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Concept development for vehicle design education projects carried out in collaboration with industry

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Abstract

This paper describes the concept development process of three vehicle design team projects carried out in successive years in our fourth year undergraduate studio course, in collaboration with industry. The problem areas for all three projects were unfamiliar to student teams, and our collaboration required close involvement of the firms, for their technical expertise and design feedback. Our framework and strategies for this process involved: user research conducted in the field; group discussions for analyzing the operations carried out by the users and mapping their relation to the functions of the related hardware; scenario building for describing the context within an activity based time-related process and searching for solutions at the same time; the generation of numerous ideas through the matching of alternative scenarios with the project dimensions; convergence of these ideas into alternative design proposals; and decision-making on the final project concepts. User research extended throughout the concept development process, supported with an intense 3D exploration and with class assignments that encouraged goal-oriented teamwork. Although we followed a similar design process in all three projects, the strategies used in the various stages were modified depending on the requirements of each project, and regarding the differences in the vehicle types involved, the users and the tasks.

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Keywords: Problem formulation; concept development; vehicle design; collaboration with industry in industrial design education, teamwork.

1. Introduction

In the final year of our four-year undergraduate industrial design education, we collaborate with firms in order to bring our educational techniques together with the sectorial expertise of industrial firms [1, 2, 3, 4]. This paper describes our collaboration in design studio for team projects carried out in the first semester of the final year, where all students in the class work on the same design brief. The motivation comes from an interest in, first, how firms contribute to the concept development process of the student teams, by providing technical support and design feedback in an uninformed area; and, second, how we, as studio instructors, manage the design process towards supporting students in gaining field experience and transferring their research findings to their design solutions. The aim of this paper is to introduce our framework and strategies followed in our design studio course focusing on the problem formulation and concept development stages. The paper presents the outcomes of these two initial stages for three projects as the demonstration of a systematic approach to problem formulation, developing hand-in-hand with concept development. The projects were carried out on vehicle design in three successive years starting from 2013, and involved the backhoe-loader workstation for Hidromek, the rear-bed of pickup trucks for Anadolu Isuzu Otomotiv Sanayi (AIOS), and the vehicle-top customization of firefighting apparatus for Karba, respectively. Following similar stages in the design process, the three projects had three concerns in common: The high level of complexity; requirement of a user-centered approach with emphasis on creative problem-solving; and involvement of a user group that was unfamiliar to the students (backhoe-loader operators, pick-up truck users requiring specialist customization, and firefighting experts).

2. The project topics

The first project was *backhoe-loader operator workstations for Hidromek*, an Ankara-based manufacturer of construction machinery. The main problem area for this project revolved around the operator's seat. The operator's seat rotates 180^{o} to two positions for operating the machinery at both ends of the vehicle. As the position of the seat changes, the position of the

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fixed controls at two ends of the cabin also change for the operator. For example, a control located at the left of the operator in one position, falls at his right when the seat is turned. Besides, during the backhoe digging operations, the vehicle is stabilized; whereas during the loader operations, the vehicle can be maneuvered. This also brings its specific requirements of interface and machinery usage. The focus for the project was solving this problematic interaction between the operator and the machinery interface. For this project, the firm representatives involved throughout the process were members of the Hidromek design team consisting of three industrial designers, a mechanical engineer and a clay modeler.

The second project was *alternative usages for the rear-bed of Isuzu D-Max pickup trucks for AIOS*, an Istanbul-based bus and coach manufacturer with shareholders from Turkey and Japan. The main problem area for this project revolved around the rear-bed of the vehicle. The production of certain parts and assembly of this vehicle started in local facilities in 2014. At the time the company contacted us, the design development team was in search for specialization solutions for the rear of the vehicle. The expectation was to differ in this exploration rather than providing vehicle modifications made for individual clients. Therefore, the project had a focus on specialization for purpose that could find market and in the meantime convey an overall vehicle identity. For this project, the firm representatives involved throughout the process were three industrial designers, and one mechanical engineer as their team leader.

