travelled in the same route. One of the main advantages of the hub point is that it allows the flow to be aggregated or disaggregated and this leads to economies of scale in transportation costs. This was done more often in location problems under the industrial and public sector category – with three of them in the context of the food industry. The multi-echelon type of hub structure seems more interesting in the remote context due to the very long distance and multiple transportations used in North Canada (a mix of sea, air, and ground transportation). We recommend that future contributions will explore the multi-layer aspect of the problem both in the location, routing, and integrated literature.

In terms of network planning and utilization, the mode of transportation becomes an important element to consider when distributing products in remote regions. However, very few contributions analyzed the appropriate mode of transportation for special terrain. For example, some regions (including Northern areas), are considered remote not only because of the distance but because of the difficulty to reach the areas due to additional terrain restrictions. In the North, roads are mostly unpaved, iced and sometimes blocked/unavailable. With that in mind, papers like (Y. Chen et al., 2021; Shrestha et al., 2014) become interesting because they proposed a model that decides on the road upgrading system (i.e., a FLP with the construction of a road and minimum distance between station or multi-objective model that takes into consideration the geometry of the roads and minimize the upgrading costs while maximizing coverage).

A third observation was the inclusion of human factors in mathematical models. They were exclusive to humanitarian problems. For example, in location-allocation problems (Anaya-Arenas et al., 2018; Geng et al., 2021; Loree & Aros-Vera, 2018) and distribution ones (Holguín-Veras et al., 2013; Nadi & Edrisi, 2017) included the notion of human suffering or survival function, that was more often presented as a penalty cost. The innovative formulation of including the human cost in an objective function is very interesting when it comes to food insecurity problems because this reveals that there is a way of quantifying the suffering engendered by an inadequate supply of foods in a similar way to the suffering caused by a shortage of rescue equipment. Likewise, the element of fairness was considered in studies (Anaya-Arenas et al., 2018; Escribano Macias, Angeloudis, et al., 2020; Ferrer et al., 2018; J. Jiang et al., 2017; Sopha et al., 2019) and authors agree in measuring the fairness by the gap between satisfied and unsatisfied demand. These mathematical formulations are a relatively new way of integrating human and social aspects. Only publications after 2017 proposed such equations. We firmly believe that the traditional commercial setting is less relevant in a remote setting. Hence, companies that supply the north, and receive governmental incentives, need to plan a distribution including factors such as equity, accessibility, and frequency.

A fourth observation is among the location problems, we found a lot of spatial analysis models that used visualization tools (GIS) to assist decision-making. This aspect is interesting, especially when looking at the terrain aspect (geography, road topography etc.) because it allows us to visually see the area and helps us understand the challenges. Interestingly, Mommens K. et al. (2021)

demonstrated that the best way to configure a sustainable network in rural areas was to consider home deliveries rather than collection points. We think that this proposition deserves to be explored more for our context in remote Canada. It was also perceived that the industrial domain of application didn't use as many technological tools as other domains, which is surprising because the industrial field usually has more resources and advanced technological tools than the public sector or humanitarian organizations.

The fifth discussion point is the data modelling environment for all our papers. Deterministic data is used in the industrial or general setting environment, which is to be expected. However, in the context of humanitarian logistics, the modelling data are too often deterministic and don't allow us to capture the reality and complexity of the problem. These stochastic types of contributions are still rare but needed. We understand that the remote aspect of the context studied is better captured by a stochastic data model. This can cover the challenges of blocked roads (by snow or other reasons), the variation of supply and demand and more. Also, it was argued by Sopha et al. (2019), that due to the characteristics of humanitarian operations which are stochastic, dynamic and adaptive, the simulation approach is preferable to analytical models. However, in our review of 91 papers, only six used the simulation tool. We believe that the field of remote logistics can indeed profit from the current trend of hybrid approaches (simulation and optimization) to better plan the distribution of products in this context.

From the systematic literature review and analysis done in the previous section, the following key considerations can be drawn for logistics in remote areas targeting food insecurity in the North.

Type of logistical problem: The most popular topic in the literature review was distribution problems in humanitarian applications. But because we want to tackle the whole system of the food supply chain, an integrated formulation would be more appropriate for our context. As an example, a classic FLP-VRP. The location portion would target increasing accessibility for the community by considering hub location to cut down distance or utilization of temporary facilities to increase coverage at lower installment costs. The network planning would need some terrain consideration with a cost function (using the current road or building new ones). Then, the distribution planning would integrate decisions on network utilization (routing) to increase product availability at lower costs. The objective function will most likely be a multi-objective and if there are some conflicting objectives, a trade-off analysis with a weighted method can be used (Cubillos & Wøhlk, 2021).

Type of network: Most likely a two echelons, which makes sense because of the integrated model. The network would need to include entities like the warehouse/distribution center, the local grocery stores, and the population nodes. Note that the analysis would be for the last-mile portion of the food supply chain, so once the cargo makes it to the remote regions (across the sea).

Transportation: The mode of transportation will need to be refined further than vehicles. Because of the unique climate, we would need to think outside the box (e.g., snowmobile, sleigh etc.), with most likely a heterogeneous fleet for different terrain access.

Constraints: One of the main elements that will need to be taken into consideration would be the social aspect of the food security crisis. The present review proved that human suffering can be incorporated as a mathematical equation. Many formulations allow to do so: penalty cost of unsatisfied demand, the social cost of even level service, the gap between unsatisfied demand, human suffering measured by waiting time, and the degree of psychological distress caused by shortages. Another important aspect would be the food spoilage constraint due to the type of products we want to target. The model would need to go beyond the covering of the demand and include an accessibility equation (e.g., the ratio between supply and demand) to provide equity in the distribution (Schlögl et al., 2019).

Remote characteristics modelling: As a starting point, the remote characteristics identified in our inclusion and exclusion criteria can be a good modelling guide. Four main characteristics reflect the remote regions according to this study: 1) the area is considered remote because it is far from the main centers (underserved region/hard-to-reach), 2) there is a long distance to travel for distribution, 3) there is a poor or inexistent infrastructure to support the operations and 4) the population is geographically dispersed. On top of that, the model will most definitely need to consider the unique aspect of the North (chapter 1), like climate constraints (iced roads), limited road availability, and limited mode of transportation. As well as include a constraint for food spoilage (fresh foods). The objective would be to provide equitable food distribution for everyone at minimum costs.

Resolution method and technology integration: an optimization model could be used to solve the problem, just like it was the resolution method of choice in the literature. In addition, a technological tool like GIS can support decision-making because it is a great visualization tool. However, an important element raised by Sopha et al. (2019) is that due to the characteristics of humanitarian operations which are stochastic, dynamic and adaptive, the simulation approach is preferable to analytical models.

CONCLUSION

In conclusion, this present work is the first of our knowledge to propose a systematic literature review for logistics in remote areas. The objective was to account for the current evidence-based research in the **operational research and management sciences** field for **logistics problem** applications in **remote areas** and see the **general trends** that could be applied in the remote regions of Northern Canada to diminish food insecurity. We attained our objective by conducting a thorough systematic literature review. Not only did this work provides a methodological compilation and summarization of the published literature on the topic, but it also links the notions of logistics in OR/MS to factors of food insecurity. The bridge between those domains of application is the notions of accessibility and availability.

