Review

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*Review*

# The Current State and Future of the Road Transport Based Cold Chain

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**Abstract:** Cold chains are essential in providing us humans with food and medicine across the globe. However, cold transportation, like all transportation, has massive negative impacts on the environment and human well-being, which especially culminate in cities. Thus, it is important to research the ways to reduce these impacts and reinvent urban logistics infrastructure. In this article, we articulate the massive problems the road-based transportation sector imposes on the environment and on the health of humans, especially in cities. We present algorithms that show promise in optimizing the whole road transportation sector as well as some innovations and alternative ways to model cities and the whole urban transportation infrastructure. We approach the issues discussed specifically from the point of view of refrigerated transportation, but many of the solutions can be applied to all the transportation sector in general.

**Keywords:** cold chains; environment; transportation; refrigerated transportation; optimization; algorithms

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## 1. Introduction

Food and medicine are vital to humans everywhere on the planet. However, their transportation isn't easy, since food and medicine quickly spoil if not kept cold, with medicine often requiring very specific storing temperatures. This continuous chain from production to the consumer in a certain temperature is called the cold chain. The cold chain is difficult to maintain, and currently requires a lot of energy and resources, a lot of which are wasted. Trucks that are specifically made to accommodate these refrigerated products are inefficient with their energy use, emit greenhouse gasses and air pollutants, and harm human and ecosystem health in many ways. On top of that, they are often dependent on the traffic conditions of the local environment, which can be highly unpredictable due to car accidents, road works, and weather conditions. These problems are especially present in cities with a lot of traffic and low levels of optimization in transportation planning. These cold chains not only can, but have to be made more efficient, as the EU is putting a ban on all but zero emission road vehicles by 35 [1] and demanding increasing cuts to emissions across all sectors of society [2].

The structure of the article is as follows. In section 2 we discuss the impact the cold chain has on the environment and human health, especially in bigger cities where traffic is present. Section 3 considers current systems in the cold chain as well as their weak points in maintaining the cold chain and examines where the biggest emission reductions can be made. In section 4 we present different solutions for the optimization of cold transportation in our current system, including algorithms for traffic prediction, traffic control, and route optimization, as well as new cold storage innovation. In section 5 we then propose modern infrastructure models for when new cities and infrastructure are being built. Conclusions are written in Section 6, followed by a list of references.

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## 2. Impact on the Environment and Human Wellbeing

The Materials and Methods should be described with sufficient details to allow others to replicate and build on the published results. Please note that the publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Interventionary studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

The cold chain, and transportation systems in general, have a massive impact on the environment, whether it is direct in the form of noise and air pollution or indirect in the form of $CO_2$ emissions. When considering the cold chain, transportation is done by a wide range of methods, like by plane, truck, or train. However, all the transportation has at least some part done by truck or a van when transporting the products from the producer to the airport, harbor, or the railway station, and then again when transporting to the final destination. A lot of the products travel the whole trip by truck or by van.

According to Eurostat [3], 67.8 % of the freight transportation was maritime, 24.9 % was roads (like trucks, vans, cars), 5.5 % was rail, 1.6 % was inland waterways and 0.2 % was by aviation. From these numbers we can see that maritime freight was the most common, followed by road transportation. Important to note is that, depending on the city, around half of the people take either their own private car or public bus to get around [4]. This increases the total modal share of roads in transportation. This consideration becomes especially important in urban areas where freight transportation and passenger traffic overlap, and traffic congestion is a common issue.

All transportation – freight and passenger transportation alike – accounts for 21 % of the world's total $CO_2$ emissions [5]. Passenger vehicles account for 45.1 % of it, and freight transportation (trucks and vans) account for 29.4 %. In other words, road transportation accounts for around three-quarters of all emissions released by the transportation sector [5]. That is around 15% of all the world's emissions. Thus it is important to pay more attention to this sector of transportation. When considering transportation in the context of smart cities, road transportation is central, as our existing logistics infrastructure is heavily car-dependent.

On top of high emissions, road transportation – like all the other forms of transportation – have negative impacts on their immediate surroundings. For road transportation, the most often considered forms of pollution are noise and air pollution, but actually create a significantly broader spectrum of problems. Still, air pollution is one of the most pressing problems and has an especially high impact on humans living in bigger cities.