Table 1. The project topics and the collaborating firms

Year and semester	2013-14 / Fall	2014-15 / Fall	2015-16 / Fall
Project topic	Backhoe-loader workstation	Alternative usages for D-Max pickups	Firefighting apparatus
Collaborating firm	Hidromek	AIOS	Karba
Number of student teams	9	8	7
Total number of students	37	36	30
Duration of the project	9 weeks	9 weeks	8 weeks

The third project was *firefighting apparatus for Karba*, an Ankara-based vehicle-top equipment manufacturer. The main problem area for the Karba firefighting apparatus project revolved around the duty-specific activities that firefighters carry out, and the layout of the related fitting on the vehicle top. Firefighters are trained towards gaining expertise in various areas besides firefighting, such as hazmat handling or underwater search and rescue. In general, the vehicle fleet is equipped with hardware that addresses diverse activities and are not specialized for specific firefighting duties. The primary clients are municipalities and due to budget limitations, they expect individual rapid intervention vehicles that contain multipurpose fittings. The project had to take into consideration various incident intervention protocols, regulations and standards, and develop design solutions for overall firefighting apparatus, which was the main challenge for this project. The firm representative involved throughout the process was a mechanical engineer working on product development in the firm. Table 1 gives further information on the projects.

3. The design process and the briefs

The design processes that we followed were distributed into the stages of research (*literature search, field research*), initial ideas generation (*problem formulation, concept development, initial ideas jury*), preliminary jury, and final jury.

The firms' contribution to the processes began at the stage of developing the design brief, by describing a context for the project and bringing true needs into attention. The design brief was distributed at the beginning of the process, defining a project setting for directing the students. The design brief is an important document for initiating a project. Ideally, the design brief gives the problem statement; describes the project requirements; performance, design and/or marketing specifications; goals and objectives; and any other information regarding the expectations of the client from the design service, in order to set agreement between parties on the final design outcomes [5, 6, 7]. We developed our own project briefs even though the project topics were suggested by the firms, and avoided briefs describing specific problems. An agreement on the brief was obtained beforehand to set a common ground for both the course instructors and the firm representatives in order to guide the design process and evaluate the outcomes.

All the briefs gave short information on the firm, problem area for the project, project dimensions, expected outcomes, stages of the project, grading criteria, project calendar, literature search topics to be distributed to each team, and field research description.

We prepared additional briefs for all interim stages that described the activities to be carried out and defined the expected outcomes. The most critical stages of the project seemed to be the initial stages where student teams conduct research, interpret their findings, carry out group discussions towards problem formulation, and work on various idea generation exercises in order to develop their project concepts. For educational purposes, we expected students to formulate their own design problems to address in their design proposals. Throughout years, we have been able to observe that the more appropriately students formulate their problem statements, the more successful they are in responding to the design brief with creative, novel and context-appropriate design concepts.

4. The research stage

The design processes began with the research stages composed of two steps: literature search and field research. Both assignments were given in the design brief distributed on the first day of the project. Both assignments expected a 15 minutes presentation shared in class by the teams, in two successive studio days on the second week of the project. The research submissions were then shared online with the class.

4.1. Literature search

The student teams were asked to carry out literature search in order to gain information on the problem area. The topics were determined by the course instructors in order to cover a wide range of information and were distributed according to the number of teams. While deciding on the topics, we aimed to cover the problem areas from various aspects, such as firm priorities and products; competitor firms and products; other related product examples and concept projects; the design, development, material selection and manufacturing processes; technical specifications, standards and regulations; product experience, users, and anthropometrics; the usage context, tasks and activities involved; and conveying brand and product identity for vehicles.

4.2. Field research

The student teams were asked to carry out field research in order to understand the usage process of the vehicles, the requirements of the tasks and the needs of the users. Teams made visits to the field to interview and observe multiple and diverse users, visually capturing them during product usage. This was an important assignment for understanding the user-product interaction, usage problems and design opportunities. It also helped teams to understand the working conditions, such as clothing, equipment, environment, incident cases, duration of usage, and time of day, which cannot be experienced unless in field.

