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CONCEPT DEVELOPMENT IN VIRTUAL COLLABORATION: AN EXPERIMENTAL IPD CASE STUDY

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ABSTRACT

The paper introduces an experimental project that was a part of the 1st Integrated Product Development (IPD) International Summer School in 2014 (IPDISS14) announced for doctoral students and doctoral candidates. In this setting and framework two different concept development assignments were given to two groups of participants, out of which one of the projects and its results are presented here. The design task of the team formed by the authors was to develop a solution for flood protection. Since the design problem was extremely superficially defined it was the task of the team to frame and specify the problem, more to create the business model and technical concept, and finally prove the concept; herewith the goal and scope of the project is already been described. Furthermore, the team had to organize itself and set up its communication, management, and collaboration methods, and choose the proper tools to maximize efficiency. The latter was of high significance because the development had to be carried out in virtual collaboration. The two weeks of IPDISS14 took place in two separate locations and were separated also in time by four months. Although the teams were formed locally at the first week, the deadline was set on the second week; in between there was no chance for the team members to meet in person, since they came from all across Europe. The team had to narrow down the design problem to flood protection at high risk (flash) flood urban areas and found that major design problems can be derived from the contradictory requirements of *i)* fast reaction securing against water, *ii)* aesthetic look, and *iii)* the feature of being see-through when not in use. In the paper the development process is described and the final concept is also introduced, as well as the methodology and tools applied in the virtual collaboration are presented. The paper concludes with a reflection of the whole project, highlighting a number of interesting observations and a number of identified pitfalls.

1 INTRODUCTION

Integrated Product Development is a well known, widely applied, and constantly developed concept, theory, approach, methodology, and a way of thinking to describe and prescribe the product development process “in order to exploit product development to enhance business performance” [VB14]. IPD is not only a field or subject of continuous research, but it also provides a framework for research on design theory and methodology.

The two-week IPD International Summer School 2014 was initiated, hosted, and lead by Prof. Sándor Vajna (Otto-von-Guericke University, Germany) and Prof. Jonathan Borg (University of Malta, Malta). It mainly came to life to provide a platform through which doctoral students and doctoral candidates carrying out their research works in IPD related fields can deepen their understanding in this multidisciplinary field (the participants of IPDISS14 came from ten universities in six European countries). “By the end of the two-week Summer School, participants would have improved their competence and ability to tackle research issues with an engineering and business oriented mind-set" [VB14]. To meet these goals the methods of the Summer School were not restricted to academic lectures and interactive oral presentations. The two-week Summer School was split into two sessions – one week in Malta in the first days of May 2014 and one week in Germany in the beginning of September 2014. The 12 participants formed two teams to work on a Summer School Project in the four months time in between, on two different topics respectively, getting the opportunity to apply in practice the IPD foundations being learned so far. The aim of this paper is two-fold. On the one hand it describes the design methodology and process the team applied, furthermore, authors attempt to collect the lessons learnt throughout this experimental "learning-by-doing" product development project. On the other hand, it presents the problem specification from the problem space to the design brief, and also introduces the solution concept along with the proposed business model.

2 METHODOLOGY FOUNDATIONS AND BACKGROUND

The setting described in chapter 1 implies a number of characteristics of multidisciplinary product development environment which is intended to be modelled and applied in the Summer School Project. The success of a product development project is determined by various key factors. Out of those – in the given setting and context, taking the practical aspects into consideration – authors found that the availability of common procedural knowledge is essential. Procedural knowledge, referring to the terminology used in the most cited designer's knowledge model from e.g. [HE96] or [U10], is a type of knowledge meaning one not only knows how processes work in theory or in principle, but one knows how to act within the process to reach its goal, i.e. one applies competence. Generally speaking, it is the possession of active knowledge of doing, managing, controlling or governing processes. Procedural knowledge in a product development project can refer to multiple processes, e.g. the design process, team management, usage of methods or tools, etc. From the perspective of the project in question authors found that the *product development approach* and *the collaborative techniques* are of the most significance. The next subsections will shed some light on the complexity of the methodological challenges the product development team has faced.

2.1 Integrated Product Development

For the common platform for approaching and structuring the product development task the IPD Model of Andreasen & Hein was chosen (Figure 1). Most participants were familiar with this concept and they were given additional lectures to recap the major points of the IPD philosophy, e.g. the three perspectives of business, product and production, human orientation, multi-disciplinary character, life-cycle thinking, etc.