According to WHO [6], 99% of humans breathe air that contains high levels of pollutants, causing around seven million premature deaths per year; a death count that a global review of health risks found to be the third biggest, only behind smoking and high blood pressure [7]. The air pollution from automobility alone is estimated to have cumulatively caused between six and nine million deaths. Combustion engine vehicles release exhaust fumes containing pollutants harmful to humans like particulate matter (PM), ozone ($O_3$) and carbon monoxide (CO), with outdoor PM and CO pollution having road transportation as their main source [8], all of which increase human health risks, especially as it comes to respiratory illness. It is also important to note that in many cities, as street level is covered in smog, the effects of bad air quality disproportionately affect the lower income classes who walk, and use public transport, thus also contributing to the problem the least; air quality then also becomes an issue of social sustainability. Totalling air pollution with all other aspects like traffic accidents, automobility is estimated to cause 1 in every 34 human deaths [9].

Road vehicles also emit environmentally damaging pollutants like nitrous and sulfuric oxides that cause acidification. Acidification can reduce soil quality, increase the solubility of aluminum in soil and waters causing harmful and sometimes deadly concentrations, reduce nutrient cycling in the ecosystem, and damage the leaves of plants and trees [10]. Additional environmental problems resulting from road transport pollution are caused by ozone, which can reduce plants' capacity for photosynthesis, and mercury (Hg), which is highly toxic in itself but can methylate into an even more harmful form and accumulate in animals, especially top predators [10]. Factors such as these cause long term effects that reduce an ecosystem's resilience, and, coupled with other stressors like unpredictable weather patterns caused by climate change, can lead to die offs [10], and ultimately the destruction of the ecosystem.

PM, in addition to soot and other combustion products, contains tire microplastics (TMP), which are the most abundant type of microplastics pollution world wide [11]. While the effects of microplastics pollution are still largely unknown, many TMP types include harmful chemicals that, as urban runoff carries these particles into aquatic ecosystems, bioaccumulate and cause toxicity in freshwater and marine animals [12]. As microplastics have now been found virtually everywhere on the planet as well as all parts of the human body, it is necessary to raise concern and increase research into their effects.

The impact of noise pollution is still being studied, but the initial research presents evidence that suggests a link between environmental noise and different adverse health effects, such as cardiovascular disease, cognitive impairment, sleep disturbance and irritability [13]. Light pollution, which can for example significantly interfere with the navigation and circadian rhythm of animals, is also relevant to road infrastructure and cars, but unfortunately very neglected in the discussion around problems caused by road traffic [14].

Car-related infrastructure also causes other problems more physical and spatial in nature: Road networks cause fragmentation of landscape and ecosystems, causing significant ecological damage [15]. Pavement used on roads and parking spaces, in addition to causing variable but often low toxicity to the immediate environment [16], causes groundwater depletion in cities, where asphalt roads and parking spaces cover most land area not taken by buildings.

In addition to problems with all road-based transport infrastructure, there are environmental challenges specific to temperature-controlled transportation. Since the products need to be kept at a certain temperature, a refrigerated truck needs additional energy to maintain the wanted temperature. The temperature maintenance raises a problem again during on- and offloading. This requires the truck doors to be open for considerable periods of time, which means that in traditional refrigerated trucks the engine needs to run to maintain the wanted temperature inside the truck. Additionally, many products are very sensitive to changes in temperature, for example food items and medicines, which have a risk of spoiling without constant refrigeration. Spoilage like this results in a waste of resources and excess emissions when the spoiled products need to be replaced. Over half of the food that is wasted is wasted during production or transportation in developed countries, and nearly all of it during production or transportation in developing countries [17]. The problem is especially pertinent in transporting high value products that are sensitive to temperature changes, like certain vaccines, to places that might not have the required infrastructure to safely and efficiently get the products to their end destination. One fifth of temperature-sensitive products in medicine are damaged due to broken cold chains [18].

## 3. Failures of the Current Cold Chain System

VCR is the most used method in refrigeration, cooling, or air conditioning. It accounts for approximately 80% of the market share. [19] This is due to the variety of different power supply methods, e.g. routing the power straight from different parts of the engine or from a separate generator. VCR operates by compressing and decompressing refrigerant, which takes the heat energy from the refrigerated compartment and releases it outside.