For the Hidromek operator's workstation project, teams made visits to construction sites on several occasions (Figure 1). Additionally, the firm arranged a visit for student teams to their operation field where they were able to try out the workstation and controls for themselves. The firm also provided the Department with a cabin to be temporarily placed in a hangar in the University for teams to work on their 1:1 scale mock-ups.

Fig. 1. From the research presentation of Hidromek Team 2.

For the AIOS D-Max pickup rear-bed project, teams made several visits to sales points of the vehicle, auto body shops, and institutions that had fleets of pickup trucks used for various purposes; they also made random interviews with users encountered in city. AIOS arranged a vehicle to come to the campus for one day, during which teams were able to explore the vehicle and its features, in parking position. A marketing expert was available for the day and answered questions regarding the customers of the vehicle. In a following event, the firm arranged a one-day driving training. Teams were able to drive the vehicle on-road and off-road under the supervision of a professional driver, to test its performance.

For the Karba firefighting apparatus project, a visit was organized to the Kurtuluş fire station in central Ankara, where students were able to observe and experience the first response/rapid intervention and aerial ladder vehicles. For this project though, due to the diverse expertise involved and accordingly changing types of apparatus, teams had to carry out multiple visits during their concept development stage, to observe and interview firefighters on site and at stations in order to further understand their needs and problems. Teams were also able to observe firefighters' own solutions to problems related to certain features of the vehicles. In order to search for more specific problem areas, some teams also conducted visits to special purpose firefighting units such as underwater search and rescue, and K-9 squads.

5. The problem formulation stage

5.1. Problem identification through group discussions

The research stage was followed by the problem identification stage. We expected our students to be able to make a timely decision on their problem area. The strategy that we followed for this stage was brainstorming, during which all team members could share their comments and suggestions [8, 9, 10, 7]. The basis of the discussions were the research findings presented in class. The expected outcomes of the sessions were a representation of the discussions summary as a mind map or concept map [8, 9] reflecting the keywords that come forth, with a documentation of the discussion notes, related diagrams and sketches. One studio session was dedicated to the discussions, and teams were expected to come prepared with their alternative problem areas for the following studio session.

For the Hidromek operator's workstation project, it was seen from the research presentations that operators placed further emphasis on other problems (*e.g. lack of space for storage, poor all-round visibility*) besides the change in the direction between backhoe and loading functions. Therefore, teams were encouraged to take into account these secondary problems as well and understand the entire process of usage, not only in terms of the operations carried out, but also in terms of the needs of the operators who spend their free times in this cabin. Following this analysis teams were expected to identify design opportunities based on the usage problems encountered.

For the AIOS D-Max pickup rear-bed project, it was seen from the research presentations that users' expectations from the vehicle and the purpose of use formed the foundation of the design problem. Therefore, team discussions were directed on prospective users, their occupations, and their usage purposes of pickups. Following this analysis, teams were expected to identify possible specialization areas, and in turn, define possible functions for the rear.

For the Karba firefighting apparatus project, it was seen from the research presentations that the purpose of the vehicle, its vehicle-top layout, and the equipment involved, were highly determinant in the performance of the vehicle, the processes of the firefighting and rescue activities carried out, and the usage problems encountered. Therefore, teams were expected to review the layout of the fitting and equipment involved, for identifying their relation with the vehicle, firefighting protocols and tasks carried out by the firefighters, in order to identify multiple problem areas.

5.2. Problem formulation through scenario building

The following stage of problem formulation used scenario building for analyzing the activities involved in reference to the features of the context, better articulating the usage problems, thinking in terms of vehicle and equipment usage as a process, and suggesting design solutions [11, 12]. It was also important for teams to start making use of sketching. Thinking with drawings is a means for facilitating the process of idea generation [13, 14]. Besides, it was important for teams to get used to vehicle proportions and technical features represented in their sketches. Teams were expected to generate a number of scenarios in which the usage process was illustrated as a storyboard, describing a process with a beginning, a course, and an end. The users took place for demonstrating usage problems and possible solutions. The outcomes of this session were elaborated design scenarios reflecting the teams' design directions, and problem statements that defined the teams' approaches to the project.

