Technical flaws that could kill Formula E

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Competent and committed people are organizing the first major high level electric racing series. They have the right contacts, deep pockets, excellent partners and skilled Media relations. What factor are they missing?

To be successful, the series needs to be designed from the start to provide exciting competitive racing, which will attract fans, at a cost proportional to the rewards that attract teams.

Formula E is not designing the series. They do not have a vision of what the series should look like that they are working towards. Instead the series is evolving based on poor choices made on marketing goals. These choices have created technical flaws that could kill Formula E.

The first bad decision is the chassis.

The top racing series in the world is Formula 1. They run winged, open wheeled, single seaters. Formula E's goal is to be the top electric racing series in the world, so for marketing reasons, their vehicle of choice is a winged, open wheeled, single seater.

The high drag, winged, open wheel, single seater is a terrible choice for an electric race car. It can go fast, but not far (see: "***Doing the Math***" for a more detailed explanation).

The extreme range limitation of the high drag, open wheel design leads to questionable decision number two.

Aero drag increases by the square of speed. This means power usage goes up exponential the higher your top speed. If the Formula E cars run on tracks with high top speeds (Le Mans, Silverstone, Daytona), their run time will be extremely short.

Conversely, if they are run on tight, twisty tracks like Monaco, they should be able to run longer. So the decision has been made to run all Formula E races on tight, temporary street courses, set up in city centers.

From the marketing perspective, this ties in nicely with the concept of electric cars as city cars. Short commutes. Limited speeds. No exhaust when stuck in traffic.

The negative impact of this decision is that the races become expensive to hold. These cars are fast and powerful. The organizers must earn enough money to pay for building a safe temporary track on city streets and pulling it down again. Teams must budget for the additional crash damage that comes from racing on a cement barrier lined track. This means the series will need to be very successful to cover the extra cost.

The decision to run on temporary street courses creates the next problem. To justify the high ticket prices the promoter must charge to pay for the track, the series needs to provide a full day's experience. The marketing people decided that means the Formula E's main event needs to be at least 1 hour long. Since, at racing speeds, the Formula E cars can only run 20 to 25 minutes, this presents a problem.

So Formula E must choose from three options. Working out a way to fast charge batteries during a fast pit stop presents huge technical challenges and no guarantees. Allowing battery pack swaps during pit stops would require a complete redesign of the car, would add weight and would need a FIA safety study before it could be sanctioned. The easiest choice to implement and the one that should not delay the series is to require the drivers to come into the pits and change to a second car.

This is kind of a disaster from the marketing point of view. 'Electric cars, one is never enough!' is not the sort of slogan that will build the market.

This is kind of a disaster from the financial side as well. Teams now must get and service two cars per driver. More equipment to maintain. More equipment to transport. More expense.

Formula E management tries to put the best face on it, promising the car swap will add excitement to the race. This is a feature, not a flaw?

This has not been thought through. To operate a modern race car with its high G forces, the driver needs to be strapped tightly in place. The standard is 6 belts (between the legs, across the waist, over the shoulders). A safety neck brace must be fitted properly under the shoulder belts while attached to the helmet. Finally, a neck brace/ arm restraint snaps around the driver. It is difficult to do this even in the calm before a race. It will be a clear safety hazard to ask a driver to do this under the pressure of competition. Drivers take chances to win. How does the sanctioning organization police the car changes so that no driver is going out with his belts not properly secured?

It gets worse. The second car will run out of power 40 to 50 minutes into the race. So Formula E announces the teams will need to recharge the first car and do a second pit stop to swap back to the first car to finish the race.

At this point, it is clear that the people at Formula E have not thought through the ramifications of this decision either. A basic understanding of battery technology helps.

The Formula E prototype uses SAFT lithium ion VL41m cells. While the final brand might change, these are fairly representative of the technology available.

SAFT specifies that the cells are capable of a 3C continuous discharge rate. That means they can be fully discharged in 1/3 of an hour and still meet their published specification. Right at the limit for a twenty minute race, but OK.

This limit is due to heat. Discharge the batteries too quickly, they get too hot. Too hot batteries fail sooner.

The normal battery rating test procedure is to discharge a single cell, starting at a standard temperature and in still air.

The Formula E's battery pack consists of 200 tightly packed cells, which will all generate heat as they discharge. To overcome the heat, the pack will need to be actively cooled. Battery pack cooling is a challenging part of the electric race car design.

SAFT also specifies that the maximum continuous recharge rate is 1C. That means the batteries can be charged at a rate that will recharge them in an hour (they cannot actual be fully charged in an hour but let us ignore this for the moment). This latest decision by Formula E requires that the batteries will be discharged at very close to their maximum rate for 20 minutes and then immediately recharged at 3 times the allowed rate.

This is a technological problem and given enough time and money, it can be solved. But first someone needs to design and build and put into production a 90 kW fast charger. At the moment, there is no unit capable of providing a twenty minute recharge.

Which brings us to the final problem. When someone develops and builds a 90 kW fast charger, where will the teams plug it in? If Formula E attracts a full field of 20 cars, there will be a sudden load of 1,771 kW. This is almost 2 megaWatts. Roughly equivalent to adding the load of 1,200 housholds to the grid.

The local power utility will need to add this capacity for use one day a year. This means power source, transmission lines and outlets or risk the race blacking out the city. This will not be cheap. This needs to be negotiated for each city. This needs to be built and tested before the race. This will not happen in all ten cities.

So instead, each car will need its own 90 kW generator. These cost around $50,000 US and weigh around 8,000 lbs (3,629 Kgs.).

To sum it up, from a team manager's point of view: Budget for four cars (five for redundancy). The value of these cars goes to zero if the series fails; Budget for two prototype fast chargers (three for redundancy); Two $50,000 generators (three for redundancy); Budget for ten street races worth of spare parts; Battery budget is a giant unknown. Batteries are currently the most expensive part of an electric vehicle and no one has any idea how long they will last or how many will be needed. Crew wise: two drivers; enough mechanics to service four race cars; specialists to run and service the generators, chargers and battery packs; plus the usual DAQ, tire guys, and truck drivers. Finally, add on the cost of transporting all this gear and all these people around the world.

Formula E Holdings will need to have very deep pockets to put together an attractive enough rewards package (appearance fee, prize money, sponsor exposure) to make this a viable risk for any race team.

The races will need to provide an amazing spectacle that catches on immediately with the public to generate enough money to pay for all this. It is difficult to imagine how long pit stops and cars rolling to a stop with multiple battery failures will provide this.

The only bright spot is that if this series as currently conceived ever happens, it will negate the electric racing naysayers' pet complaint. One third of the way into the race, when the twenty 90 kW generators lined up behind pit lane go to full power, the earth will shake. And nobody will miss the roar of the internal combustion engine.