The general observation and trend identified could be transposed to a context like the North of Canada. The thorough description of the context and unique environment is also very important to this work. As part of the contributions, defining and documenting the living conditions in the specific region of northern Canada is the first step to understanding. Only then, we will be able to tackle the real problem.

Now we know that 1) food security can be influenced by OR/MS activities of logistics, either by location and/or distribution planning, 2) that the notions of accessibility and availability are the link between these two distinct domains and 3) the literature analyzed among three axes of applications (industrial, healthcare, humanitarian), revealed that remote regions share some similar characteristics to the ones in humanitarian logistics context. Moreover, one question remains: is the food insecurity crisis in the North considered a logistic problem or a humanitarian one?

Limitations

We chose the systematic literature review method to deliver clear, meticulous, transparent and reproducible research. However, the following limitations were acknowledged.

- Our proposed framework only targets the planning phase of logistical activities and more specifically only location and distribution models. That reflects only a tiny portion of activity among many others that could influence food security in remote regions. In the same way, we focus only on the accessibility and availability components of the food system.

- We are conscious that the paper focused on a transposable application for Northern Canada. The research could eventually be broadened to other areas in the world.

APPENDIX A

Geographical delimitations of the North

Nord canadien

Archipel Arctique

Nunavik

APPENDIX B

Available roads and distances

Table 2: Road infrastructure

Community access to road systems (local and regional)					
		Number of communities per category			Total
		Local roads only	Seasonal regional road access	All-season regional road access	
Region	Nunatsiavut	5	0	0	5
	Nunavik and Eeyou Istchee	15	0	8	23
	Nunavut	25	0	0	25
	Northwest Territories	4	12	16	32
	Yukon	1	0	14	15
Total		50	12	38	100

Source: Aboriginal Affairs and Northern Development Canada 2014; Conference Board of Canada 2014; Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Centre for Topographic Information, "National Road Network 2.0," 2007

Table 3: Road infrastructure - Average travel distances

Road travel distances between peripheral communities and regional hubs (including travel by ferry service, and seasonal and all-season roads)				
		Geographic information		
		# of peripheral communities with road network access to regional hub	Closest regional hub	Average distance in km
Region	Nunatsiavut	5	Happy Valley-Goose Bay	540 (includes ferry travel)
	Eeyou Istchee	8	Chibougamau	420
	Northwest Territories	27	Yellowknife or Whitehorse (whichever is closest)	764
	Yukon	13	Whitehorse	313

Source: Government of the Northwest Territories, "Distance in Kilometres Between Northwest Territories Communities"; Yukon Government, "Yukon Distance Chart"; Transport Québec, "Travelling Distance Estimation Tool"; Government of Newfoundland and Labrador, "Road Distance Data Base."

APPENDIX C

Air transportation

Table 4: Air transportation infrastructure

Community access to air transport systems							
		Number of communities per category					Total
		No airport	Local airport[50]	Indirect flights to regional air transit hub[51]	Direct flights to regional air transit hub[52]	Regional air transit hub[53]	
Region	Nunatsiavut	0	0	4	1	0	5
	Nunavik and Eeyou Istchee	2	1	13	5	2	23
	Nunavut	0	0	10	13	2	25
	Northwest Territories	2	9	5	12	3	32
	Yukon	2	11	0	2	1	15
Total		6	21	32	33	8	100

Source: Aboriginal Affairs and Northern Development Canada 2014; Conference Board of Canada 2014

APPENDIX D

Maritime transportation

Table 5: Water transport infrastructure

Community access to water transport facilities								
		Number of communities per category						Total
		No resupply service (small boating facilities present)	Irregular resupply (barge)	Seasonal resupply (barge)	Seasonal resupply (sealift)	DFO-recognized small craft harbour	DFO-recognized small craft harbour (supports core fishing and resupply)[65]	
Region	Nunatsiavut	0	0	0	0	3	2	5
	Nunavik and Eeyou Istchee	5	1	2	15	0	0	23
	Nunavut	0	0	0	24	0	1	25
	Northwest Territories	18	1	7	4	1	1	32
	Yukon	13	2	0	0	0	0	15
Total		36	4	9	43	4	4	100

Source: Aboriginal Affairs and Northern Development Canada 2014; Conference Board of Canada 2014; Fisheries and Oceans Canada, http://www.dfo-mpo.gc.ca/sch-ppb/list-liste-eng.htm

Company	Characteristics	Capacity	Number of destinations served
Nunavut Eastern Arctic Shipping Inc., (NEAS)	Jonction of 4 entities Base: Valleyfield, QC	4 ships Between 4864 et 12 784dwt. each	40
Nunavut Sealink and Supply Inc.	Combination of Copperatives Limited and Desgagnés Transarctik Inc. Base : Côte-Sainte-Catherine, QC	5 ships Between 7239 et 17 850dwt. each	25
Northern Transportation Corporation Limited	Contract of transporters for government deliveries	A fleet of 13 tugs: 1500 et 7200 bhp. + 100 barges + 1500 in-house containers	22

Source: Mary R. Brooks, J. D. F. (2012). "Providing freight services to remote arctic communities: Are there lessons for practitioners from services to Greenland and Canada's northeast?" ELSEVIER **Research in Transportation Business & Management 4 (2012) 69–78**: 69-78.

APPENDIX E

Filing system

1. Article synthesis	
Reference : Scopus	Code
Authors: John Clarke, Viviae Gascon, and Jacques A. Ferland Title : A Capacitated Vehicle Routing Problem with Synchronized Pick-Ups and Drop-Offs: The Case of Medication Delivery and Supervision in the DR Congo Journal : IEEE Transactions of engineering management Year : 2017 Pages : 10	Routing problem (CVRP-air), Healthcare, Solver, software, Case study (Congo)
Abstract	
In postemergency contexts such as the Democratic Republic of Congo (DR Congo), one of the crucial challenges that rural hospitals face is maintaining a pharmacy with essential medications and supplies. There is a negative humanitarian impact when hospitals do not have medications for treatable diseases; hospitals incur financial losses when too much medication is ordered and expires. Moreover, the cost of transporting medications and providing on-site supervision to remote hospitals is an extremely expensive endeavor. Sometimes, the transportation costs can exceed the cost of the medications. Using as a case study, the province of Bandundu, in the DR Congo, we attempt to determine the feasibility (in terms of problem complexity and potential savings) of a synchronized routing problem for medication delivery and on-site supervision visits. We propose a capacitated vehicle routing problem formulation handling several novel requirements: activity-wise synchronization, precedence, and two activity frequencies. We implement a new heuristic procedure with a geospatially enabled database to solve the problem. Administrators can use a web-based tool to view the results as interactive maps. Preliminary results suggest that a synchronized solution allows rural hospitals to increase accessibility to medical services to rural populations by increasing delivery frequencies from 4 months to 1 month.	
Objectives	
This research aims at planning and determining medication delivery routes by air and supervision visits, where the maximum payload of an aircraft must be respected. by solving a CVRP with synchronized pick-ups and drop-offs (CVRP-SyncPD) in order to improve access to medical care in developing countries.	
Themes/domain of application	
Healthcare – Humanitarian logistic problem	
Problem description/type	
Cooperstive rich vehicle routing problem by air, Mathematical formulation p.3 : Objective function: minimize cost of route and the marginal cost of the least expensive aircrafts with sufficient capacity	
Resolution method used	
Heuristic solution approach, column generation approach. Entered solving a mixed integer problem with CPLEX. Solver, software	
Data (artificial or real data)	
Case study (Congo)	
Results / conclusion	
A synchronized solution allows rural hospitals to increase accessibility to medical services to rural populations by increasing frequencies of deliveries from 4 months to 1 month. It contributes to the existing humanitarian logistics literature by exposing, describing, and modeling a (is well-known to practitioners but is under researched by theoreticians. Also, a sufficient illustration of the concept is provided for an eventual GIS-enabled web-based decision tool for practitioners in the field. A CVRP-SyncPD is formulated and solved.	