For the Hidromek operator's workstation project, prior to scenario building, an industrial designer from the firm gave a presentation to the students describing the functions of the controls and hierarchical groupings. Initially, teams used scenario building to study the existing situation in the cabin, the sequence of the primary operations (operating the digger and the loader) and secondary operations (listening to radio, air ventilation, storing personal belongings). Teams then made a functional analysis of the interface in the cabin interior represented as a storyboard. The related interface features were mapped on the plan view of the cabin (Figure 2). This session helped to identify the interaction problems. The scenarios covered the following topics.

- Components, controls and operation: Classification of controls according to usage frequency, access of controls, integration of technology, use of graphics and color.
- Visibility issues: Night time usage, lighting, cabin frame blocking the driver's field of vision, dust and mud on the window surface, visibility of the displays.
- Field and weather conditions: Summer and winter conditions, ventilation, dust and mud inside the cabin.
- Storage: Storage for personal belongings, including mobile phones, water bottles, and food.
- Break time: Uncomfortable cabin interior, lack of space for resting or eating inside the cabin.

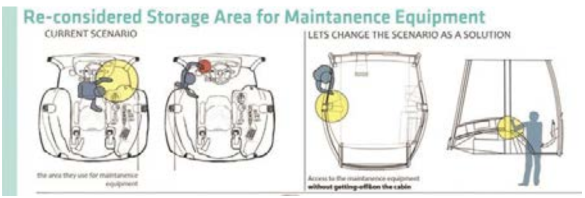

Fig. 2. Scenario by Hidromek Team 4.

For the AIOS D-Max pickup rear-bed project, scenario building was used for determining and analyzing four functions for each team member's scenario. Teams had to decide on the purpose of the vehicle at this stage, and generate design solutions accordingly, with the primary and secondary users integrated in the scenarios. The scenarios covered the following topics.

- Convertibles: Pickups turning into performance stages, tents, temporary accommodation, mobile health centers.
- Sales and display: Pickups used as stalls for merchandise products, fruits, vegetables, fish, cakes, bakery, flowers.
- Passenger transfer: Pickups used for touristic expeditions, military purposes, rescue transfer.
- Transportation: Pickups used for loading and carrying large size heavy items, water demijohns, fishing equipment, sporting equipment, mountaineering equipment, hunting equipment, handyman's equipment; animal transfer, motorbike transfer, cake delivery, delivery of urgent medical supplies.
- Special purposes: Pickups used for camping, hobby and hunting, travel, house moving, waste collection, farming, search and rescue, festivals, funeral services.

For the Karba firefighting apparatus project, scenario building was used for describing the situation from the eyes of the user, following through the task-related activities, and familiarizing with the intervention processes. This required from the scenarios to incorporate the work distribution and hierarchy between the firefighters and their tasks. The teams were expected to think on worst case scenarios with unexpected circumstances. As a result, teams were expected to identify various themes for their project concepts. The scenarios covered the following topics.

- Types of fires: Residential, industrial, rural.
- Locations of fires: Residential areas with narrow streets, narrow entrances, high-rise buildings, commercial districts.
- Types of incidents: Traffic accidents, underwater search and rescue, earthquake search and rescue, flood rescue, K-9 rescue.
- Unexpected circumstances: Obstacles on the road, harsh climatic conditions, insufficient supply, night time usage.
- Public education: Public training in city, drills in schools.

6. The concept development stage

6.1. Idea generation through divergent design activities

Based on their scenarios, teams were next expected to generate numerous design solutions. For the Hidromek operator's workstation project, students were encouraged towards idea generation following a problem-oriented approach. They were expected to respond to the design opportunities that they identified, with various design solutions. Critique sessions were held both in the studio and in the hangar in which the cabin was placed, therefore this idea generation process included 3D design exploration. The design solutions gathered around the following themes.

