**Thursday August 15 | Patrick, Melanie, Jade | RE: Simulation**

**Summary of discussion**

* No charger location optimisation yet. For the conference, just want to test a few handpicked scenarios. Andrea and Grant to be involved in optimisation part.
* May need to use domain knowledge to decide practical charger placements, e.g. Europaplatz is a small side-of-the-road rank which may not be suitable for plugin charging.
* Many ranks have low plugin charger utility compared to wireless charging. For these ranks, try getting rid of plugin chargers to see if wireless chargers alone are sufficient.
* ‘Nearby attractive rank’ selection function looks good enough for the moment.
* Doesn’t seem like taxis are getting ‘stuck’ at ‘unpopular’ ranks since all achieve a similar number of total trips.
* Should really implement taxi shifts at this point. Not simple but totally worth doing to make model way more realistic.
* Should enforce maximum capacity at ranks, but where to send the taxi if it arrives at a full rank?

**TODO**

* **Unfulfilled trip requests**~~[Jade] Find out reason.~~
* **Maximum rank capacity**[Jade] Implement rank capacity[Patrick/Melanie] Decide on maximum capacity and whether or not to constrain the availability of charger types at each rank.

In front of the train station: 10

Behind the train station: 3-5

Europaplatz: 3-5

Kaiserallee: 3

Weinbrennerplatz: 3

Vincentius: 5

Kussmaulstr: 5

Durlach Bhf: 5

Adenauerring: 3

* **‘Rerouting from full rank’ function**[Jade] Implement another rank selection function to send a taxi to another rank if it arrives at one that is full.
* **Taxi shifts**[Patrick/Melanie] Try to find out real taxi shift information if possible. Otherwise…  
  [Jade] Make the number of operating taxis proportional to demand density over time.
* **Scenarios**~~[Patrick/Melanie] Decide on 5 or so scenarios (including Rolf’s optimal solution) to present for the conference.~~  
  **Scenario 0:** Rolf’s solution (only FCS)  
  **Scenario 1:** Rolf’s solution but with inductive charging and FCS (concrete allocation: 2 FCS plus number of inductive charging stations according lots per rank (see above))  
  **Scenario 2:** Rolf’s solution but only inductive charging (according lots per rank (see above))  
  **If still possible: Scenario 3:** Rolf’s solution but with inductive charging and FCS (same as Scenario 1 but FCS only at main station)

**If still possible: Scenario 4:** Solution of Scenario 2, but if one charging option has hardly been used, only the other is included in Scenario 4

@Jade: Do you think we need a starting solution independent of Rolf’s? 0-4 could all base on a different starting solution if there is one

* **Performance metrics**

~~[Jade] Record total time idling at rank for each taxi.~~

~~[Jade] Record total distance travelled with passenger.~~

~~[Jade] Record total distance travelled without passenger.~~

~~[Patrick/Melanie] Think of some more metrics that could be insightful.~~  
~~@Jade: can you store all the individual values so that we can determine distributions, draw box plots etc.?~~

**Wednesday July 24 | Grant, Andrea, Jade | RE: Simulation**

**Grant | Andrea & Jade**

**Summary of discussion**

* Ranks should have maximum holding capacity
* Wireless chargers are able to provide the same charging rate as plugin chargers  
  No real benefit of plugin chargers then
* Drivers will disconnect from a plugin charger much sooner than 80%  
  Need some kind of behaviour model and reference for this
* With the current system of fast plugin charging and slow wireless charging, interested to know at what rate of wireless charging will drivers prefer wireless charging and not need plugin charging at all, perhaps by simulating the dynamics of a single rank

**Friday July 19 | Andrea, Jade | RE: Optimisation**

**Summary of discussion**

* Local search
* Generate neighbourhood, feed into simulation, evaluate
* Solution vector ***x*** where *x2r–1* is the number of plugin chargers at rank *r*, *x2r* is the number of wireless chargers at rank *r*, for *r* = 1, 2, … , no. of ranks
* Neighbourhood N(***x***) consists of all ***y*** such that *y*i = xi ± 1 for exactly one component/rank *i*
* Objectives (in order of importance):  
  1. No. of calls rejected  
  2. No. of chargers, equivalent to cost of chargers

3. Wait time to charge

4. Total distance travelled by taxis  
5. Total distance travelled by taxis to reach charger

6. No. of times an e-taxi at front of queue must refuse a trip due to insufficient SoC

* Initial try: Only 1 or only 3 or weighted combination of 1 + 3 (+ 2)
* Alternatives: tabu search, simulated annealing, genetic algorithm
* Andrea has a multiobjective genetic algorithm

**Thurday July 18 | Patrick, Melanie, Andrea, Jade | RE: Simulation**

**Dispatch logic**  
SoC requirement for trip needs to include (to customer) + (*s* to *t*) + (*t* to nearest charger), at the moment “to nearest charger” isn’t included. Should we include it? Testing without at the moment. TODO later.

**Charging scenarios**1) Only plugin charging, which occurs outside the queue.2) Only wireless charging, which occurs as taxis move into the first *n* positions in the queue.3) Mixed: both types of charging available. If low SoC: plugin then join queue. If high SoC: join queue.

**Vehicle type scenarios**Different vehicle types, i.e., e-taxi versus petrol – call allocation might be tricky as this might favour petrol vehicles with longer range.4) Both types treated the same – FIFO queue  
5) E-taxis prioritised as is done in Norway (?), i.e. get to jump to front of queue petrol.

**Charger type distinctions**Wireless: Taxis connect to a wireless charger as soon as they are in the first *n* positions in the queue; disconnect from the charger and leave the queue to take a call if they meet the SoC requirement.Plugin: Taxis always charge to 80% before disconnecting to join the queue. Can pick up further charge if they reach a wireless charging position while in the queue.

