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STRATEGY FOR SIMULTANEOUS FORMULA SAE AND WORLD SOLAR CHALLENGE ELECTRIC VEHICLES DEVELOPMENT

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Abstract. Companies and design teams would profit if already developed projects could be reused, and whether new endeavors could be designed synchronously to other projects' requirements and needs. Aiming to expand its know-how in electric mobility, the Ampera Racing team wants to develop a new solar vehicle for the World Solar Challenge in parallel to its established Formula SAE operation. However, due to limited resources, the new solar car is not feasible if both cars don't share key characteristics. In order to understand how a Formula SAE vehicle could be adapted to the World Solar Challenge competition, a framework was developed to provide insights on key decision-making aspects involved in the approval of the venture project, such as requirements and regulations compatibility, project indexation, and energy analysis. The proposed strategy, which proved to be feasible and advantageous, can be replicated to a myriad of domains, not only the automotive, but also to architecture, construction, or tech projects.

Keywords: Vehicle development strategy, Electric mobility, Formula SAE, World Solar Challenge, Solar car.

1. INTRODUCTION

1.1 Motivation

The Ampera Racing Team, from the Federal University of Santa Catarina (UFSC), was born to help accelerate e-mobility in Brazil by contributing to the formation of professionals suited to develop innovations in the mobility industry. Since 2012, Ampera has developed 7 electric Formula SAE (FSAE) cars, being one of the pioneer teams in Brazil completely dedicated to e-mobility, winning several awards in Brazil and Europe, such as the *MVM Special Award* in the Formula Student Online 2020 for the most innovative electric drivetrain concept.

To increase its know-how and influence, Ampera aims to develop new vehicles in parallel to its current FSAE operation. The group seeks opportunities to expand its know-how on topics related to electric mobility, but are not fully explored in the FSAE competition, such as vehicle to grid systems and energy efficiency. Among the options, one that highlights is the World Solar Challenge (WSC), an international competition hosted in Australia with spin-offs around the world, including in South America (known as Carrera Solar Atacama), where the teams must develop electric solar cars to cross 3000 km of public open roads in the desert (Challenge (2020); Atacama (2019)).

The implementation of such vehicle presents huge challenges, but also huge opportunities. By successfully implementing both FSAE and WSC cars, Ampera would have know-how on all key areas for vehicle development, working at the same time with track performance and road efficiency, two complementary topics. However, resources in an university team are finite and its management poses a major challenge to the implementation of both cars at the same time.

This paper is characterized as being exploratory and qualitative research, bound by the information available and the context of an academic competition team. The fundamental research question applied to the context of electric competition vehicles is: how to reuse the FSAE car know-how in a solar car adaptation capable of completing the WSC?

2. Literature review

From an OEM (Original Equipment Manufacturer) perspective, a key competitive advantage is not to increase the complexity involved to deploy the whole line of products each time it enters a new market segment. This allows the OEM to explore multiple markets with its established manufacturing infrastructure and supply chain. The platform strategy is widely used to optimize this competitive advantage by creating standards between multiple vehicles in its product lineup, reducing costs and development time (Eckstein (2014)).

Usually, identical parts and components between two vehicles built on the same platform are the ones not visible, carrying no emotional value for the customer. In the case of Ampera, the team only develops competition vehicles, where most components carry no emotional value, increasing the platform strategy potential (Eckstein (2014)).

In this sense, regarding the vehicle's subsystems, and the competitions that present particularly rules, the strategy consists of analysing the compatibilities between the projects' objectives (i.e. completing and fulfilling the competition's requirements), and identifying similarities between projects technical requirements to verify whether there exists the possibility of reusing subsystems, and, even, if new projects could embrace requirements that may be sufficient for both projects contexts.

The technical knowledge sustaining the analyses used to reach the objectives are provided bellow.

2.1 Energy demand analysis

The energy demand analysis evaluates the amount of energy spent by a vehicle in a given road environment with a given performance standard (Eckstein (2016)).

2.1.1 Road model

The road model consists of segments generated by 204878 GPS data points of latitude, longitude, and altitude of the 2013 WSC route from the Stanford Solar Car Team. Road segments are generated by connecting two data points after data noise treatment. Each segment has unique values for distance (km), altitude difference (m), and road grade ($^{\circ}$), as shown by Figure 1. Figure 2 shows the final road model profile formed by combining all road segments (Zbrozek (2013)).