- Solutions for dashboards, controls and displays for their placement, grouping, rearrangement and usage.
- Joysticks and steering wheels for multiple operations.
- Interior design solutions for a streamlined, easy to clean and spacious interior. Material and color suggestions for dashboards, controls and seat.

- Solutions for rotating seats and shifting positions.
- Storage of personal belongings, maintenance equipment and supplies; their location and ease of access.
- Effective cabin interior lighting, visibility of controls and critical features.
- Communication and feedback on site during operation.

For the other two projects, idea generation was carried out using an exercise that we call the matrix. This matrix exercise was developed in the Department by the third and fourth year studio instructors for facilitating students' idea generation process [15]. Basically, the matrix is a chart in which the first column defines around four to five project themes, contexts (*e.g. outdoor public use, hotel lobbies, schools*) or scenarios. The top row defines around four to six project dimensions (*e.g. specific user group, time of usage, sustainability*), related keywords (*e.g. convertible, modular, safety*) or directive tasks (*e.g. switch user, consider material experience, pack the product*). For each cell of the matrix, students are expected to generate at least one design idea. The exercise resulted in a design ideas portfolio for each team (Figure 3).

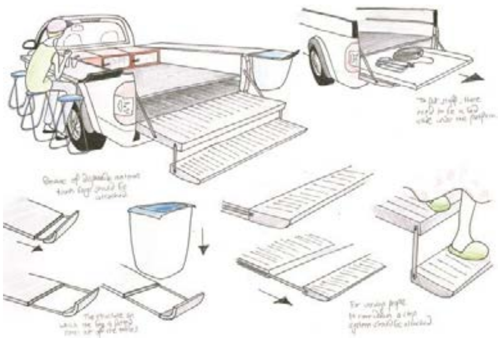

Fig. 3. A design idea from the matrix of AIOS Team 3.

For the AIOS D-Max pickup rear-bed project, the first column of the matrix contained individual team member scenarios and one team scenario. The project dimensions defined in the top row were *specialization for purpose*, *localization*, and *reflection of brand identity*. The design solutions gathered around the following themes.

- Solutions for tail lids and side covers, and their convertibility for purpose.
- Solutions for setting up platforms on or from rear-bed.
- Various types of storage.
- Convertible cabins for passengers, livestock and pets.
- Extra accessories for vehicle front, rear and top.
- Styling solutions for reflecting specialization for purpose.

The outcomes of the matrix exercise for this project were presented in the **Initial Ideas Jury**.

For the Karba firefighting apparatus project, the first column of the matrix contained individual team member scenarios. The tasks listed at the top row were *change time/location of incident*, *change type/scale of incident*, *change type of vehicle*, *change number of team members*, *change type/number of equipment*, and one task defined by the teams (*e.g. change gender*). The design solutions gathered around the following themes.

- Vehicle-top layout: Organization, access, usage and maintenance of fittings and equipment on vehicle.
- Utilities and details: Drainage of wet items; refill of supply; vehicle top or portable lighting.
- Storage units and compartment lids.
- Solutions for frequently used main equipment: Hoses and reels; ladders; rescue boats and motors.
- Firefighter safety in cabin interior.
- Visual and verbal communication.

The outcomes of the matrix exercise for this project were then converged into design proposals in the following stage.

6.2. Concept development through convergent design activities

Following a review of the generated ideas, teams were expected to bring them together into holistic design proposals. In doing so, teams were given certain strategies to follow, such as combining, modifying, using analogies, transferring solutions, or eliminating some that remained out of context [16, 17]. In order to obtain a holistic overall vehicle appearance, the design solutions had to be revised and adapted to the vehicle. If necessary, the teams had to develop new design solutions in order to respond to the design brief.