Article	Problem description	Model	Mathematical model	Objective function
1	52 zones Serving 106 000 each 41 hospitals Deliveries: hospital prepare orders large enough to fill an entire aircraft with deliveries every 4 months Goal: at least one delivery every month **CVRP-air**	Modeled as a set partitioning problem Generates a set of routes R a priori with clusters of the shortest path and lowest marginal cost Single depot, single supervisor Restrictions: Each route must be completed in one day (time limit) Aircraft capacity	The model determines two sets of binary decisions variables. If the route r takes place on at t and month k and 2. If hospital I receives its medication on day t. 10 constraints -Exactly one monthly delivery -At least one supervisor visits each hospital -Supervisor is picked up at the same hospital he was dropped off -Supervisor is picked up at the depot on the first travel day of every month - Supervisor is dropped off at the depot the last travel day of every month - Exactly one route is assigned to a travel day -Each hospital receives its medication delivery on the same day each month -Each hospital receives its medication on exactly one travel day	Min $\sum_{r\in R}\sum_{k\in K}\sum_{t\in T} c_r y_{rkt}$ Minimize cost of routes
	Solution approach		**Results**	
	Heuristic approach using only a subset of the routes, including three phases. 1- Generate subsets of medical delivery routes based on hospital adjency. With a Voronoi diagram. Then, generating several subsets with a relaxed set-partitioning problem to determine the least costly delivery routes allowing all hospital to receive their medication. The problem is solved with CPLEX. 2- Specify a strategy using different subset to generate synchronized MSR leading to a feasible solution. And for each month, a sequence of synchronized MSR is constructed. On most travel days, a TSP has to be solved to obtain a new route. After a solution is generated, travel days are scheduled in the calendar according to the hospital needs. 3- The best feasible solution is selected – the cheapest solution		2612 feasible solutions in 30 seconds for phase I and 5 near-optimal or n-opt-solutions were obtained by solving the relaxed MIP with CPLEX in 1 sec. For phase II, synchronized MSR were generated for the 5 near-opt solutions. The corresponding 110 feasible solutions were evaluated in 30 sec. to find the cheapest solution. This approach (monthly deliveries with supervision) offers the same transportation costs as the current min-cord strategy. The heuristic provides a good feasible solution, but future research could be devoted to testing an exact solving approach as column generation.	

				Type of logistic problem			Constraints		
#	Authors	Domain of application ++	Country of authors	Type of logistic problem	Specifics	Specifics+	S / M	Applied on	Category
1	(Clarke J. et al., 2017)	Humanitarian - post-disaster	Canada	Distribution planning	VRP	VRP: CVRP-SyncgPD	Single	Time frame, drone capacity, flight time	Time, units
2	(Yang F. et al., 2020)	Industrial	China	Distribution planning	VRP	VRP: Co-VRP	Single	Different truck capacities	Units and volume
3	(Es Yurek and Ozmutlu H.C., 2018)	General	Turkey	Distribution planning	TSP	TSP: TSP-D	Multi	Drone capacity, battery life	Units, Battery life
4	(Rabta B. et al., 2018)	Humanitarian - disaster	Austria	Distribution planning	VRP	Routing problem	Multi	Maximum payloads, battery life, demand, priority	Units, Battery life, levels
5	(Tirkolaee B. E. et al., 2020)	Humanitarian - disaster	Iran	Distribution planning	TSP	TSP: TSP+UPMS	Single	Severity priority	Levels
6	(Chen H. et al., 2018)	Public sector	United-Kingdom	Distribution planning	VRP	VRP: MMMDRPP	Multi	me limit of day work, closed routes and traversal constrair	Time, other
7	(Vazifeh Z. et al., 2021)	Biomass	Canada	Network planning	Flow problem	Methodology: stackelberg game theor	Single	Inventory levels at different entities	Weight
8	(Cherkesly M. et al., 2019)	Community healthcare	Canada	Network planning	Location-routing-covering model	LRCP: location routing covering	Multi	Time limit of day work, max radius covergae, max populat	Time, distance, units

APPENDIX F

Accessibility measure by (Luo et al., 2017)

floating catchment area (2SFCA) method to account for both aspects. Given m resident locations and n facilities, the accessibility index is measured such as

$$A_i = \sum_{j=1}^{n} R_j f\left(d_{ij}\right) \tag{1}$$

$$R_j = \frac{S_j}{\sum_{k=1}^{m} D_k f\left(d_{kj}\right)}, \tag{2}$$

where A_i is the accessibility index of residents at the ith area, S_j is the supply capacity of the jth facility, that is, here CHCI for hospital j, D_k is the demand of the kth area, that is, here population in village k, d_{ij} or d_{kj} is the distance from residential area i or k to facility j, f is the distance decay function, m is the number of residential areas, n is the number of facilities, i or k is the index of residential areas from 1 to m, and j is the index of facilities from 1 to n.

BIBLIOGRAPHY

Afshar, A., & Haghani, A. (2012). Modelling integrated supply chain logistics in real-time large-scale disaster relief operations. *Socio-Economic Planning Sciences*, *46*(4), 327–338.

Alasia, A., Bédard, F., Bélanger, J., Guimond, E., & Penney, C. (2017). Measuring remoteness and accessibility - A set of indices for Canadian communities. *Statistics Canada*, *18-001–X*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www150.statcan.gc.ca/n1/en/pub/18-001-x/18-001-x2017002-eng.pdf?st=-1wu5heU

Alinaghian, M., & Goli, A. (2017). Location, Allocation and Routing of Temporary Health Centers in Rural Areas in Crisis, Solved by Improved Harmony Search Algorithm. *International Journal of Computational Intelligence Systems*, *10*(1), 894–913. https://doi.org/http://dx.doi.org/10.2991/ijcis.2017.10.1.60

Amarilies, H. S., Redi, A. A. N. P., Mufidah, I., & Nadlifatin, R. (2020). Greedy Heuristics for the Maximum Covering Location Problem: A case study of Optimal Trashcan Location in Kampung Cipare – Tenjo – West Java. *IOP Conference Series. Materials Science and Engineering*, *847*(1). https://doi.org/http://dx.doi.org/10.1088/1757-899X/847/1/012007

Anaya-Arenas, A. M., Ruiz, A., & Renaud, J. (2018). Importance of fairness in humanitarian relief distribution. *Production Planning & Control*, *29*(14), 1145–1157. https://doi.org/10.1080/09537287.2018.1542157

Anuar, W. K., Lee, L. S., Pickl, S., & Seow, H.-V. (2021). Vehicle routing optimisation in humanitarian operations: A survey on modelling and optimisation approaches. *Applied Sciences* (Switzerland), 11(2), 1–70. https://doi.org/10.3390/app11020667

Anwar, S., Elagroudy, S., Razik, M. A., Gaber, A., Bong, C. P. C., & Ho, W. S. (2018). Optimization of solid waste management in rural villages of developing countries. *Clean Technologies and Environmental Policy*, *20*(3), 489–502. https://doi.org/http://dx.doi.org/10.1007/s10098-018-1485-7