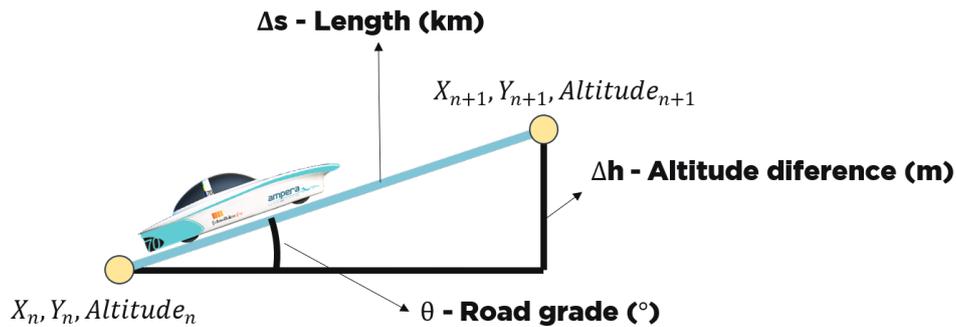


Figure 1. Road segment visualization (authors).

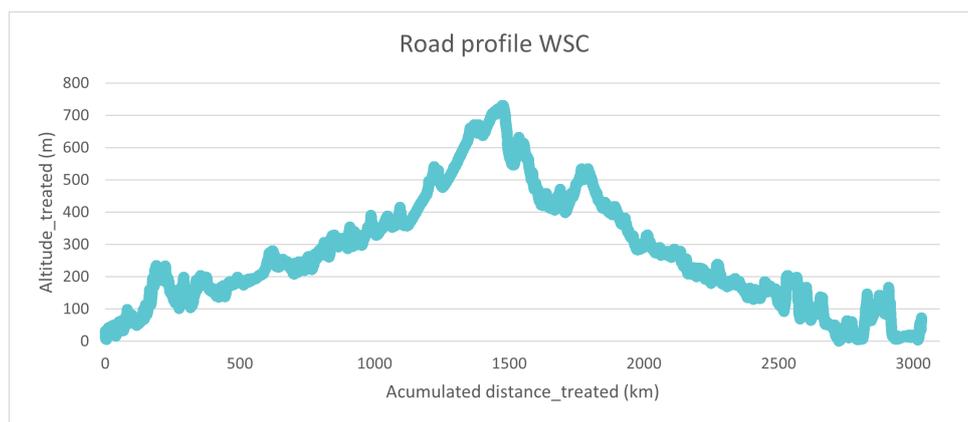


Figure 2. Road profile of the 3020 km WSC route after the data treatment (Zbrozek (2013)).

2.1.2 Vehicle model

The vehicle model assesses the vehicle's power consumption based on powertrain losses and driving resistance forces for a given performance standard in a given road segment n . The considered powertrain losses are battery (η_b), inverter (η_i), motor (η_m), transmission (η_t), and MPPT (η_{ipv}). Of the four main driving resistance forces of the standard longitudinal vehicle model, three are considered (Eckstein (2016); Nicolazzi *et al.* (2018)). The inertia resistance is neglected because the vehicle cruises at constant speeds for most of its desert journey:

- Air resistance: Related to air friction and pressure difference.

$$F_{air} = \frac{C_d * \rho * A * v^2}{2} \quad (1)$$

ρ -air density, C_d -drag coefficient, A -vehicle frontal area, v -vehicle velocity.

- Climb resistance: Related to the longitudinal component of weight.

$$F_{\theta} = m * g * \sin(\theta) \quad (2)$$

g -acceleration of gravity, θ -climb angle, m -total mass.

- Rolling resistance: Related to tire characteristics and friction between moving parts.

$$F_{roll} = (\mu_1 + \mu_2 * v) * m * g * \cos(\theta) \quad (3)$$

g -acceleration of gravity, θ -climb angle, μ_1 -rolling coefficient 1, μ_2 -rolling coefficient 2, m -total mass, v -vehicle speed.

Therefore, the total driving resistance force in a road segment n is:

$$Fr_n = \frac{C_d * \rho * A * v_n^2}{2} + m * g * \sin(\theta_n) + (\mu_1 + \mu_2 * v_n) * m * g * \cos(\theta_n) \quad (4)$$

The vehicle model is represented by the power consumption in each segment as follows:

$$P_n = Fr_n * v_n * \left(\frac{1 - b}{\eta_b * \eta_i * \eta_m * \eta_t} + b * \eta_t * \eta_m * \eta_i * \eta_b \right) \quad (5)$$

Where b is the braking input given by the driver, being equal to 1 if the brakes are deployed and 0 if not. In the energy analysis, the regenerative brakes are considered activated when the total driving resistance (equation 4) for a road segment is negative due to a significant negative climb angle.