The biggest concern for VCR systems is efficiency. This is especially clear when the system gets its power from the engine. The weak point for VCR systems is the on- and offloading of the vehicle, since the doors to the cooled area will be open for longer periods of time, leading to the cooled air being let out and replaced with warm air. Engine needs to keep running to keep cooling [20]. A similar efficiency problem arises when the load is not full. The system still needs to keep the entire truck cold, even though it is only half full. The efficiency of the engine drops to 1-10% in these two cases. [20]

The idea behind PCM on the other hand is to have some material in the container that is changing phase and thus keeping the products cold. An easy example of this is melting ice in a box with fish. These materials seem to have some potential, especially when used alongside VCR systems, but they have some notable downsides. Firstly, they can take up a lot of extra space and do not always fit the container optimally. Secondly, as PCMs are an imprecise method of cooling, that is the temperature will change over time, they aren't suitable for products with very specific storing temperatures, like many medicines.

## 4. Solutions for More Efficient Refrigerated Transportation

Since the solutions most widely used in cold transportation today have much room for optimization, we next look at algorithms for optimizing different aspects of the cold chain. Most of the presented solutions would aid not only cold transportation, but all road transportation in general. The most notable points for optimization are movement in cities, especially during traffic, and the optimization of delivery routes with multiple stops. When considering solutions to these problems, we need to take a few restrictions into account. The first restriction on deliveries is put on by the opening and working hours of the delivery destinations: nighttime is often the optimal time to deliver products to the stores, as traffic is at its lowest, but this cannot always be done due to the receiving location being closed or a lack of nighttime delivery workers. Secondly, we need to consider the availability of resources overall, like how many vans and drivers are available for making deliveries at any specified time. The third restriction comes in the form of the volume and variety of products being shipped, as more volume means more cargo space required and more variety often means different temperatures required, which again requires more delivery vehicles. Overall, it is important to remember that refrigerated transportation does not exist in a vacuum, but dynamically as a part of the transportation network of a society. That is why most of this section is reserved for solutions that would help all road transportation, not just refrigerated transportation. In this chapter we will discuss different algorithms that aid in the prediction of traffic, optimization of delivery routes, as well as a technological solution for shifting from big, cooled trucks and vans to a more flexible and modular form of cold transportation.

### *4.1. Prediction and Control of Traffic Flow*

One very clear and effective way to optimize transportation is controlling the flow of traffic. Having to constantly accelerate and decelerate in traffic wastes a significant amount of energy and produces extra emissions, while also increasing the time the vehicle is standing still with the engine running. To combat idling and keep the vehicle from having to frequently reaccelerate better traffic control methods should be employed. In this section we describe different solutions to predict and direct the flow of traffic. Some of them are very concrete, like the use of smart traffic lights, and some are more theoretical that could be applied in different navigation systems or route optimization tools.

Firstly, let's take a look at already existing research on traffic-prediction algorithms. One of the key proposed tools to estimating travel times with real time traffic taken into account is the use of deep learning. One such deep learning model is a stacked autoencoder (SAE) model [21]. The idea of the SAE model is to stack autoencoders on top of each other so that the output of the $k$th layer is the input of $(k+1)$th layer. When applied to traffic prediction, the deep architecture has a SAE model to extract traffic flow features and on top of that it has a predictor layer. In the study this layer was a logistic regression layer. The deep network was trained using a greedy layerwise unsupervised learning algorithm due to its better performance compared to the BP method. Mean absolute error (MAE), mean relative error (MRE) and RMS error (RMSE) were used to evaluate and compare the SAE model to other models. When compared to BP NN, the random walk (RW) forecast method, the support vector machine (SVM) method, and the radial basis function (RBF) NN model the SAE model's performance was superior. SAE was more accurate than all of the other models, especially when the time interval for prediction got larger. This is useful when optimizing the routes for vans and trucks, since a 15-minute interval might be too small a window to change the route to a more optimal one. A bigger interval is especially necessary in bigger cities where it takes more than 15 minutes to drive from one end to the other and for routes where the delivery vehicle has more than one stop.