For the Hidromek operator's workstation project, for supporting this process, teams were asked to prepare a concept board in which they represented the identity of the operator and of the vehicle interior, based on their symbolic interpretation. Accordingly, teams revised their design solutions and brought together those suitable for the determined themes, in at least two alternative cabin layouts. The outcomes were presented at the **Preliminary Jury**. The design concepts consequently suggested for the project are presented in Table 2.

Table 2. The design concepts for the Hidromek project.

Team	Concept
H-1	User-friendly, health-conscious and spacious cabin interior.
H-2	Power and comfort for the operator, precision.
H-3	Increased operation control with haptic feedback.
H-4	Cooperative interior, fresh experience.
H-5	Operator-centered technology, lesser and improved controls.
H-6	Smooth experience, operator and machinery as a single body.
H-7	Minimalist interior, simplified controls, organized cabin.
H-8	Operation-based adaptable and spacious cabin; multi-tasking.
H-9	Operator-centered control; dynamic, powerful, aggressive.

For the AIOS D-Max pickup rear-bed project, the teams followed a 3D design exploration process and developed their concepts by trying out their ideas in alternative compositions modelled on the CAD data for the vehicle provided by the firm. The expected outcome for this stage was two alternative design proposals developed for different contexts, which were presented at the **Preliminary Jury** (Figure 4). The design concepts consequently suggested for the project are presented in Table 3 (*Those marked with an * were chosen as the final design concepts*).

Fig. 4. Preliminary Jury submission by AIOS Team 7.

Table 3. The alternative design concepts for the AIOS project.

Team		Concepts
A-1	1	Display & sales vehicle for packaged food in public areas.*
	2	Fishermen's pickup with specially compartmented rear-bed.
A-2	1	Mobile library for preschool age children.*
	2	Medical supply vehicle for search and rescue missions.
A-3	1	Traditional pastry preparation, sales and service vehicle.*
	2	Transfer of equipment for professional paragliding teams.
A-4	1	Mobile eye examination medical vehicle.*
	2	Transportation of specialized equipment for field surveyors.
A-5	1	Mobile performance stage for small scale events.*
	2	Mobile screen for outdoor public areas.
A-6	1	Expedition vehicle for transporting equipment & samples.*
	2	Off-road motorbike transporter.
A-7	1	Cargo delivery vehicle with specialized compartments.*
	2	DJ cabin for open-air performances.
A-8	1	Mobile stage for medium size interactive events.*
	2	Waste paper collection pickup.

For the Karba firefighting apparatus project, teams reviewed their design solutions and sorted them into problem areas. The ideas were discussed and revised if necessary, and brought together into three vehicle concepts. The vehicle types could differ or be the same, depending on the proposal. The three concepts were expected to incorporate at least 18 design solutions. The outcomes of this stage were presented at the **Initial Ideas Jury**. The design concepts consequently suggested for the project are presented in Table 4.

From their three vehicle concepts, teams had to select one in order to develop into a detailed design proposal. For this, the teams were directed to assess the vehicle concepts overall, partially and in detail. It was also important to ensure the correct selection of a vehicle type for their apparatus. This had to be done based on the technical properties that the apparatus required. The teams had to be aware of the required motor power and load capacity to achieve the required performance. Therefore, the engineer from the collaborating firm came to the studio to give students a lecture on the selection of motor power, wheel base, and calculations of the load distribution on the front and rear shafts. Based on this technical information students determined a vehicle for their concepts, obtained the CAD data, and worked on the design. The outcomes of this stage were presented at the **Preliminary Jury** (Figure 5).

Table 4. The alternative design concepts for the Karba project.