2.1.3 Energy demand analysis calculation

There are four energy components influencing the final energy balance during a WSC event, as shown in equation 6 (Carroll (2003); Thacher (2015)):

$$E_{wsc} = E_{b0} + 5 * E_{pv} - E_v - E_{lv} \quad (6)$$

The components can be computed, in kWh , as follows:

- Initial energy (E_{b0}):

$$E_{b0} = 4,4$$

- Daily photovoltaic generation (E_{pv}):

$$E_{pv} = G_{pv} * A_{pv} * \eta_s * \eta_{ipv} * \eta_b \quad (7)$$

G_{pv} ($\frac{kWp}{m^2}$)-specific photovoltaic cell power, A_{pv} (m^2)-installed photovoltaic area, η_s ($\frac{kWh}{kWp}$)-average daily specific yield, η_{ipv} -MPPT efficiency, η_b -accumulator efficiency.

- Overall energy consumption by the powertrain (E_v):

$$E_v = \sum_{n=1}^{204848} P_n * \frac{\Delta s_n}{v_n} \quad (8)$$

P_n (kW)-instant power consumption/regeneration at road segment, Δs_n (km)-length of road segment n , v_n ($\frac{km}{h}$)-average speed at road segment n .

- Overall energy consumption by the LV system (E_{lv}):

$$E_{lv} = P_{lv} * t \quad (9)$$

P_{lv} (kW)-instant power consumption by the LV system, t (h)-overall race time.

The result value of E_{wsc} can represent 3 scenarios:

- If $E_{wsc} < 0$: The solar car won't have enough energy to finish the WSC;
- If $E_{wsc} > 0$: The solar car will finish the WSC but it could have been faster;
- If $E_{wsc} = 0$: The solar car will finish the WSC with optimum performance.

The energy demand analysis provides a way to evaluate which of the E_{wsc} scenarios the vehicle project will be and allows the team to set project parameters to get E_{wsc} as close to zero as possible.

3. Methodology

The synchronous implementation of both cars has to be based on how much know-how can be shared between both. To find out, the analyses shown in Figure 3 are proposed. These 4 steps provide reliable data for the decision-making process of the necessary changes that transform the FSAE car base project on a WSC concept capable of completing the 3000 km desert crossing.

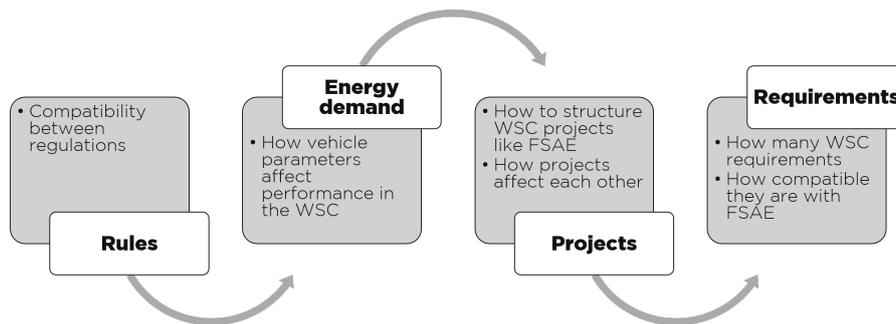


Figure 3. Steps followed to generate a data driven FSAE based WSC concept (authors).

- **Rules analysis:** Assess the compatibility between the FSAE and WSC regulations;
- **Energy demand analysis:** Establish vehicle requirements to achieve minimal energy efficiency to finish the WSC;
- **Project analysis:** Assess if the projects indexation structure of the FSAE car can be shared with the WSC car;
- **Requirements analysis:** Assess if the already implemented FSAE projects are compatible with the findings of the rules and energy demand analyses.

3.1 Rules analysis

The first step to understanding whether a FSAE based WSC car is reasonable to be developed is by analysing how the FSAE and WSC regulations relate to each other, because the *vehicle* related rules of both competitions act as a parallel requirements list. Since the aim is to develop a WSC concept based on projects that were successfully implemented in the FSAE, one can assume that they will follow the FSAE regulations and, therefore, only the *vehicle-related* WSC rules need to be analyzed. Three categories were established to label them:

- *Compatible* (the WSC rule has a pair in the FSAE regulations and is equally or less restrictive than it);
- *Conflict* (the WSC rule has a pair in the FSAE regulations and is more restrictive or contradicts it);
- *Not regulated* (the WSC rule does not have a pair in the FSAE regulations and does not contradict any FSAE rule).

3.2 Energy demand analysis

Even though it is not desirable to start the detailed project phase and make a complete engineering development of the *WSC concept*, basic energy-related project goals (e.g energy stored, losses, power output) need to be defined to assure that the vehicle will, in theory, be able to finish the 3000 km desert crossing.

The *energy demand analysis* used to assess how vehicle properties affect its power consumption and evaluates if a vehicle would have enough energy to finish a route on a given performance standard. For the *WSC concept* energy demand analysis, a longitudinal vehicle model runs through a road model based on GPS data points of the route and then calculates the final energy balance of the race. The parameters that can be iterated in the energy demand analysis simulation are the *drag area*, *LV power*, *roll coefficient*, *vehicle mass*, *battery efficiency* and *powertrain efficiency*.