However, another study discussed the SAE model as well, and compared it to their own DNN-BTF model [22]. DNN-BTF is constructed by combining CNN and RNN model to learn spatial and temporal features respectively. CNN was a conventional 1D CNN whereas the RNN used was a simpler RNN model, Gated recurrent neural network (GRU). In the study the model was trained in an end-to-end fashion with Adamax optimizer. They concluded that DNN-BTF model had notably smaller error indexes compared to other methods, including SAE. The study also noted that all the other models performed better in near-term future time points, which contradicts what the previous study concluded about the behavior of SAE. Thus, it is hard to make a direct conclusion about the efficiency of the SAE model.

Many of the algorithms proposed for the problem of traffic prediction, such as the Ant colony optimizer (ACO) and bee colony optimizer (BCO), get their inspiration from nature and are suitable for hybrid complex optimization problems. The idea behind ACO is to model how certain species of ants share information with each other. It could be applied to real life traffic in a way that cars share information with each other about incoming traffic or accidents on the road. The BCO on the other hand is suitable for more difficult combinatorial optimization problems. BCO has a fuzzy bee system, or FBS that uses fuzzy logic and is capable of working under uncertainty. That attribute is especially useful when making decisions in a system like transportation, where traffic is sometimes unpredictable (e.g. car crashes).

Let's take a closer look at ACO. Certain ant species spread pheromones when they travel from the food source back to the nest. Other ants sense these pheromones and follow the strongest paths to carry the food to the nest in an efficient way [23]. A study proposed that the vehicles could use ACO efficiently if they communicated with each other through the Internet of Vehicles (IoV)[24]. This could be used to combat congestion and find the shortest paths to destinations. The study concluded that the use of ACO through IoV would decrease the waiting time and travel time significantly when compared to the performance of other shortest-path algorithms; Dijkstra, Kruskal's and Prim's. The decrease was especially significant with a lower number of cars. The biggest decrease happened with the low number of cars and when compared to the Dijkstra- algorithm, where travel time was halved and waiting time dropped by three-fourths.

The idea behind BCO, on the other hand, is that multiple artificial bees are searching for a solution to a problem. They exchange information and collaborate between each other to find the best solution to the problem at hand. Research has shown that BCO could offer solutions for optimizing the transportation network [25,26]. A recent study [26] focused on using BCO to develop signal timing, and the results showed a promising decrease when compared to other models.

One practical way to apply these algorithms to the real world is to use smart traffic lights. A study showed smart traffic lights using cue lengths and other traffic data to calculate optimal turning times would reduce the idling time of vehicles in that intersection [27]. The researchers compared a traffic light with a fixed signal to a traffic light with an adaptive smart algorithm. They simulated a part of the city using the method of electrodynamic modeling to determine if installation of smart traffic lights would be beneficial. The results showed a drastic decrease in the queuing time for vehicles, which leads to less idling and emissions, thus showing that smart traffic lights can be an effective solution for optimizing traffic.

The flow of traffic can also be directed by providing real time data of traffic to drivers, and offering the quickest route based on that data. This could be done through different navigation systems. For example, Google maps has over a billion monthly users and thus is by far the most used navigation application [28]. It uses the Dijkstra algorithm alongside the A* algorithm [29]. If Google

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Maps implemented a more efficient way of predicting traffic, it could direct its users to a different, less crowded road to avoid the traffic altogether. For example, a van is setting out to drive from one side of the town to the other. The shortest route would be through the city center, but the algorithm predicts that by the time the van gets to the city center the traffic will have increased drastically. Thus, it is able to direct the van to a different route with less traffic. When the traffic prediction is accurate, the available roadspace is used efficiently, and congestion is decreased.

### *4.2. Optimization of Multiple Stop Distribution Routes*

Algorithms are a vital part of not only traffic control, but also route optimization. In a way, traffic control and route optimization go hand in hand, because a good route optimization algorithm will avoid congested areas and direct drivers to use road space efficiently, easing the flow of traffic, as we saw in the last example of the previous section. Historically, these route optimization problems have been classified as Vehicle Routing Problems, like shown in our previous studies[30,31]. However, when considering more complex problems that take things like food quality degradation and supplemental technology like drones into consideration, we need algorithms that are capable of accurately handling these new challenges. This part focuses on the algorithms that are able to find the most efficient route to a destination, when efficiency is not measured only in distance or time.