Team		Concepts
K-1	1	Underwater search and rescue vehicle.
	2	Rapid intervention vehicle organizing hoses.
	3	K-9 unit vehicle with extending rear compartment.
K-2	1	Vehicle for distant access operations.
	2	First response vehicle for urban and rural areas.
	3	Natural disaster search and rescue vehicle.
K-3	1	Reorganization of rapid intervention equipment layout.
	2	Compartmentation for rapid intervention vehicles.
	3	Rural search and rescue vehicles for harsh climates.
K-4	1	Firefighting apparatus for narrow streets.
	2	Firefighting apparatus with removable units.
	3	Firefighting apparatus for firefighter safety in cabin.
K-5	1	Rescue vehicle adaptable to different incident scenarios.
	2	Pumper access in narrow streets.
	3	Rescue vehicle for harsh climatic conditions.
K-6	1	Firefighting apparatus with 'smart' compartments.
	2	Firefighting apparatus providing communication on site.
	3	Firefighting apparatus with removable incident kits.
K-7	1	Rapid intervention vehicle with portable pump.
	2	Reorganization of first response vehicle equipment layout.
	3	Rapid intervention vehicle for rural areas.

Fig. 5. Karba representatives at the Preliminary Jury.

For this project, it took longer than expected for the teams to determine the vehicle type suitable to their design concept, as the technical issues in vehicle selection and adapting the concept onto the vehicle proved to be difficult. In the preliminary jury it was seen that three out of seven teams had determined wrong vehicle types, due to misjudgments and technical miscalculations. The vehicle selection either was insufficient in terms of required apparatus performance, or did not fit the usage scenario. The technical feedback provided in the preliminary jury was helpful in guiding the teams, and it took another week for the teams to revise their concepts and finalize their vehicle selection accordingly.

It was seen that all teams carried out a visit to Karba for engineering support, and also to firefighting stations, for user feedback on design decisions, although not particularly required by the course instructors. Teams then obtained the CAD data for each vehicle type either via Karba or the Internet for the design development stage. Teams were thus able to produce a 1:10 scale precise model of the front cabin and chassis of their vehicle, as requested by the course instructors, on which to carry out detailed 3D design exploration. During this process, it was seen that five teams determined their vehicle based on their concept, whereas one team had to revise their concept in order to fit the selected vehicle affordances, and another team changed their concept entirely. The final design concepts and vehicle types are given in Table 5.

Table 5. The final design concepts for the Karba project.

Team	Vehicle brand	Vehicle model	Concept
K-1	Ford	Transit 350M	Underwater search and rescue vehicle providing better working conditions for divers.
K-2	Alke	ATX 240E	Company-owned rapid intervention firefighting vehicle for industrial fires.
K-3	Ford	F-450	Initial response and rescue vehicle based on local geographical and climatic requirements.
K-4	Dodge	Ram 3500	4x4 first intervention vehicle specialized for quick response.
K-5	Mercedes	Sprinter 3500	Firefighting rescue vehicle for difficult climatic working conditions, with modular solutions.
K-6	MAN	TGM	Firefighter truck with mobile pumper for ceaseless intervention and with intelligent features.
K-7	Ford Cargo	1832 Double cabin	Pumper/firefighting truck for various incidents with specialized modular intervention kits.

7. Discussions and Conclusion

The problem formulation and concept development stages of the projects were thus concluded. The final stage for the design processes of the projects was dedicated to design development and detailing for the final submission, which took around two to three more weeks. For the AIOS and Karba projects, two individual sketch problem exercises were given to students, one requiring new detail solutions, the other styling exploration. These exercises enabled each student contribute to the finalization of designs.

Although we followed a similar structure for the design processes, we modified our strategies in the conduct of certain assignments, depending on the project requirements and the availability of opportunities. For this, we adopted a step-by-step approach towards building on the outcomes of each stage. For example, during field research, while AIOS was able to provide us with a pool of users to contact, we had to make our own contacts with operators for the Hidromek project, and with firefighters for the Karba project. For the Hidromek project, accessing users and carrying out observations with them were relatively easier due to the nature of the work involved. Students were able to spend time with operators on site in the cabin, and discuss with them during operations. On the other hand, for the Karba project, although accessing users was possible, observing them on site intervening with an incident was not, due to the limited probability of coming across such an incident, and safety regulations if the chance arose. Therefore, teams had to work with user accounts of situations or provide for themselves with second hand information.