3.3 Project analysis

In order to properly compare the FSAE car and the *WSC concept*, both have to follow a similar project indexations. The *WSC concept* is directly derived from the FSAE car and is built by identifying shared projects between both cars, followed by the removal of incompatible FSAE projects and the addition of eventual new WSC projects.

This is achieved by assessing the functions of each item in the indexation structure. They are used to describe the intended objective of an item (Back *et al.* (2008)). In this case, indexation items are, from highest to lowest hierarchy, the *overall vehicle*, a *vehicle system* or a *vehicle project*. Ampera already established all functions of its FSAE car, therefore it is desired to assess if they would be compatible with the *WSC concept*. The assessment is ruled by the following steps:

1. Define *WSC concept* overall vehicle function based on the *rules analysis* and the *energy demand analysis*;
2. Asses compatibility of the FSAE car's systems functions with the *WSC concept*'s overall vehicle function of step 1;
 - (a) For systems with functions labeled as *incompatible*, define new function.
 - (b) For systems with functions labeled as *compatible*, reuse the FSAE function.
3. Asses compatibility of the FSAE car's project functions with *WSC concept*'s systems defined on step 2;
 - (a) Within a system, for projects with functions labeled as *incompatible*, define new function or remove project.
 - (b) Within a system, for projects with functions labeled as *compatible*, reuse the FSAE function.
 - (c) If all projects within a system are removed, remove system.
4. Based on the *regulations* and *energy demand* analyses, propose new WSC projects in order to fulfill WSC regulations and performance standards not covered by current projects.

4. Analyses implementation

All analyses were implemented by the authors with support of the Ampera team during the year of 2020.

4.1 Rules analysis

The *WSC vehicle* regulations are divided into 29 subsections and has 139 rules. In order to make the FSAE car WSC legal, the project changes of Table 1 would have to be implemented. In general, they are of medium to minor complexity and reasonable to be implemented in the context of adapting the FSAE project.

The rules analysis showed that the main issue coming from the regulations isn't the conflict of aspects from the FSAE projects with the WSC rules, but the need to implement adaptations and even entire new projects to comply with WSC rules out of the scope of the FSAE regulations. As shown in Table 2 48% of the WSC rules are not regulated by FSAE and only 10% have direct conflicts with them. With exception of the PV arrays, only minor changes are required to adapt the FSAE car to WSC regulations.

4.2 Energy demand analysis

Multiple simulations were implemented by testing different vehicle parameters until a slightly positive final energy balance was achieved. The best result was obtained with parameters of Table 3. The simulations must comply with the minimum average speed of 60 km/h (Challenge (2020)). The final energy balance of +0,32 kWh (7.3% of the accumulator's capacity) is reasonable given the simplifications adopted in the model. The following project changes have to be implemented in order to the control vehicle to achieve the target values of Table 3.

The energy analysis has proven that the major challenge to adapt the FSAE car to a WSC race is the energy efficiency gap. Racing a "WSC legal" FSAE car will only allow it to complete 28% of the route. Deeper changes are required, the majority must be implemented on the aerodynamics and the powertrain, therefore promoting the biggest discrepancies between the original FSAE car and the adapted WSC car.