BCO and ACO are good for both traffic control and route optimization. A variation of BCO called Artificial Bee Colony (ABC) optimizer [32] was used to minimize the food quality degradation during transportation. The algorithm is more varied than the regular Vehicle Routing Optimization algorithm, since it considers more factors, like food quality degradation. Because the problem discussed in this paper has multiple variables that need to be taken into account, ABC optimizer presents itself as a viable solution. The study in reference 18 already took into account time constraints as well as the prevention of food degradation. The solution presented could be modified to include our need for the minimization of $CO_2$ emissions by adding a punishment cost for idling in traffic, so that routes with smoother driving and less standing still are prioritized over shorter routes that end up burning more fuel.

The use of drones also presents a valuable solution to parts of the route optimization problem. Drones are able to deliver small packages faster and more efficiently than a van or a truck. Drones are also unaffected by traffic conditions, because they don't need roads to travel. In Vehicle Routing Problem with Drone (VRPD) the truck is accompanied by a drone. The key objective is to optimize and synchronize the routes for the truck and the drone so that neither one needs to wait for the other and efficiency is maximized. The use of Ant Colony Optimizer was proposed as a solution for this optimization problem [33]. The ACO was able to find the optimal route, so that the truck's idling was minimized while waiting for the drone. It was also able to find the better modes (serving multiple feasible customers or serving only one feasible customer) for instances where 200 customers are clustered, random and random-clustered.

### *4.3. Smaller, Movable Cold Containers as a Flexible Cold Storage Solution*

When considering the optimization of transporting medicine and food, we need to take a closer look at temperature-controlled transportation. Alongside the solutions proposed by traffic control and route optimization, temperature-controlled transportation needs an extra layer of solutions due to the nature of cold transportation. The challenge is to ensure that all products maintain the required temperature regardless of what other products are being transported, what the temperature outside is, or how long the transportation takes. The current system, as discussed above in section 3, relies on cooling mechanisms inside the van that draw their energy from the engine, which is not very efficient, as it requires the engine to be running at all times. In this section we propose the use of a new innovation. The proposed solution is to have the products in well-insulated, movable cold containers, like in the patent in reference [34], instead of a single big, refrigerated compartment.

The cold box consists of a pre-frozen cold gel mat, a sensor and well-insulated walls and lid. Since the box insulates the products very effectively, the same truck can transport products that require different temperatures. These boxes would also solve the problem of on- and offloading

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present in the VCR system, where the insulated space needs to be opened whenever products are moved, and the temperature control doesn't extend outside the vehicle. As the boxes don't draw their power from the engine, the vehicle can be turned off when on- and offloading, unlike in the VCR system. The smaller cold spaces provided by the boxes also solve the issue of trucks driving half-empty, as the temperature of each box can be set to that required by its contents, where one large cargo space can only be controlled for one type of product, for which the demand might not be high enough to fill the cargo space.

The sensor inside a box sends data wirelessly to the driver to provide them with information on the temperature and humidity inside the box without the need to open the cold container. Later, data collected in this way could be used to optimize some aspects of the transportation procedure, like keeping the temperature inside the box steady over varying time frames. The box would also provide a cheaper, universal solution to replace expensive special equipment like refrigerated vans.

Of course, though the box has clear benefits over the current systems, this solution does not come without challenges. Since the boxes are reusable, there needs to be infrastructure for their reuse: after a shipment they need to be transported to cleaning facilities and made available to transporters again. This is a difficult challenge especially in long-distance transportation, like international freight, but building this kind of recycling infrastructure locally seems plausible and even desirable.

## 5. The Future of Urban Logistics Infrastructure

Building infrastructure is slow and expensive, which is why optimizing existing infrastructure is of utmost importance in pursuit of lowering emissions and other environmental impacts. When we do undertake new infrastructure projects, though, it is untenable to continue with old practices. A recent meta-analysis shows that automobility is deeply damaging to the wellbeing of both humans and the rest of the biosphere in ways that can't be fixed by just phasing out combustion engines [9]. Though freight transportation also needs to become less dependent on road vehicles, this cannot be achieved without a complete paradigm shift in the structuring of society.