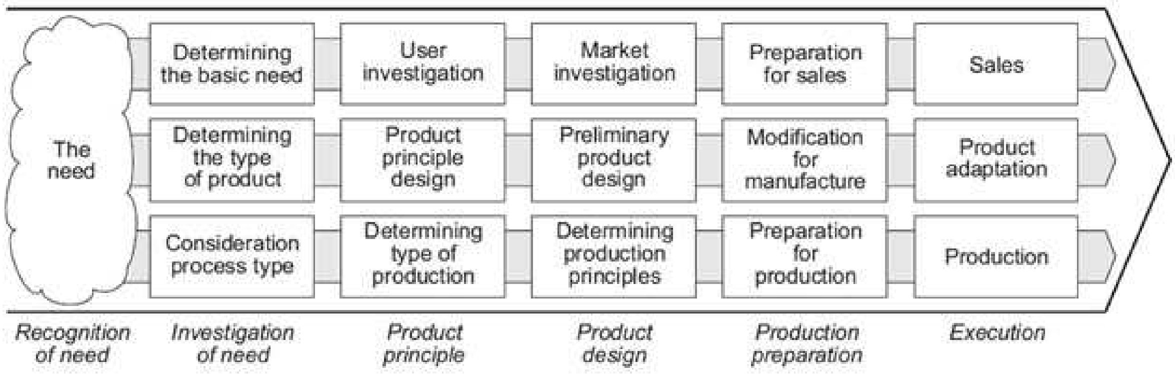


Figure 1: Andreasen & Hein IPD model [AH87]

Team members were challenged to adapt their design process knowledge (e.g. different terminology, different models of product innovation and product design, etc.) to the IPD model and to start breaking down the project into manageable activities. It soon became clear that 'Production preparation' and 'Execution' phases are out of scope, thus the early phases came in focus.

2.2 Collaboration in a Virtual Environment

The project participants had to realize that, despite the team was formed on site, the development project had to be performed in a (geographically scattered) virtual environment, in a so-called *virtual team*. Nevertheless, “understanding how to work in or lead a virtual team is becoming a fundamental competence for people in many organizations, they need to have special skills, including an understanding of human dynamics, knowledge of how to manage across functional areas, disciplines and cultures, and the ability to use communication technologies as their primary means of communicating and collaborating. What these teams have in common with all teams is that team members must communicate and collaborate to get work done. Virtual teams, unlike traditional ones, however, must accomplish this by working across distance, time, and/or organizational boundaries and by using technology to facilitate communication and collaboration.” [DS06]

	One meeting sites (same places)	Multiple meeting sites (different places)
Syncrhronous communications (same time)	**Face to face Interactions** • Public computer displays • Electronic meeting rooms • Group decission support systems	**Remote Interactions** • Shared vew desktop conferencing system • Desktop conferencing with collaborative editors • Video conferencing • Media spaces
Asyncrhronous communications (different time)	**Ongoing Tasks** • Team rooms • Group displays • Shift work groupware • Project management	**Communication and Coordination** • Vanilla email • Asynchronous conferencing bulletin boards • Structured messaging system • Workflow management • Version control • Meeting schedulers • Cooperative hypertext & organisational memory

Figure 2: Johansen CSCW matrix [J88]

Remote collaboration tools are one species of “groupware” – collaborative software that enables Computer-Supported Co-operative Work (CSCW) [G88]. Either CSCW or “remote collaboration” are the terms used to describe those Information and Communications Technology (ICT) based tools and services that enable collaborative work to take place between individuals in multiple locations. As shown in Figure 2, it is possible to segment the available solutions for groupware tools according to whether or not the collaboration is in real-time, and whether in the same or in different locations [ITU08]. Product development benefits from the synergy of teamwork, so collaboration has to be very effective; collaboration calls for more than communication or co-operation, therefore product development in virtual environment is really challenging.

3 PRODUCT DEVELOPMENT PROCESS

The initial task given to the project team was to develop a novel solution that increases the effectiveness of flood protection. The problem is obviously superficially defined, so the team not only had to design a solution, but also to develop the concept, even both problem clarification and specification was assigned to them. The ultimate goal was to develop a solution with the demanded functionalities, and also to prove that the concept is feasible and viable.