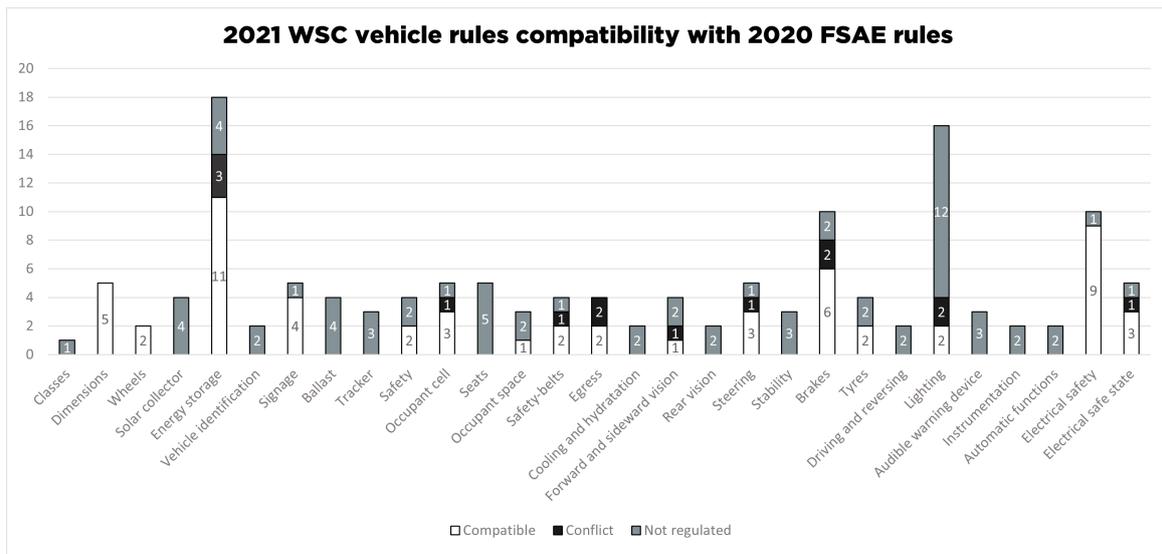


Figure 4. Classification of WSC vehicle rules with the 2020 FSAE rules by section (authors).

FSAE project change	Reason
Reduce accumulator mass and adjust container size	Conflicts between WSC 2.5.2, WSC 2.5.4, WSC 2.5.6 & FSAE EV 4.1
Strengthen harness	Conflict between WSC 2.14.3 & FSAE 7.10.1
Add new rear lighting	Conflict between WSC 2.24.5 & FSAE T.3.2.2
Change position of main brake light	Conflict between WSC 2.24.6 & FSAE T.3.3.2
Stick Brazilian flag in the vehicle body near the driver	Fulfil rule WSC 2.7.5 not regulated by FSAE
Add drink and forced ventilation to the cockpit	Fulfil rules WSC 2.16.1 and WSC 2.16.2 nor regulated by FSAE
Add cockpit canopy to the vehicle body	Fulfil rules WSC 2.17.3 and WSC 2.17.4 not regulated by FSAE
Add mirrors to cockpit	Fulfil rules WSC 2.18.1 and WSC 2.18.2 not regulated by FSAE
Change slick tires to road legal tires	Fulfil rule WSC 2.22.2 not regulated by FSAE
Change transmission ratio	Fulfil rule WSC 2.23.1 not regulated by FSAE
Program reverse gear	Fulfil rule WSC 2.23.2 not regulated by FSAE
Program horn feature in TSAS	Fulfil rules WSC 2.25.1, WSC 2.25.2 and WSC 2.25.3 not regulated by FSAE
Total changes	12

Table 1. Project changes due to conflicting and not regulated WSC rules (authors).

Compatible	58 (42%)
Conflict	14 (10%)
Not regulated	67 (48%)

Table 2. Classification of the vehicle section of the 2021 WSC rules (authors).

4.3 Project analysis

Given the information provided by the *Rules analysis*, *Energy demand analysis*, and Ampera's strategy, the overall vehicle function of the *WSC concept* was defined as "**Travel 3020 km with solar energy**". By following the analysis' steps, starting with the given overall vehicle function, the following indexation (Figure 5) was achieved. It guides the *requirements analysis* and provides the basis for data assessment between both cars.

The project analysis provides a great approach to make the two-vehicle projects speak the same language, allowing easier control of project changes and better visualization of the differences between the vehicles (Table 4). The fact that they share 45 out of the 51 projects also indicated that most of the current know-how would be reused.

<i>Vehicle parameters</i>	<i>Values</i>
Average roll coefficient ($\mu_1 + v * \mu_2$)	0,004698
Drag area ($Cd * A$) (m^2)	0,07
LV power (kW)	0,05
Vehicle mass (kg)	220
Efficiencies	
Battery (η_b)	0,94
Drivetrain ($\eta_i * \eta_m * \eta_t$)	0,857
Final energy balance (E_{wsc}) (kWh)	+0,32

Table 3. Target values of vehicle parameters and efficiency for the WSC concept to finish the journey.

Project change	Reason
Replace 2 brushless motors for 1 permanent magnet motor.	Motor efficiency of 0,955 or more required, mass reduction required.
Replace 2 inverters for 1 smaller and more efficient.	Inverter efficiency of 0,955 or more required, mass reduction required.
Optimize transmission gear for efficiency.	Transmission efficiency of 0,965 or more required, motor operation on most efficient rotation required.
Extend wheelbase and adopt bullet design for the vehicle.	Drag coefficient of 0,1 or less required, 4 m ² of solar arrays required
Cover wheels with drag reduction fenders.	Drag coefficient of 0,1 or less required.
Reduce vehicle width	Drag area of 0,07 m ² or less required.
Total changes	6

Table 4. Project changes required in the FSAE car in order to have enough efficiency to finish the WSC (authors).