Overall, it was seen that students needed strategical guidance in carrying out user research. Conducting user research also required that the data was analyzed and the findings applied to the problem formulation and concept development stages. Brainstorming sessions and scenario building seemed to support the teams in doing this, who had to come together for this process, think towards a goal, and determine a common approach to the design problem. Conducting user research in the early stages of the process was not found enough. Most teams chose to carry on with regular visits to users throughout the concept development and design development stages, also for user feedback on design ideas.

Scenario building was used as both an analytical tool and a generative tool, in order to familiarize with the processes, understand the features of the contexts, define interactions, identify problems and generate solutions. Scenario building initiated design divergence, but particularly for the Karba project, it was also used by some teams as a tool for design convergence, through which teams revised and elaborated on their vehicle concepts.

As for decision making for the final concept, it was seen that different strategies were followed for the projects. For the AIOS project, the focus was specialization for purpose and teams had to identify specific areas of usage for the vehicles, involving different users and needs. The project required teams to develop two alternatives in parallel, in order to encourage thinking in parallel lines of thought [18]. The project calendar allowed this exploration, and teams handled two concepts easily, developing both almost in equal level, and were able to select their preferred concept following the preliminary jury. The concepts were then developed into design proposals and did not have to be much revised. On the other hand, the Hidromek and Karba projects had specific focuses regarding the tasks. For the Hidromek project, the teams were expected to learn the complex tasks employed by the operators and bring novel approaches to the various aspects of usage processes. Therefore they proposed numerous design solutions and then combined them into overall design concepts. This required teams to adopt a concept theme and consider their design solutions accordingly.

For the Karba project, the focus was again specific, but teams had to first decide on the type of firefighting or rescue task, then identify problem areas, to be able to generate design ideas. Since deciding on a vehicle type depended on the determination of a project concept, the design divergence stage of idea generation had to be kept short. Teams were asked to bring their numerous design solutions under three vehicle concepts for the Initial Ideas Jury. In the course of the project, these concepts went through several revisions; it was seen that some teams chose to combine concepts, whereas some chose to modify them to develop new ones. We consider this to be partly due to the fact that teams were asked to come up with vehicle concepts quite early within the design process, and partly due to not being given a pre-determined vehicle type to work on. Having noticed this delay in decision making, as a strategy, we asked teams to submit one design concept for the preliminary jury, so that they could prepare in-depth.

An intense 3D exploration based on technical data contributed to concept development. Those teams who worked on 3D models and particularly in 1:1 scale, were able to make critical decisions on their concepts earlier. For the Hidromek project, the availability of a real cabin on the premises starting from the beginning of the project made a huge contribution to concept development, as teams mainly developed their designs with 1:1 scale models directly handling the controls acting out their usage scenarios. The design solutions were tried out in the cabin interior and an industrial designer from the firm was present at all critique sessions for feedback. For the AIOS project, 3D design exploration was carried out with scaled models, until the firm provided a professional driving experience with a vehicle brought to the university campus. Following this experience, teams realized that their design ideas may not be in correct proportion to the vehicle rear and continued their 3D exploration mostly on a 1:1 scale basis.

For the Hidromek and AIOS projects the vehicles were pre-determined and the CAD data were provided, which facilitated 3D design exploration earlier on in the design process. On the other hand, there were no pre-determined vehicles for the Karba project, and teams had to make this technical decision based on their design concepts. This delayed 3D design exploration for this project. We will have to consider new strategies to overcome similar difficulties, for future cases.

Finally, it was seen that the firms were highly motivated and committed to the projects. All predetermined activities were carried out according to schedule. Firms were willing to respond to students outside of studio activities, and accepted visits and inquiries that were not planned within the project calendars. Particularly following the initial ideas stage, the collaborating firms were more frequently involved through visits, telephone communication and e-mail correspondence.

Overall, in these three projects we have gained fulfilling educational experiences with our collaborations, and the outcomes have been rewarding for all parties involved. We believe in the importance of carrying out educational projects in collaboration with the industry, as this is an opportunity to exchange expertise, and contribute to the generation of further knowledge.

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