Araya, F., Dell, R., Donoso, P., Marianov, V., Martínez, F., & Weintraub, A. (2012). Optimizing location and size of rural schools in Chile. *International Transactions in Operational Research*, *19*(5), 695–710. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=78386634&lang=fr&site=ehost-live

Araya-Córdova, P. J., Dávila, S., Valenzuela-Levi, N., & Vásquez, Ó. C. (2021). Income inequality and efficient resources allocation policy for the adoption of a recycling program by municipalities in developing countries: The case of Chile. *Journal of Cleaner Production*, *309*, N.PAG-N.PAG. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=150695958&lang=fr&site=ehost-live

Arriagada, P. (2017). Study: Food insecurity among Inuit living in Inuit Nunangat, 2012. *Insights on Canadian Society*, *2017001*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www150.statcan.gc.ca/n1/en/pub/75-006-x/2017001/article/14774-eng.pdf?st=bNXt7t6E

Baidya, A., & Bera, U. K. (2019). New model for addressing supply chain and transport safety for disaster relief operations. *Annals of Operations Research*, *283*(1/2), 33–69. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=140064202&lang=fr&site=ehost-live

Banques alimentaires Canada. (2016). *L'insécurité alimentaire dans le Nord : Un fléau que l'on ne peut plus ignorer*.

Berg, P. L. van den, Fiskerstrand, P., Aardal, K., Einerkjær, J., Thoresen, T., & Røislien, J. (2019). Improving ambulance coverage in a mixed urban-rural region in Norway using mathematical modeling. *PLoS One*, *14*(4). https://doi.org/http://dx.doi.org/10.1371/journal.pone.0215385

Bo-Cheng, L., Chao-Wen, C., Chien-Chou, C., Kuo, C.-L., I-chun, F., Chi-Kung, H., I-Chuan, L., & Ta-Chien, C. (2016). Spatial decision on allocating automated external defibrillators (AED) in communities by multi-criterion two-step floating catchment area (MC2SFCA). *International Journal of Health Geographics*, *15*. https://doi.org/http://dx.doi.org/10.1186/s12942-016-0046-8

Bozorgi-Amiri, A., Jabalameli, M. S., Alinaghian, M., & Heydari, M. (2012). A modified particle swarm optimization for disaster relief logistics under uncertain environment. *International Journal of Advanced Manufacturing Technology*, *60*(1–4), 357–371. https://doi.org/10.1007/S00170-011-3596-8

Bradette-Laplante, M., Courtemanche, Y., Desrochers-Couture, M., Forget-Dubois, N., Bélanger, R. E., Ayotte, P., Jacobson, J. L., Jacobson, S. W., & Muckle, G. (2020). Food insecurity and psychological distress in Inuit adolescents of Nunavik. *Public Health Nutrition*, *23*(14). https://doi.org/10.1017/S1368980020000117

Burnett, K., Skinner, K., Hay, T., LeBlanc, J., & Chambers, L. (2017). Retail food environments, shopping experiences, First Nations and the provincial Norths. *Health Promotion and Chronic Disease Prevention in Canada*, *37*(10), 333–341. https://doi.org/10.24095/hpcdp.37.10.03

Campbell, A. M., & Jones, P. C. (2011). Prepositioning supplies in preparation for disasters. *European Journal of Operational Research*, *209*(2), 156–165.

Canadian Feed the Children. (2022). *Why is there food insecurity in Canada ?* https://canadianfeedthechildren.ca/the-feed/why-food-insecurity/

Center for the North at the Conference Board of Canada. (2014). *Study on Addressing the Infrastructure Needs of Northern Aboriginal Communities*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=http%3A

%2F%2Fwww.naedb-cndea.com%2Freports%2Fnorthern-infrastructure-report.pdf&clen=1750397&chunk=true

Chaovalitwongse, P., Somprasonk, K., Phumchusri, N., Heim, J., Zabinsky, Z., & Chaovalitwongse, W. (2017). A decision support model for staff allocation of mobile medical service. *Annals of Operations Research*, *249*(1/2), 433–448. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=121061380&lang=fr&site=ehost-live

Chauhan, D., Unnikrishnan, A., & Figliozzi, M. (2019). Maximum coverage capacitated facility location problem with range constrained drones. *Transportation Research Part C: Emerging Technologies*, *99*, 1–18. https://doi.org/10.1016/j.trc.2018.12.001

Chee Yew Wong. (2021). International Journal of Physical Distribution & Logistics Management. *Editorial*, *51*(3), 205–211.

Chen, A. Y., & Yu, T. Y. (2016). Network based temporary facility location for the Emergency Medical Services considering the disaster induced demand and the transportation infrastructure in disaster response. *Transportation Research Part B: Methodological*, *91*, 408–423. https://doi.org/10.1016/J.TRB.2016.06.004

Chen, H., Cheng, T., & Shawe-Taylor, J. (2018). A Balanced Route Design for Min-Max Multiple-Depot Rural Postman Problem (MMMDRPP): a police patrolling case. *International Journal of Geographical Information Science*, *32*(1), 169–190. https://doi.org/10.1080/13658816.2017.1380201

Chen, Y., Lai, Z., Wang, Z., Yang, D., & Wu, L. (2021). Optimizing locations of waste transfer stations in rural areas. *PLoS ONE*, *16*(5 May). https://doi.org/10.1371/journal.pone.0250962

Cherkesly, M., Rancourt, M. È., & Smilowitz, K. R. (2019). Community Healthcare Network in Underserved Areas: Design, Mathematical Models, and Analysis. *Production and Operations Management*, *28*(7), 1716–1734. https://doi.org/10.1111/poms.13008

Chowdhury, A. I., Haider, R., YousufAbdullah, A., Christou, A., Ali, N. A., Rahman, A. E., Iqbal, A., Bari, S., Emdadul Hoque, D. M., Arifeen, S. el, Kissoon, N., & Larson, C. P. (2018). Using geospatial techniques to develop an emergency referral transport system for suspected sepsis patients in Bangladesh. *PLoS One*, *13*(1). https://doi.org/http://dx.doi.org/10.1371/journal.pone.0191054

Clarke, J., Gascon, V., & Ferland, J. A. (2017). A Capacitated Vehicle Routing Problem with Synchronized Pick-Ups and Drop-Offs: The Case of Medication Delivery and Supervision in the DR Congo. *IEEE Transactions on Engineering Management*, *64*(3), 327–336. https://doi.org/10.1109/TEM.2017.2673541

Contreras, I., & Fernández, E. (2012). General network design: A unified view of combined location and network design problems. *European Journal of Operational Research*, *219*(3), 680–697. https://doi.org/10.1016/j.ejor.2011.11.009

Cooper, G. S., Shankar, B., Rich, K. M., Ratna, N. N., Alam, M. J., Singh, N., & Kadiyala, S. (2021). Can fruit and vegetable aggregation systems better balance improved producer livelihoods with more equitable distribution? *World Development*, *148*, N.PAG-N.PAG. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=152498140&lang=fr&site=ehost-live

Cubillos, M., & Wøhlk, S. (2021). Solution of the maximal covering tour problem for locating recycling drop-off stations. *Journal of the Operational Research Society*, *72*(8), 1898–1913. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=152230582&lang=fr&site=ehost-live