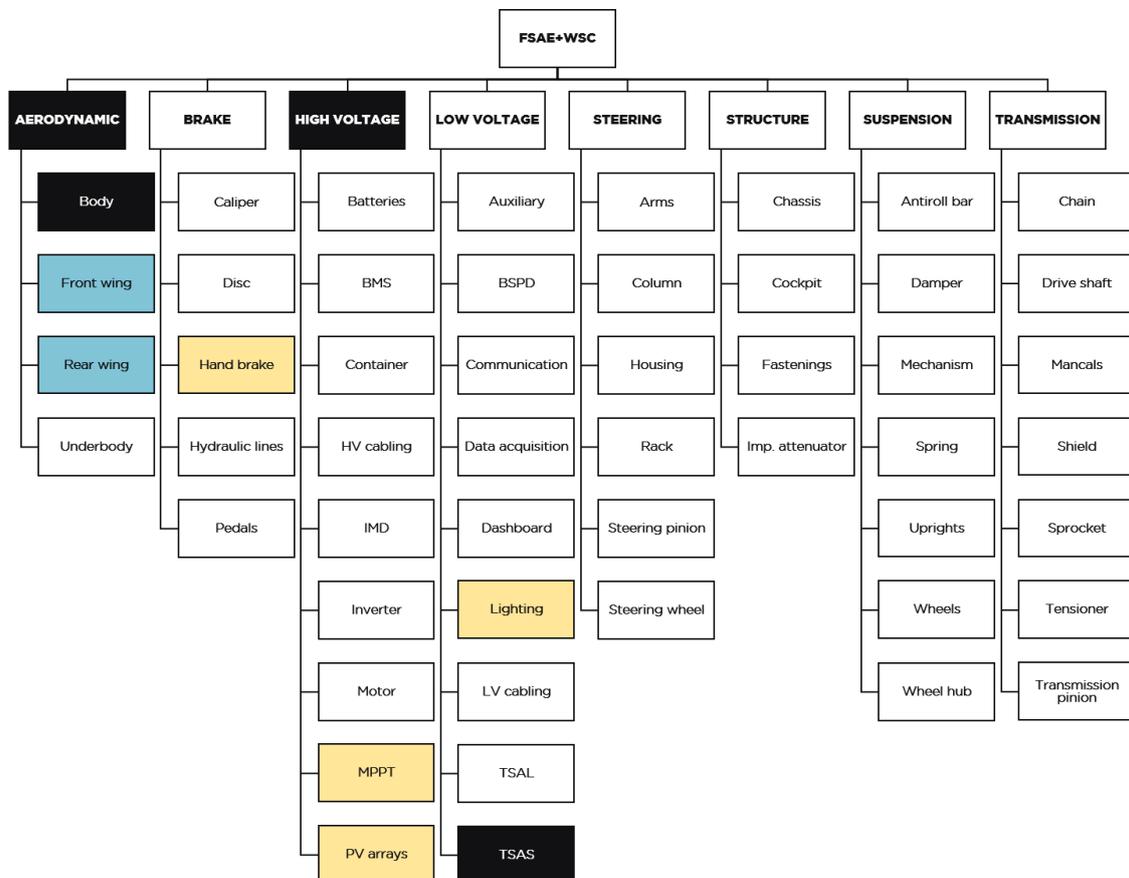


Figure 5. Merged view of FSAE car and WSC concept project indexation structure. Subtitles in Table 5 (authors).

Subtitle	Systems	Projects
Shared item with same function	6	43
Shared item with different function	2	2
FSAE exclusive item	0	2
WSC exclusive item	0	4
Total	8	51

Table 5. Subtitle of Figure 5 (authors).

4.4 Requirements analysis

Each project change is related to one or more requirements that are incompatible with both cars simultaneously. The requirements are organized by a mutually exclusive and collectively exhaustive (MECE) indexation whose main categories are *manufacture*, *norms*, *operability* and *performance* (Schröder (2017)).

Once the WSC requirements lists are ready, a comparison between FSAE and WSC requirements is made and they are classified as *shared*, *FSAE exclusive* or *WSC exclusive*. Some of the *WSC exclusive requirements* may not be incompatible with the *FSAE exclusive requirements* and, therefore, won't impose changes to the FSAE projects used in the *WSC concept*. In order to assess the compatibility, the requirements are classified as one of the following categories:

- *Compatible* (the requirement *won't* impose changes to the base FSAE project used in the *WSC concept*);
- *Incompatible* (the requirement *will* impose changes to the base FSAE project used in the *WSC concept*);
- *Compatibility uncertain* (it is not possible to assess the requirement without starting the detailed project phase).

