**To design a reward function for your reinforcement learning (RL) problem of clearing snow and ice from roads, you'll need to consider several factors including the cost of plowing and salting, the effects of snow accumulation on traffic speed, and the probability and cost of accidents due to snowy conditions. Here's how you can construct a reward function that takes all of these factors into account:**

1. **Cost of Actions:**
   * **Define the cost associated with each action the agent can take:**
     + **Cost of plowing per mile including driver stipend (C\_p)**
     + **Cost of applying salt per mile including driver stipend (C\_s)**
     + **Cost of salt material per mile (C\_m)**
   * **Let's say the agent can take actions A = {Plowing, Salting, Do Nothing}.**
   * **Define a function R\_action(a) that returns the cost associated with action a.**
2. **Impact of Snow Accumulation on Traffic Speed:**
   * **Define a function f\_speed(snow\_depth) that correlates the snow accumulation depth (in inches or any relevant unit) to decreased traffic speed.**
   * **This function could be linear or non-linear, depending on the specific effects of snow accumulation on traffic speed in your environment.**
   * **Let's denote the decreased traffic speed cost as C\_speed.**
3. **Impact of Snow Accumulation on Accident Probability:**
   * **Define a function f\_accident(snow\_depth) that correlates the snow accumulation depth to accident probability.**
   * **This function could also be linear or non-linear, reflecting how the likelihood of accidents increases with snow depth.**
   * **Additionally, consider the cost of accidents (C\_accident) which could include damage to vehicles, medical expenses, and potential legal fees.**
   * **Let's denote the accident probability cost as C\_acc.**
4. **Combined Reward Function:**
   * **Now, you can define your reward function as a combination of these costs and benefits:**

*R*(*s*,*a*)=*Raction*​(*a*) − *fspeed*​(*snow*\_*depth*)×*Cspeed*​ − *faccident*​(*snow*\_*depth*)×*Caccident*​

Where:

* *R*(*s*,*a*) is the reward for taking action a in state s.
* *Raction​(a)* is the cost associated with action a.

*Raction​(a)=*

Costs per mile:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Action** |  |  |  |  |  | **Total**  **per mile** |
|  | With MPG 7  Diesel per G $4  **$0.60** | [link](https://www.plowsite.com/threads/what-does-your-plow-truck-really-cost-you.127666/)  **$1.00** | **0** | **2 drivers**  **15 MPH**  **20$/HR/Driver**  **=2\*20/15= $2.7** | [**link**](https://www.statista.com/statistics/916733/us-salt-prices-by-type/#:~:text=The%20price%20of%20vacuum%20and,ton%20during%20the%20same%20year.)  **0** | **$4.3** |
|  | **$0.60** | **0** | **$1.00** | **$2.7** | **$0.07 /lb** | **$4.3 + 0.07 \*salt** |
|  | **$0.60** | **$0.60** | **$0.60** | **$2.7** | **$0.07 /lb** | **$4.5 +0.07\*salt** |

* *fspeed​(snow\_depth)* is the function correlating snow accumulation depth to decreased traffic speed. (speed reduction percentage)
* *Cspeed​*  is the cost associated with decreased traffic speed.

[Link](https://ops.fhwa.dot.gov/weather/weather_events/snow_ice.htm#:~:text=Snow%20and%20ice%20reduce%20pavement,40%20percent%20in%20heavy%20snow.)

*fspeed​(snow\_depth)=*

*fspeed​(ice\_depth)=*

*max(fspeed​)=1*

*Cspeed:*

[Link](https://blog.iceslicer.com/true-cost-of-winter-maintenance) cost of traffic.

|  |  |  |
| --- | --- | --- |
| State | Cost of no WM in a day/mile  $ | Cost per 3h/mile  $ |
| Michigan | 2056 | 257 |
| New York | 2910 | 363 |
| Ohio | 1136 | 142 |

*faccident​(snow\_depth)* is the function correlating snow accumulation depth to accident probability.

[Link](https://ops.fhwa.dot.gov/weather/weather_events/snow_ice.htm#:~:text=Snow%20and%20ice%20reduce%20pavement,40%20percent%20in%20heavy%20snow.)

* *faccident​ (snow\_depth)=*
* *faccident​ (ice\_depth)=*
* *Caccident​* is the cost associated with accidents.

[Link](https://www.michigan.gov/msp/-/media/Project/Websites/msp/cjic/Traffic-Crash-Reporting-Unit-Files/Year-End-2022-Traffic-Crash-Report.pdf?rev=c5b5e4cfcebe400e9fe143efee232e0a)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Material | Crash in MI | Cost | Fatal crash | Cost | Total cost in 1 year in MI  X | Per mile per 3h(assume that this is for one season of the year)  Y |
| Ice | 14831 | =96000\*14831 | 42 | =1000000\*42 | 1465776000 | 17 |
| snow | 22105 | =96000\*22105 | 34 | =1000000\*34 | 2156080000 | 25 |

Y= X / 90 days / 8 (every 3hr) / 122040 miles

**This reward function takes into account both the direct costs of plowing and salting actions and the indirect costs associated with decreased traffic speed and increased accident probability due to snow accumulation. You may need to calibrate the parameters of the functions and costs based on empirical data or domain expertise.**

**Functions and Costs for Snow Removal Optimization:**

1. **Total Travel Distance Optimization:**
   * Mathematical optimization model based on the Capacitated Arc Routing Problem (CARP) minimizes the total travel distance for snowplow routes [[1](https://cdnsciencepub.com/doi/10.1139/cjce-2013-0409)].
2. **Prediction of Road Surface Temperature:**
   * Machine learning techniques predict road surface temperature for intelligent and cost-effective winter road maintenance [[2](https://www.sciencedirect.com/science/article/pii/S0950705122003136)].
3. **Cost Management Variables:**
   * Variables include road length, width, snowfall amount, road surface condition, snow removal frequency, and amount of hauled snow for a cost management method in road maintenance [[3](https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=5650ffa2ee13c5cbb85942b59d5326345e0067ad)].
4. **True Cost of Winter Maintenance:**
   * Direct and indirect costs impact budgets beyond just deicing products. These costs may include labor, equipment maintenance, fuel, and potential liabilities [[4](https://blog.iceslicer.com/true-cost-of-winter-maintenance)].

**🌐 Sources**

1. [cdnsciencepub.com - Optimization of snow plowing cost and time in an urban ...](https://cdnsciencepub.com/doi/10.1139/cjce-2013-0409)
2. [sciencedirect.com - Intelligent cost-effective winter road maintenance by ...](https://www.sciencedirect.com/science/article/pii/S0950705122003136)
3. [citeseerx.ist.psu.edu - Development of a Cost Management Method for Road ...](https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=5650ffa2ee13c5cbb85942b59d5326345e0067ad)
4. [iceslicer.com - True Cost of Winter Maintenance](https://blog.iceslicer.com/true-cost-of-winter-maintenance)