Dantzig, G. and Ramser, J. (1959) The Truck Dispatching Problem. Management Science, 6, 80-91.http://dx.doi.org/10.1287/mnsc.6.1.80

Davis, L. B., Sengul, I., Ivy, J. S., Brock III, L. G., & Miles, L. (2014). Scheduling food bank collections and deliveries to ensure food safety and improve access. *Socio-Economic Planning Sciences*, *48*(3), 175–188. https://doi.org/10.1016/j.seps.2014.04.001

Davoodi, S. M. R., & Goli, A. (2019). An integrated disaster relief model based on covering tour using hybrid Benders decomposition and variable neighborhood search: Application in the Iranian context. *Computers & Industrial Engineering*, *130*, 370–380. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=136178602&lang=fr&site=ehost-live

Delisle, H. (1998). La sécurité alimentaire, ses liens avec la nutrition et la santé. *Canadian Journal of Development Studies/Revue Canadienne d'études Du Développement*, *19*(4). https://doi.org/10.1080/02255189.1998.9669789

Desjardins, R., & Monderie, R. (2007). *The Invisible Nation*. https://www.nfb.ca/film/invisible_nation/

Dharmadhikari, N., & Farahmand, K. (2019). Location Allocation of Sugar Beet Piling Centers Using GIS and Optimization. *Infrastructures*, *4*(2), 17. https://doi.org/http://dx.doi.org/10.3390/infrastructures4020017

Dillabough, H. (2016). *Accès à l'alimentation dans le Nord éloigné du Canada*. Northern Policy Institute. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww.northernpolicy.ca%2Fupload%2Fdocuments%2Fpublications%2Fcommentaries-new%2Fdillabough_food-for-thought-fr.pdf&clen=4316529&chunk=true

Dufour, É., Laporte, G., Paquette, J., & Rancourt, M. È. (2018). Logistics service network design for humanitarian response in East Africa. *Omega (United Kingdom)*, *74*, 1–14. https://doi.org/10.1016/j.omega.2017.01.002

Durach, C. F., Kembro, J. H., & Wieland, A. (2021). How to advance theory through literature reviews in logistics and supply chain management. *International Journal of Physical Distribution and Logistics Management*, *51*(10), 1090–1107. https://doi.org/10.1108/IJPDLM-11-2020-0381

Es Yurek, E., & Ozmutlu, H. C. (2018). A decomposition-based iterative optimization algorithm for traveling salesman problem with drone. *Transportation Research Part C: Emerging Technologies*, *91*, 249–262. https://doi.org/10.1016/j.trc.2018.04.009

Escribano Macias, J., Angeloudis, P., & Ochieng, W. (2020). Optimal hub selection for rapid medical deliveries using unmanned aerial vehicles. *Transportation Research Part C: Emerging Technologies*, *110*, 56–80. https://doi.org/10.1016/j.trc.2019.11.002

Escribano Macias, J., Goldbeck, N., Hsu, P.-Y., Angeloudis, P., & Ochieng, W. (2020). Endogenous stochastic optimisation for relief distribution assisted with unmanned aerial vehicles. *OR Spectrum*, *42*(4), 1089–1125. https://doi.org/10.1007/s00291-020-00602-z

EunSu Lee, M. M. E. O. and W. M. (2021). Statewide Ambulance Coverage of a Mixed Region of Urban, Rural and Frontier under Travel Time Catchment Areas. *International Journal of Environmental Research and Public Health*, *18*(5), 2638. https://doi.org/http://dx.doi.org/10.3390/ijerph18052638

Feng, Z. (2020). Constructing rural e-commerce logistics model based on ant colony algorithm and artificial intelligence method. *Soft Computing*, *24*(11), 7937–7946. https://doi.org/10.1007/s00500-019-04046-8

Ferrer, J. M., Martín-Campo, F. J., Ortuño, M. T., Pedraza-Martínez, A. J., Tirado, G., & Vitoriano, B. (2018). Multi-criteria optimization for last mile distribution of disaster relief aid: Test cases and applications. *European Journal of Operational Research*, *269*(2), 501–515. https://doi.org/10.1016/j.ejor.2018.02.043

Ford, J. D., & Beaumier, M. (2011a). Feeding the family during times of stress: Experience and determinants of food insecurity in an Inuit community. *Geographical Journal*, *177*(1), 44–61. https://doi.org/10.1111/j.1475-4959.2010.00374.x

Ford, J. D., & Beaumier, M. (2011b). Feeding the family during times of stress: experience and determinants of food insecurity in an Inuit community. *The Geographical Journal*, *177*(1). https://doi.org/10.1111/j.1475-4959.2010.00374.x

Ford, J. D., Pearce, T., Duerden, F., Furgal, C., & Smit, B. (2010). Climate change policy responses for Canada's Inuit population: The importance of and opportunities for adaptation. *Global Environmental Change*, *20*(1). https://doi.org/10.1016/j.gloenvcha.2009.10.008

Frank, L., Dirks, N., & Walther, G. (2021). Improving rural accessibility by locating multimodal mobility hubs. *Journal of Transport Geography*, *94*, N.PAG-N.PAG. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=151328834&lang=fr&site=ehost-live

Gao, W., Luo, J., Zhang, W., Yuan, W., & Liao, Z. (2020). Commanding Cooperative UGV-UAV with Nested Vehicle Routing for Emergency Resource Delivery. *IEEE Access*, *8*, 215691–215704. https://doi.org/10.1109/ACCESS.2020.3040790

Geng, J., Hou, H., & Geng, S. (2021). Optimization of warehouse location and supplies allocation for emergency rescue under joint government–enterprise cooperation considering disaster victims' distress perception. *Sustainability (Switzerland)*, *13*(19). https://doi.org/10.3390/su131910560

Ghiani, G., Laporte, G., & Musmanno, R. (2013). *Introduction to Logistics Systems Management*. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118492185

Giguère, M.-A., Comtois, C., & Slack, B. (2017). Constraints on Canadian Arctic maritime connections. *Case Study on Transport Policy* , *5*(2), 355–366. http://www.sciencedirect.com/science/journal/2213624X

Görmez, N., Köksalan, M., & Salman, F. S. (2011). Locating disaster response facilities in Istanbul. *Journal of the Operational Research Society*, *62*(7), 1239–1252. https://doi.org/10.1057/JORS.2010.67

Gough, D., Oliver, S., & Thomas, J. (2017). *An Introduction to Systematic Reviews* (Sage publications Ltd, Ed.).