Once all requirements have their compatibility assessed, a *compatibility index* (C_i) is proposed for each project by dividing the number of *compatible requirements* by the total number of requirements of that project. Table 6 provides an overview of the requirements analysis.

$$C_i = \frac{\text{Compatible requirements}}{\text{Total requirements}} = \frac{C}{T} \quad (10)$$

CATEGORY	T	S	F	W	C	U	I	C_i
Operability	460	394	27	39	394	0	66	86%
Norms	427	311	27	89	353	23	51	83%
Manufacture	474	365	50	59	373	6	95	79%
Performance	690	319	145	226	482	75	133	70%
Total	2051	1389	249	413	1602	104	345	78%

Table 6. Requirements analysis output by category. T-Total, S-Shared, F-FSAE exclusive, W-WSC exclusive, C-Compatible, U-Uncertain, I-Incompatible, C_i -Compatibility index (Ampera et al., 2020).

The requirements analysis provided a detailed view of the complexity level surrounding each project and its adaptation to the WSC. In general, the majority had over 80% of requirements compatibility, a high value that strongly supports the components sharing strategy for the WSC car. With 78% overall compatibility among the 2051 requirements analyzed, it was clear that the component sharing strategy is viable. Some projects got a low compatibility index due to high uncertainties. Most cases are related to fatigue (especially from transmission and steering), however, if proven compatible, they can generate an even better result.

5. WSC concept generation

A good project change proposal deals with as many incompatible requirements as possible while being subtle to the original FSAE design. Table 7 lists the number of changes for each FSAE system shared with the *WSC concept* for the scenario where all uncertain requirements are considered incompatible.

This shows that core features are shared between both cars, however, the changes are not equally distributed among the vehicles' systems. This indicates that some of the engineering divisions would be more stressed than others on the task of making both cars. Based on the changes proposed, key shared and divergent vehicle features were identified as shown in Table 8. With the previous analyses in hands, the final vehicle specifications were estimated as shown in table 9. A visualization of the *WSC concept* was proposed by the professional vehicle designer, Ivor Braga, in Figure 6.

System	Changes	Avg per project
Suspension	19	2,7
Aerodynamic	5	2,5
Transmission	14	2,0
High voltage	13	1,9
Structure	6	1,5
Steering	4	0,7
Brake	2	0,5
Low voltage	4	0,5
TOTAL	67	1,5

Table 7. Project change distribution among vehicle systems in descending order of average changes per project (authors).

Convergences	Divergences
With exception of the suspension, everything to the front of the cockpit's firewall can be virtually the same	With exception of the nose and part of the underbody, everything in the aerodynamic system is significantly different, requiring interventions to reduce drag such as wheel fenders and the inclusion of a canopy over the cockpit
With exception of the PV arrays mounting, all fabrication processes, suppliers, and materials can be shared	Due to the different geometry and performance requirements, the suspension mechanism has to work differently on both cars, however, they share the double-A layout and have similar fabrication processes
Even though considerably over-dimensioned, the brake system can be virtually the same	The chassis to the back of the cockpit's firewall has to be elongated to support the PV arrays and to reduce drag, however, the fabrication processes remain similar
Low voltage electronics are also virtually the same, with only minor programming changes required in most cases	The two motors and two inverters have to be respectively replaced for one less powerful, lighter, and more efficient
The chain transmission can be kept, but with revised gear ratio and powering one wheel instead of two	
Both cars can share the same battery cell type and BMS. The container can be mounted in the same place, however, its capacity has to be reduced	

Table 8. Convergences and divergences between the original FSAE car and the WSC *concept* (authors).

Specifications	FSAE car	WSC concept
Accumulator (kWh)	5,3	4,4
Dimensions (W x L x H mm)	1235 x 2000 x 1200	1100 x 5000 x 1300
Drag area (m^2)	0,36	0,07
Power (kW)	40	9,1
Powertrain efficiency	0,634	0,806
PV power (kWp)	0	1,12
Weight (kg)	300	220

Table 9. FSAE car and WSC *concept* specifications (Ampera et al., 2020).

6. CONCLUSIONS

All analyses made were proven very effective to clarify the complexity of developing FSAE and WSC cars synchronously. The results show that, despite their very different use cases, it is possible to make a FSAE based solar car capable of finishing the WSC. Even though resulting in performance compromises that wouldn't make such a solar car the favorite to win the race, the components sharing strategy is very effective for a first-year team.

The fact that a FSAE car is, in general, more complex and refined than a WSC car, also benefits the components sharing strategy when the team already dominates the FSAE development, such as Ampera. Many of the quality standards required for the FSAE, when reapplied in a WSC car, would already rank it among the best vehicles in terms of safety.