3.1 Core Problem – the Floods

A flood in general is an overflow of water in a normally dry area. There are only a very few places in the world that are not affected by floods, which is the number one natural disaster on Earth. Generally, floods are caused by diverse reasons - most common way is when rivers overflow their banks. Other basic reasons are for example excessive rain, rapid ice melting, or a ruptured dam. Apart from floods caused by heavy rain, costal floods occur due to storms or tsunamis. The majority of floods develop over hours even up to days. In this case residents are able to prepare for floods and evacuate the area that is endangered by a prospective flood. However, there are floods that arise quickly with nearly no warning. These so-called flash floods are extremely dangerous because small rivers can turn into ragging torrents.

3.2 Potential Markets

The following subsection contains the market research for flood protection products and services. The market research gathers the most important information about target markets and possible customers. It is a major part of the problem definition in order to identify the need, size, and competition of the market. In addition, the analysis of the market builds the foundations for the business plan. The analysis of the market for flood protection products and services is based on The International Disaster Database of the Centre for Research on the Epidemiology of Disaster [CR+14], the analyzed data covers the last 50 years, starting from 1964.

Table 12: Affection by different types of flooding [CR+14]

	Occurrence	Deaths	Affected	Injured	Homeless	Total Damage
Flash flood	504	61.372	168.965.995	64.369	2.566.714	51.003.136
General flood	2.416	120.696	2.390.274.375	792.107	55.436.336	485.933.745
Coastal flood	80	3.258	19.151.856	1.259	1.672.524	10.022.976

Floods are categorized in flash floods, general floods, and costal floods. For the estimating of affection of these flood types the following attributes are analysed: Occurrence, deaths, (people) affected, injured homeless, and total damage. According to the attributes, Table 1 shows that general floods due to persistent rain are the main cause of disasters. In comparison to the occurrence and the number of deaths, flash floods seem to be more dangerous for humans. However, general floods form the biggest target market for new flood protection products and services due to its 10-times higher total damage than flash floods and nearly 50-times higher than coastal floods.

Table 13: Affection of floods by continents [CR+14]

	Occurrence	Deaths	Affected	Injured	Homeless	Total Damage
Africa	857	22.231	61.849.285	28.398	5.970.074	7.493.723
Americas	968	58.405	83.978.401	44.621	3.635.657	102.890.812
Asia	1.686	210.286	3.280.912.835	1.224.777	73.303.030	381.808.983
Europe	512	5.199	13.037.024	25.856	1.742.309	126.671.616
Oceania	131	439	1.124.066	92	107.485	14.501.375

Table 2 analyses the affection of floods by different continents. The main continents of interests regarding floods are Africa, Americas, Asia, Europe, and Oceania. In summary, Asia is the continent with the highest affection of floods. Especially, number of affected people as well as injured and homeless people is by far the most. However, the ratio of total damage per affected person is way higher for Europe and America. As a result of Table 2, it can be stated that Asia is the preferred market for low priced solutions of flood protection products and services. On the contrary, Europe and America should be focused for high priced products and services. With a detailed look at Europe, it can be stated that Germany, Italy, and the United Kingdom are the most affected countries and, therefore, should be targeted first.

3.3 State-of-the-art of Flood-protecting Solutions

Some methods for flood protection have been practiced since ancient times, including plant vegetation, terracing hillsides, and constructions of flood-ways. Other techniques for flood protection are the constructions of levees, lakes, and dams. These are big-scale constructions in a system with low probability of failure and low risk, but most often high cost, therefore dam and reservoir systems will be out of scope in this project. Three dominant solutions for flood protection were identified: (1) sandbags, (2) tube type, and (3) wall type solutions.

For a long time, emergency flood protections were mainly based on sandbags. And for some flood endangered areas there is still a heavy reliance on sandbags. To use sandbags for flood protection offers some heavy advantages: Sandbags are cheap and simple to use. Nevertheless, sandbags are mainly useful for protecting small, uneven, or such places that are hard to reach. Moreover, sandbags are prone to leaking; erecting sandbag for flood defences is slow and mainly manual work.

In order to overcome these disadvantages of sandbags for flood protection, tube type solutions were developed. This kind of solution offers the special concept of fighting water with water. The barrier is basically an inflatable dam based on a large and lightweight tube that is filled with air during initial deployment, as shown in Figure 3. During floods the incoming water starts to replace the air inside the tubes to create a stable barrier. Additionally, tube type solutions decrease the volume of the rising water. The system can be deployed both preventively and curatively, can be set up in sections of up to 200 meters and can be installed quickly. Moreover, the structure is lightweight and flexible, and therefore can be configured in a variety of shapes and sizes. Due to its characteristics, tube type solutions deliver major advantages at low costs, and they can be reused multiple times.