Gregory, P. J., Ingram, J. S. I., & Brklacich, M. (2005). Climate change and food security. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1463), 2139–2148. https://doi.org/10.1098/rstb.2005.1745

Grubesic, T. H., Murray, A. T., & Matisziw, T. C. (2013). A strategic approach for improving rural air transport in the United States. *Transport Policy*, *30*, 117–124. https://doi.org/10.1016/j.tranpol.2013.09.004

Gu, Y., & Wallace, S. W. (2021). Operational benefits of autonomous vessels in logistics—A case of autonomous water-taxis in Bergen. *Transportation Research: Part E*, *154*, N.PAG-N.PAG. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=152769939&lang=fr&site=ehost-live

Gupta, K. (2017). Inventory and transportation cost minimization in the delivery logistics of swine flu vaccine. *Yugoslav Journal of Operations Research*, *27*(4), 481–497. https://doi.org/10.2298/YJOR160617022G

Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Systematic Reviews*, *18*(2), e1230. https://doi.org/https://doi.org/10.1002/cl2.1230

Han, Y., Guan, X., & Shi, L. (2011). Optimization based method for supply location selection and routing in large-scale emergency material delivery. *IEEE Transactions on Automation Science and Engineering*, *8*(4), 683–693. https://doi.org/10.1109/TASE.2011.2159838

Holguín-Veras, J., Pérez, N., Jaller, M., van Wassenhove, L. N., & Aros-Vera, F. (2013). On the appropriate objective function for post-disaster humanitarian logistics models. *Journal of Operations Management*, *31*(5), 262–280. https://doi.org/10.1016/J.JOM.2013.06.002

Hong, J. D., Xie, Y., & Jeong, K. Y. (2012). Development and evaluation of an integrated emergency response facility location model. *Journal of Industrial Engineering and Management*, *5*(1), 4–21. https://doi.org/10.3926/JIEM.415

Humpert, M. (2018). Shipping Traffic in Canadian Arctic Nearly Triples. *High North News*. https://www.highnorthnews.com/en/shipping-traffic-canadian-arctic-nearly-triples

Jánošíková, Ľ., Jankovič, P., Kvet, M., & Zajacová, F. (2021). Coverage versus response time objectives in ambulance location. *International Journal of Health Geographics*, *20*(1). https://doi.org/10.1186/s12942-021-00285-x

Jiang, J., Li, Q., Wu, L., & Tu, W. (2017). Multi-objective emergency material vehicle dispatching and routing under dynamic constraints in an earthquake disaster environment. *ISPRS International Journal of Geo-Information*, *6*(5). https://doi.org/10.3390/ijgi6050142

Jiang, X., Guo, X., & Ran, B. (2014). Optimization Model for Headway of a Suburban Bus Route. *Mathematical Problems in Engineering*, *2014*. https://doi.org/http://dx.doi.org/10.1155/2014/979062

Kasaei, M., & Salman, F. S. (2016). Arc routing problems to restore connectivity of a road network. *Transportation Research Part E: Logistics and Transportation Review*, *95*, 177–206. https://doi.org/10.1016/j.tre.2016.09.012

Kenny, T. A., Little, M., Lemieux, T., Joshua Griffin, P., Wesche, S. D., Ota, Y., Batal, M., Chan, H. M., & Lemire, M. (2020). The retail food sector and indigenous peoples in high-income countries: A systematic scoping review.

In *International Journal of Environmental Research and Public Health* (Vol. 17, Issue 23, pp. 1–48). MDPI AG. https://doi.org/10.3390/ijerph17238818

Khare, A., Batta, R., & Kang, J. E. (2021). On the analysis of last-mile relief delivery on a tree network: Application to the 2015 Nepal earthquake. *Journal of the Operational Research Society*, *72*(4), 727–743. https://doi.org/10.1080/01605682.2019.1708824

Khayal, D., Pradhananga, R., Pokharel, S., & Mutlu, F. (2015). A model for planning locations of temporary distribution facilities for emergency response. *Socio-Economic Planning Sciences*, *52*, 22–30.

Klein, M. G., Verter, V., & Moses, B. G. (2020). Designing a rural network of dialysis facilities. *European Journal of Operational Research*, *282*(3), 1088–1100. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=141115817&lang=fr&site=ehost-live

Laporte, G. (2009). Fifty years of vehicle routing. *Transportation Science*, *43*(4), 408–416. https://doi.org/10.1287/trsc.1090.0301

Laporte, G., Nickel, S., & Saldanha da Gama, F. (2015). *Location Science*.

Leblanc-Laurendeau, O. (2020). *FOOD INSECURITY IN NORTHERN CANADA: AN OVERVIEW*.

Li, G. Q., Zhou, X. G., Yin, J., & Xiao, Q. Y. (2014). An UAV scheduling and planning method for post-disaster survey. In *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences: Vol. XL* (Issue 2, pp. 169–172). Copernicus GmbH. https://doi.org/http://dx.doi.org/10.5194/isprsarchives-XL-2-169-2014

Lin, J., Zhang, Z., Liu, Z., & Rommel, J. (2020). The impact of cooperatives' transportation services on farm income: Evidence from tobacco farmers in Guizhou, China. *Agribusiness*, *36*(1), 146–158. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fonlinelibrary-wiley-com.proxy.bibliotheques.uqam.ca%2Fdoi%2Fpdfdirect%2F10.1002%2Fagr.21620

Lin, Y. H., Batta, R., Rogerson, P. A., Blatt, A., & Flanigan, M. (2012). Location of temporary depots to facilitate relief operations after an earthquake. *Socio-Economic Planning Sciences*, *46*(2), 112–123.

Liu, W. (2020). Route Optimization for Last-Mile Distribution of Rural E-Commerce Logistics Based on Ant Colony Optimization. *IEEE Access*, *8*, 12179–12187. https://doi.org/10.1109/ACCESS.2020.2964328

Loree, N., & Aros-Vera, F. (2018). Points of distribution location and inventory management model for Post-Disaster Humanitarian Logistics. *Transportation Research Part E: Logistics and Transportation Review*, *116*, 1–24. https://doi.org/10.1016/J.TRE.2018.05.003

Luo, J., Tian, L., Luo, L., Hong, Y., & Wang, F. (2017). Two-Step Optimization for Spatial Accessibility Improvement: A Case Study of Health Care Planning in Rural China. *BioMed Research International*, *2017*. https://doi.org/http://dx.doi.org/10.1155/2017/2094654

Maghfiroh, M. F. N., & Hanaoka, S. (2018). Dynamic truck and trailer routing problem for last mile distribution in disaster response. *Journal of Humanitarian Logistics and Supply Chain Management*, *8*(2), 252–278. https://doi.org/10.1108/JHLSCM-10-2017-0050

Maranzana, F. E. (1964). On the location of supply points to minimize transport costs. *Operational Research Soc. 15*, 261–270.

MBA Skool team. (2016). *Distribution Planning Meaning & Definition*. Operations and Supply Chain. https://www.mbaskool.com/business-concepts/operations-logistics-supply-chain-terms/15951-distribution-planning.html

Mejía, G., Granados-Rivera, D., Jarrín, J. A., Castellanos, A., Mayorquín, N., & Molano, E. (2021). Strategic supply chain planning for food hubs in central colombia: An approach for sustainable food supply and distribution. *Applied Sciences (Switzerland)*, *11*(4), 1–22. https://doi.org/10.3390/app11041792

Miranda, P. A., Blazquez, C. A., Vergara, R., & Weitzler, S. (2015). A novel methodology for designing a household waste collection system for insular zones. *Transportation Research Part E: Logistics and Transportation Review*, *77*, 227–247. https://doi.org/10.1016/j.tre.2015.02.019

Molenbruch, Y., Braekers, K., Hirsch, P., & Oberscheider, M. (2021). Analyzing the benefits of an integrated mobility system using a matheuristic routing algorithm. *European Journal of Operational Research*, *290*(1), 81–98. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=147649438&lang=fr&site=ehost-live

Mommens, K., Buldeo Rai, H., van Lier, T., & Macharis, C. (2021). Delivery to homes or collection points? A sustainability analysis for urban, urbanised and rural areas in Belgium. *Journal of Transport Geography*, *94*, N.PAG-N.PAG. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=151328825&lang=fr&site=ehost-live