As for the impact on Ampera's engineering division, it was also made clear that the suspension, high voltage, and especially the aerodynamics teams would be disproportionately more impacted than others. On the other hand, the impact

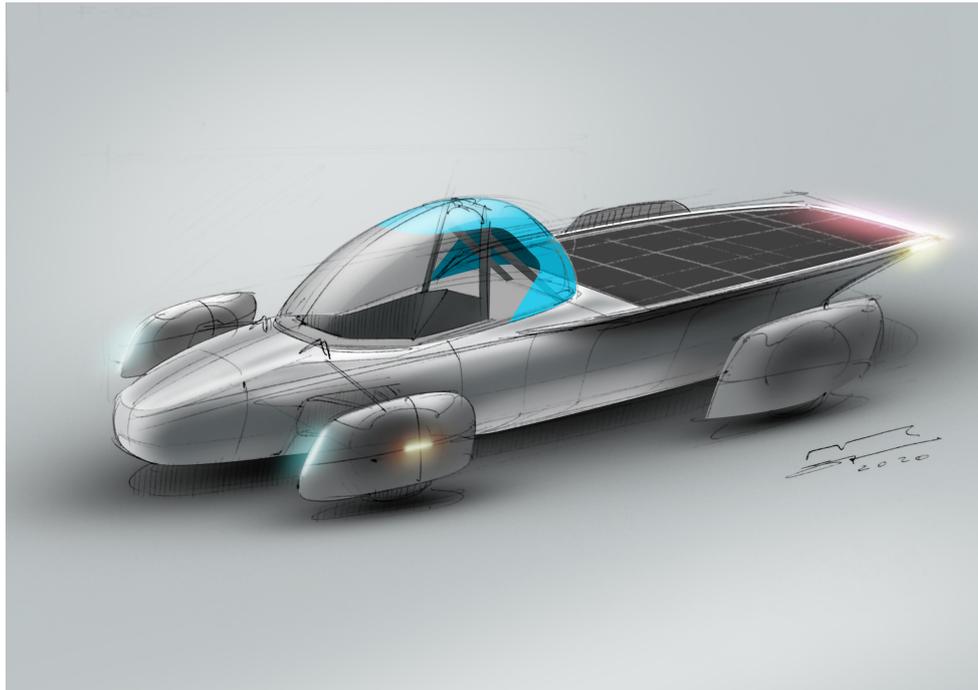


Figure 6. Final WSC concept visualized by the vehicle designer, Ivor Braga (Braga (2020)).

on areas working with brakes, electronics, and steering would be very small, because most of the work they do for the FSAE car can be reused. Areas related to structure and transmission require attention because, despite having many similarities among their projects in both cars, also have to deal with significant changes to some projects.

One of the most relevant highlights is the fact that, even for projects with significant changes, all manufacturing and development know-how used in the FSAE car can be shared with the WSC car. This means that the vast majority of suppliers, tools, and processes remain the same, reducing the fabrication complexity and costs. This concludes that, from the engineering design perspective, the strategy of developing a WSC in parallel to an established FSAE operation is very effective to expand the team's influence and know-how in energy efficiency and vehicle to grid technology.

7. REFERENCES

- Atacama, C.S., 2019. "Regulations carrera solar atacama 2020 - solar class". <https://www.carrerasolar.com>, accessed on 12 February 2020.
- Back, N., Dias, A., Ogliari, A. and da Silva, J.C., 2008. *Projeto Integrado de Produtos - Planejamento, concepção e modelagem*. Manole, 1st edition.
- Braga, I., 2020. "Strategy for simultaneous formula sae and world solar challenge electric cars development". Bachelor thesis in Mechanical Engineering, Federal University of Santa Catarina, Florianópolis, Brazil.
- Carroll, D.R., 2003. *The Winning Solar Car - A Design Guide for Solar Race Car Teams*. SAE International, Warrendale, 1st edition.
- Challenge, W.S., 2020. "Bridgestone world solar challenge regulations - 2021". <https://worldsolarchallenge.org>, accessed on 27 October 2020.
- Eckstein, L., 2014. *Structural Design of Vehicles*. Institut für Kraftfahrzeuge RWTH Aachen, Aachen, 4th edition.
- Eckstein, L., 2016. *Alternative and Electrified Vehicle Propulsion*. Institut für Kraftfahrzeuge RWTH Aachen, Aachen, 2nd edition.
- Nicolazzi, L.C., da Rosa, E. and da Costa Machado Leal, L., 2018. *Veículos Automotores de Rodas*. UFSC, Florianópolis, 1st edition.
- Schröder, K.U., 2017. "Processes and principles for lightweight design". Aachen, IKT RWTH Aachen, Lecture slides - Conceptual Design I.
- Thacher, E.F., 2015. *A Solar Car Primer - A Guide to the Design and Construction of Solar-Powered Racing Vehicles*. Springer, New York, 1st edition.
- Zbrozek, S., 2013. "Wsc route elevation profile". <https://solarcar.stanford.edu/2013/10/wsc-route-elevation-profile/>, accessed on 4 November 2020.