Updates to the questions & answers from **Friday July 12** in yellow.

**Publication**Conference paper: Feedback mid-July.  
Full paper**:** May be due October, if we want to do it.

**Friday July 12 | Patrick, Andrea, Jade | RE: Simulation**

**Patrick | Melanie | Andrea**

**General comments**Not all ranks have chargers  
A normal rank will have space for 5-10 taxis  
Can model non-electric taxis by giving them infinite battery capacity  
Give all taxis infinite battery capacity to begin with and step down to see effect on trip rejection  
Start by placing chargers only at the 9 ranks from the previous optimisation  
Implementing different dispatch strategies can be done easily but is not priority at the moment

1. **Energy consumption model**
   * Charge loss is linearly proportional to distance (25kWh/100km)  
     25kWh/100km would be a good conservative model which accounts for the below
   * Ignore elevation and road curviness  
     OK as Karlsruhe and roughly 90% of trip terrain is totally flat
   * Incorporate starting/stopping at traffic lights  
     Not necessary as EV can recuperate charge; at least much less energy loss than ICEs  
     Thought there would be much more energy loss due to starting/stopping – Patrick said he could look into this  
       
     *Conclusion*: Use distance-based energy model.
2. **Charging model**
   * 20 min for 0% → 80% (linear)
   * 20 min for 80% → 100% (nonlinear)  
     0% → 80% at the max charge rate; 80% → 100% at half the max charge rate  
     Current charging model good for 50kW  
     Suggestion for 20kW wireless charger: 40 min for 0% → 80%; 20 minutes for 80% → 100%  
     Last 20% much slower for fast charging than normal charging

*Conclusion*: Use charge model dependent on charge rate. Patrick to confirm what is suitable.

1. **Taxi dispatch assumptions**
   * Must charge immediately if SoClow < 35%
   * 5 km trip requires > 50% SoC
   * 10 km trip requires > 70% SoC
   * 20 km trip requires > 80% SoC  
     Does not sound too bad; best to have a sensitivity analysis on it

*Conclusion*: Use model as is, but has to be relative to battery size and energy consumption rate assumed elsewhere. Ideally we want: (to customer) + (s to t) + (to nearest charger). TODO.

1. **What SoC should be attained before disconnecting from a plug-in charger and joining the queue?**  
   Probably 80%

*Conclusion*: Use 80% for plug-in charger, wireless taxis can join the queue immediately but only get dispatched from front of queue if their charge is sufficient for the next job.

1. **Considerate taxi drivers: disconnect from a plug-in charger once ~~80%~~ → now 70% (ie lower than the 80% from the previous), SoC is attained if all chargers are occupied?**Could be a possible scenario to see if it has any effect

*Conclusion*: Too complicated, maybe later.

1. **Can taxi drivers access live information on the busy-ness of the ranks?**  
   They can call the coordination centre hoping they keep track there; it will be necessary when we have e-taxis  
   Drivers should have a gut feeling about the number of requests and the number of taxis already waiting at the rank  
   Drivers can expect high demand at ranks around train arrival times  
   Central dispatcher can ask taxis to go to busy ranks

*Conclusion*: Assume live information is available.

1. **Number of taxis in operation across the day/week**Still open topic; currently trying to get that out of the original data  
   Scale the 160 taxi fleet proportional to the amount of trips across time

*Conclusion*: Scale down for now so we can get onto the next steps. At KIT they should be able to find out how many taxis are around during any hour, then try to use that as basis of how many taxis we have available per hour.

1. **Shift regulations**Usually no break if shift < 6 hr, then 30 min break at some point  
   Average shifts are 8 hr but longer shifts are allowed, e.g., if we count idling time as breaks  
   Without shift information we can assume taxis working proportional to demand during time period. We’ll have to somehow make taxis “leave” the simulation as we go from a busier to a quieter period. Perhaps make taxis which have been working longest end their shift first? Entering the simulation again is easy – just add an extra taxi at the main station rank.

*Conclusion*: Not an issue at the moment, no shift.

1. **Maximum length of time a caller will wait for a taxi**

Depends on the time of day but around 10 min  
If outside the city centre, would order a taxi in advance to avoid waiting  
But how do we put it into the simulation? Do we know what is outside the city centre? And what it should be at different times of day. An easy first approach might be to assume fixed maximum time, eg 20 minutes.

*Conclusion*: Assume 20 minutes all across? Assume requests get scheduled just at the time the are picked up in the data for now. Later: If we varied max wait time that would be different. Even later: Or if we allocated who picks up which request if they are known in advance

1. **Maximum length of time a taxi will idle before driving to a different rank**For e-taxis, this behaviour would not be dependent on idling time  
   In future, we could add a relocation approach based on expected demand  
   It only makes sense to move the taxi if this saves driving time/distance for future trips  
   Not a good idea to let e-taxis drive around like conventional taxis do  
   Agreed to not worry about this for now.

*Conclusion*: Taxis stay where they are. Relocation is future work, and would need some better forecasting.

1. **A person at a rank must always pick the first taxi in the queue**Currently yes; when we have e-taxis, maybe no

Dispatch by order in queue, but if a vehicle at the front of the queue doesn’t have sufficient charge, then they are skipped.

*Conclusion*: Dispatch by order in queue, but if a vehicle at the front of the queue doesn’t have sufficient charge, then they are skipped.

1. **Initial taxi allocation**Should be time-dependent as demand is not constant over time  
   Often many taxis at the central station, not sure if it can fit 50 though  
   Definitely not enough space at Europaplatz for 20  
   We can also use a warm-up period of the simulation that is discarded. Then it might sort itself out?

*Conclusion*: Taxis allocated based on popularity of location + warm up period.