Mosayebi, A., Mojaradi, B., Naeini, A. B., & Hosseini, S. H. K. (2020). A Mathematical Model for Locating the Medical and Emergency Centers considering the Failure Probability of Centers. *Mathematical Problems in Engineering*, *2020*. https://doi.org/http://dx.doi.org/10.1155/2020/4167590

Munawar, H. S., Ullah, F., Khan, S. I., Qadir, Z., & Qayyum, S. (2021). Uav assisted spatiotemporal analysis and management of bushfires: A case study of the 2020 victorian bushfires. *Fire*, *4*(3). https://doi.org/10.3390/fire4030040

Munir, B. A., Hafeez, S., Rashid, S., Iqbal, R., & Javed, M. A. (2020). Geospatial assessment of physical accessibility of healthcare and agent-based modeling for system efficacy. *GeoJournal*, *85*(3), 665–680. https://doi.org/10.1007/s10708-019-09987-z

Mussells, O., Dawson, J., & Howell, S. (2017). Navigating pressured ice: Risks and hazards for winter resource-based shipping in the Canadian Arctic. *Ocean & Coastal Management*, *137*. https://doi.org/10.1016/j.ocecoaman.2016.12.010

Nadi, A., & Edrisi, A. (2017). Adaptive multi-agent relief assessment and emergency response. *International Journal of Disaster Risk Reduction*, *24*, 12–23. https://doi.org/10.1016/j.ijdrr.2017.05.010

Nikbakhsh, E., & Zanjirani Farahani, R. (2011). Logistics operations and management: concepts and models. In *Humanitarian logistics planning in disaster relief operations* (Elsevier Insights, pp. 291–332).

Niyomubyeyi, O., Pilesjö, P., & Mansourian, A. (2019). Evacuation planning optimization based on a multi-objective artificial bee colony algorithm. *ISPRS International Journal of Geo-Information*, *8*(3). https://doi.org/10.3390/ijgi8030110

Oxford Languages. (2022). *Availability.* Oxford Languages Dictionary. https://www.google.com/search?q=availability+definition&oq=availability+definition&aqs=chrome..69i57.4424j0j4&sourceid=chrome&ie=UTF-8

Pacheco, J., Caballero, R., Laguna, M., & Molina, J. (2013). Bi-Objective Bus Routing: An Application to School Buses in Rural Areas. *Transportation Science*, *47*(3), 397–411.

https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=90140194&lang=fr&site=ehost-live

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Pan, J.-S., Pei-Cheng, S., Chu, S.-C., & Yan-Jun, P. (2020). Improved Compact Cuckoo Search Algorithm Applied to Location of Drone Logistics Hub. *Mathematics*, *8*(3), 333. https://doi.org/http://dx.doi.org/10.3390/math8030333

Parent, S. (2019). *8 $ pour un seul pain ou 27 $ pour du jus d'orange : au Nunavut, ce n'est pas un poisson d'avril*. Radio-Canada. https://www.rcinet.ca/fr/2019/04/01/8-pour-un-seul-pain-ou-27-pour-du-jus-dorange-au-nunavut-ce-nest-pas-un-poisson-davril/

Park, S.-Y., Shin, C. S., Jeong, D., & Lee, H. (2018). DroneNetX: Network Reconstruction Through Connectivity Probing and Relay Deployment by Multiple UAVs in Ad Hoc Networks. *IEEE Transactions on Vehicular Technology*, *67*(11), 11192–11207.

https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=132967473&lang=fr&site=ehost-live

Parvin Hoda, Beygi Shervin, Helm E. Jonathan, Larson S. Peter, & Oyen Van P. Mark. (2018). *Online Appendices A Alternative Stochastic Programming Model Formulations*.

Pirkle, C. M., Lucas, M., Dallaire, R., Ayotte, P., Jacobson, J. L., Jacobson, S. W., Dewailly, E., & Muckle, G. (2014). Food insecurity and nutritional biomarkers in relation to stature in Inuit children from Nunavik. *Canadian Journal of Public Health*, *105*(4). https://doi.org/10.17269/cjph.105.4520

Pochan, J., Pichayapan, P., & Arunotayanun, K. (2020). A modeling framework of hierarchical earthquake relief center locations under demand uncertainty. *International Journal of GEOMATE*, *18*(65), 23–33. https://doi.org/10.21660/2020.65.12752

Power, E. M. (2007). *Conceptualizing Food Security for Aboriginal People in Canada*. www.dietitians.ca

Prentice, B. E., & Russel, S. (2009). Competing Technologies and Economic Opportunities for Northern Logistics: The Airship Solution. *Canadian Transportation Research Forum*, *44*(No. Annual Meeting Proceedings), 685–698. https://doi.org/10.1159/000398828

Rabbani, M., Alamdar, S. F., & Farrokhi-Asl, H. (2016). Capacitated Windy Rural Postman Problem with several vehicles: A hybrid multi-objective simulated annealing algorithm. *International Journal of Supply and Operations Management*, *2*(4), 1003–1020. https://www.proquest.com/scholarly-journals/capacitated-windy-rural-postman-problem-with/docview/1906339059/se-2?accountid=14719

Rabta, B., Wankmüller, C., & Reiner, G. (2018). A drone fleet model for last-mile distribution in disaster relief operations. *International Journal of Disaster Risk Reduction*, *28*, 107–112. https://doi.org/10.1016/j.ijdrr.2018.02.020

Rau, H., & Vega, A. (2012). Spatial (Im)mobility and Accessibility in Ireland: Implications for Transport Policy. *Growth & Change*, *43*(4), 667–696. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=83585317&lang=fr&site=ehost-live

Rawls, C. G., & Turnquist, M. A. (2012). Pre-positioning and dynamic delivery planning for short-term response following a natural disaster. *Socio-Economic Planning Sciences*, *46*(1), 46–54. https://doi.org/10.1016/J.SEPS.2011.10.002

Reuter-Oppermann, M., Nickel, × Stefan, & Steinhäuser, J. (2019). Operations research meets need related planning: Approaches for locating general practitioners' practices. *PLoS One*, *14*(1). https://doi.org/http://dx.doi.org/10.1371/journal.pone.0208003

Rezapour, S., Naderi, N., Morshedlou, N., & Rezapourbehnagh, S. (2018). Optimal deployment of emergency resources in sudden onset disasters. *International Journal of Production Economics*, *204*, 365–382. https://doi.org/10.1016/j.ijpe.2018.08.014

Rodríguez-Espíndola, O., Albores, P., & Brewster, C. (2016). GIS and Optimisation: Potential Benefits for Emergency Facility Location in Humanitarian Logistics. *Geosciences*, *6*(2), 18. https://www.proquest.com/scholarly-journals/gis-optimisation-potential-benefits-emergency/docview/1780818048/se-2

Ryosuke, N., Erick, M., Moya, L., & Shunichi, K. (2021). Model-based analysis of multi-UAV path planning for surveying postdisaster building damage. *Scientific Reports (Nature Publisher Group)*, *11*(1). https://doi.org/http://dx.doi.org/10.1038/s41598-021-97804-4

Saeidian, B., Mesgari, M. S., Pradhan, B., & Ghodousi, M. (2018). Optimized location-allocation of earthquake relief centers using PSO and ACO, complemented by GIS, clustering, and TOPSIS. *ISPRS International Journal of Geo-Information*, *7*(8). https://doi.org/10.3390/ijgi7080292