In recent years the "15-Minute City" planning concept has garnered a lot of attention, with the promise of a more sustainable way of structuring cities. As the name suggests, its goal is in creating neighborhoods and areas where all basic necessities and services are at most a fifteen-minute walk, bike, or commute away from a household. Although not without problems – financial incentives have so far often overpowered other goals in implementing this design principle – the concept is among the best candidates for rethinking our urban infrastructure and decreasing car dependency [35].

Automobility-free planning concepts such as 15-Minute Cities hold great relevance to the future of logistics planning. The absence of passenger cars in an urban area frees up a huge amount of space as roads are refitted for public transportation, cycling and foot traffic, and parking spaces, gas stations, as well as other infrastructure around automobility are rendered obsolete. As there is less competition for space and no congestion caused by passenger cars, localized on-demand shipping becomes possible, which again creates possibilities for more individualized, high efficiency and low waste services.

In densely populated China, as new cities are being built and planning isn't restricted by old infrastructure, research in Underground Logistics Systems (ULS) has grown fast [36]. Moving urban logistics underground means the big material streams in and out of a city along with their unwanted effects like noise pollution can be hidden from the rest of society, increasing efficiency and improving the wellbeing of citizens. One form of ULS is metro-based ULS, or M-ULS – also significantly contributed to by Chinese research – that can synergistically combine freight and passenger transport under the same dynamically managed infrastructure network [37]. A recent literature review in M-ULS – purporting to be the first of its kind – found that the system brings wide ranging and comprehensive sustainability benefits to society, from energy savings and more fluid transportation to environmental, economic and social benefits, but also that these benefits scale with the system, meaning as the scale of the network grows, the positive impacts on sustainability also become more pervasive [38].

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In future cities, if above-ground infrastructure planning concepts like 15-Minute-Cities are combined with below-ground infrastructure systems like M-ULS, both implemented using cutting edge data analysis and machine learning tools, the result can be significantly more than the sum of its parts. The urban logistics of a future city form a network resembling veins and arteries: big streams moving resources into a city and to its limbs, the big streams dividing into local capillary streams, taking the goods to their final destination, then returning with the refuse and recycle, combining back into bigger streams, forming the veins that transport the recycle and empty transport vehicles back into the heart of the city to be reused, and the refuse out of the city. As biological systems are a result of a long running optimization algorithm – that is, evolution – modeling our own systems after them is often remarkably efficient.

For systems like this to function, it is unavoidable to move away from transport vehicles delivering a single item in bulk, and to more modern cold transport solutions such as the cold container boxes [34] presented in section 4.3. Being able to simultaneously transport many different products in different temperatures removes the need for separate cold chains for individual products and producers, and allows for efficient, conjoint deliveries with a high variety of goods. This eliminates much of the now pervasive overlap of regional logistics chains and takes efficiency optimization to a wholly new level. As the boxes are also recyclable, the recycling could be efficiently combined with local restocking centers where the ULS deposits goods and local, above-ground distribution begins, thus creating another synergistic transport system.

## 6. Conclusions

Unbroken cold chains are vital to transporting perishable food and medicine to people. As practically all logistics and cold chains rely significantly, if not entirely, on road transportation, specifically the sustainability and efficiency of automobility based cold chains was examined.

Looking at the current body of research around automobility in general, it is evident that road transportation and related infrastructure cause a complicated network of environmental issues as well as significant health risks to humans. The health burden caused by road transportation is a global issue especially dire in, but not limited to, cities. Current technologies used to maintain automobility reliant cold chains are quite inefficient and use a lot of energy to run; idling becomes an even worse problem than it already is in traffic as the cold compartments draw their power from the running engine, and whenever the big compartments are on- or offloaded the cold air is let out and a lot of energy wasted.

This paper recaps a variety of algorithms that could be used to control traffic or find the optimal route for a transport vehicle. It presents a new innovation for refrigerated transportation in the form of a well-insulated box. We suggest that the future of the cold chain and logistics research lies in ULS and localized, highly flexible distribution, where a large cold compartment filled with a low variety of products is replaced with a compartment filled with small cold containers, holding various different products with varying temperature requirements. We believe that, if adopted widely, the presented algorithms, new innovations and new infrastructure models will decrease negative impacts the transportation system has on people and the environment, as well as increase efficiency and provide better, faster services with fewer resources.

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