Saldanha-da-Gama, F. (2022). Facility Location in Logistics and Transportation: An enduring relationship. *Transportation Research Part E: Logistics and Transportation Review*, *166*. https://doi.org/10.1016/j.tre.2022.102903

Salman, F. S., Yücel, E., Kayı, İ., Turper-Alışık, S., & Coşkun, A. (2021). Modeling mobile health service delivery to Syrian migrant farm workers using call record data. *Socio-Economic Planning Sciences*, *77*, N.PAG-N.PAG. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=151593485&lang=fr&site=ehost-live

Samson, C. (2019). *L'approvisionnement de denrées dans l'Arctique canadien, ce n'est pas une mince affaire*. Radio-Canada: Regard Sur l'arctique. https://www.rcinet.ca/regard-sur-arctique/2019/04/03/nunavut-nutrition-nord-alimentation-denrees-prix-arctique-approvisionnement-difficulte/

Schlögl, M., Richter, G., Avian, M., Thaler, T., Heiss, G., Lenz, G., & Fuchs, S. (2019). On the nexus between landslide susceptibility and transport infrastructure – an agent-based approach. *Natural Hazards and Earth System Sciences*, *19*(1), 201–219. https://doi.org/http://dx.doi.org/10.5194/nhess-19-201-2019

Shin, Y., Kim, S., & Moon, I. (2019). Integrated optimal scheduling of repair crew and relief vehicle after disaster. *Computers and Operations Research*, *105*, 237–247. https://doi.org/10.1016/j.cor.2019.01.015

Shrestha, J. K., Benta, A., Lopes, R. B., & Lopes, N. (2014). A multi-objective analysis of a rural road network problem in the hilly regions of Nepal. *Transportation Research Part A: Policy and Practice*, *64*, 43–53. https://doi.org/10.1016/j.tra.2014.03.005

Skinner, K., Burnett, K., Williams, P., Martin, D., Stothart, C., LeBlanc, J., Veeraraghavan, G., & Sheedy, A. (2016). Challenges in assessing food environments in northern and remote communities in Canada. *Canadian Journal of Public Health*, *107*(S1). https://doi.org/10.17269/CJPH.107.5324

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Sopha, B. M., Achsan, R. E. D., & Asih, A. M. S. (2019). Mount Merapi eruption: Simulating dynamic evacuation and volunteer coordination using agent-based modeling approach. *Journal of Humanitarian Logistics and Supply Chain Management*, *9*(2), 292–322. https://doi.org/10.1108/JHLSCM-05-2018-0035

Statistics Canada. (2015). *Transportation in the North*. https://www150.statcan.gc.ca/n1/pub/16-002-x/2009001/article/10820-eng.htm

Thomas, S. A., & Kopczak, R. L. (2005). From logistics to supply chain management: the path forward for the humanitarian sector. *Fritz Institue*.

Thorsen, A., & McGarvey, R. G. (2018). Efficient frontiers in a frontier state: Viability of mobile dentistry services in rural areas. *European Journal of Operational Research*, *268*(3), 1062–1076. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=129049854&lang=fr&site=ehost-live

Tirkolaee, E. B., Aydın, N. S., Ranjbar-Bourani, M., & Weber, G.-W. (2020). A robust bi-objective mathematical model for disaster rescue units allocation and scheduling with learning effect. *Computers and Industrial Engineering*, *149*. https://doi.org/10.1016/j.cie.2020.106790

Tîtu, M., Oprean, C., Pîrnau, C., & Tîtu, S. (2015). Using the Modelling and Simulation Techniques to Improve the Management of SMEs Belonging to Regional Clusters. *Management of Sustainable Development*, *7*(2), 17–21. https://doi.org/http://dx.doi.org/10.1515/msd-2015-0025

Tomej, K., & Liburd, J. J. (2020). Sustainable accessibility in rural destinations: a public transport network approach. *Journal of Sustainable Tourism*, *28*(2), 129–146. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=140311613&lang=fr&site=ehost-live

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. In *British Journal of Management* (Vol. 14, Issue 3, pp. 207–222). https://doi.org/10.1111/1467-8551.00375

Uniktour. (n.d.). *Arctic*. Travel, Designed by You. Retrieved September 19, 2021, from http://www.uniktour.com/en/arctic/climat.php

van Barneveld, T., Jagtenberg, C., Bhulai, S., & van der Mei, R. (2018). Real-time ambulance relocation: Assessing real-time redeployment strategies for ambulance relocation. *Socio-Economic Planning Sciences*, *62*, 129–142. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=128564560&lang=fr&site=ehost-live

Vazifeh, Z., Mafakheri, F., & An, C. (2021). Biomass supply chain coordination for remote communities: A game-theoretic modeling and analysis approach. *Sustainable Cities and Society*, *69*. https://doi.org/10.1016/j.scs.2021.102819

Vidal, T., Laporte, G., & Matl, P. (2019). *A concise guide to existing and emerging vehicle routing problem variants*. http://arxiv.org/abs/1906.06750

VonAchen, P., Smilowitz, K., Raghavan, M., & Feehan, R. (2016). Optimizing community healthcare coverage in remote Liberia. *Journal of Humanitarian Logistics and Supply Chain Management*, *6*(3), 352–371. https://doi.org/10.1108/JHLSCM-03-2016-0006

Wallemacq, P. (2018). *Natural disasters in 2017-Lower Mortality, higher cost Human Cost of Natural Disasters-EM-DAT View project*. https://doi.org/10.13140/RG.2.2.27820.92808

Xavier, I. R., de Mello Bandeira, R. A., de Oliveira Silva, L., de Paula Fontainhas Bandeira, A., & Gouvêa Campos, V. B. (2021). Planning the use of helicopters for supply distribution in response operations to sudden disasters | Planejando o uso de helicópteros para distribuição de suprimentos em operações de resposta a desastres súbitos. *Gestao e Producao*, *28*(1). https://doi.org/10.1590/1806-9649.2020V28E5000

Xu, C., Xu, M., & Yin, C. (2020). Optimized multi-UAV cooperative path planning under the complex confrontation environment. *Computer Communications*, *162*, 196–203. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=146036786&lang=fr&site=ehost-live

Yang, F., Dai, Y., & Ma, Z.-J. (2020). A cooperative rich vehicle routing problem in the last-mile logistics industry in rural areas. *Transportation Research Part E: Logistics and Transportation Review*, *141*. https://doi.org/10.1016/j.tre.2020.102024

Yenice, Z. D., & Samanlioglu, F. (2020). A Multi-Objective Stochastic Model for an Earthquake Relief Network. *Journal of Advanced Transportation*, *2020*. https://doi.org/10.1155/2020/1910632

Yuan Y, Hunt RH. Systematic reviews: the good, the bad, and the ugly. *National Library of Medicine.* 2009 May;104(5):1086-92. doi: 10.1038/ajg.2009.118. PMID: 19417748.

Zhang, G., Zhu, N., Ma, S., & Xia, J. (2021). Humanitarian relief network assessment using collaborative truck-and-drone system. *Transportation Research Part E: Logistics and Transportation Review*, *152*. https://doi.org/10.1016/j.tre.2021.102417

Zhang, J. H., Li, J., & Liu, Z. P. (2012). Multiple-resource and multiple-depot emergency response problem considering secondary disasters. *Expert Systems with Applications*, *39*(12), 11066–11071.