Figure 3: Examples of tube type flood protection solutions (www.oeko-tec.de, www.bevezetem.hu)

On the contrary, wall type solutions are storm stable as well as physically and chemically resistant due to metal structures. Wall type solutions as shown in Figure 4 are based on metal structures supported by synthetic materials. Therefore, wall type solutions are made for any desired length of flood protection that needs to be set up fast. Moreover, it can be applied for smaller sections like doors, gates, or windows. Wall type flood protection solutions are mainly temporary; however, there also exist solutions that are used as a fence to protect private property. These water fence solutions are originally used to protect highly sensitive locations like electrical or pump stations. In recent years, water fence solutions have gotten more and more attention. The biggest advantage of water fences is that those solutions combine flood protection with a normal fence.

Figure 4: Examples of wall type flood protection solutions (www.liningservices.com, www.buildingarena.co.uk)

3.4 Patent Research

In the area of flood protection products there exist already several patents that restrict possible solutions. With respect to the existing solutions, there are patents for (1) sandbags, (2) tube type solutions, and also for (3) wall type solutions. Figure 5 shows a selection of the patent research. For instance, there is a patent on “Collapsible and reusable flood barrier” (US6715960 B2). Tube type solutions are as well protected, c.f. patent US6840711 B1. Further, there are patents like CN103306237 A that describes a wall type flood protection product. To summarize, while developing a new flood protection product, a detailed analysis of patents is necessary.

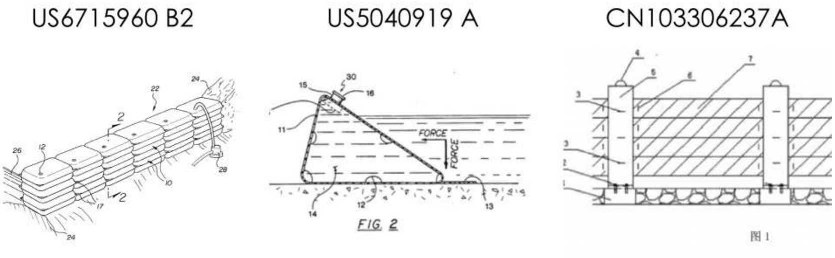


Figure 5: Examples of patents for sandbag, tube type and wall type solutions

3.5 Goal Formulation

After a careful research phase the team started to set up the design goals. Each team member used different techniques to distil the possible design targets from the information available. Some applied deductive techniques (e.g. SWOT analysis, market niche technique, benchmarking, weak point analysis), some rather applied inductive methods (e.g. ideal use case scenarios, law of ideality, vision forming, available resources principle). Eventually the team arrived at a set of core functionalities and requirements that the flood protection product or service had to fulfil:

1) Completely watertight, 2) fastest possible to install, 3) ease of installation and dismantling, 4) efficient storage and/or transport, 5) adaptability for uneven ground, 6) aesthetic, see-through design, 7) novel design. The question whether the solution would be ideally temporary or permanent was left open, obviously the fulfilment of certain requirements would be case dependent.

3.6 Conceptual Design

The team performed several rounds and iterations in the conceptual design phase. In the beginning all members ideated individually upon the problem space. As a result a great variety of principle solutions came to life. In the second round, after an evaluation and screening step, each team member continued to develop the few individual best ideas. After the second round of idea generation the sketches were collected and reviewed. A few dominant design directions emerged from the ideas; all of them were permanent, wall-type solutions, yet they were non-prototypical.

3.6.1 Dominant design directions

The three dominant concept directions were a) Permanent Sandbags, b) Modular Wetfence, and c) Lamella Curtain (see Figure 6). Each of the principle solutions had their strengths and weaknesses (Figure 6), but in order to continue the process, for resource reasons, the design directions had to be narrowed down to one at this stage. The decision was made mostly on qualitative comparison, although it was not easy. For example, as the design brief did not specify the target market and the environment of usage this requirement had not been already applied. For that reason it was difficult to assess and to compare for instance the low-cost sandbag wall with the expectedly high-cost lamella fence at this stage of the development.

Eventually, the lamellas have been chosen for further development by the potential it had to meet the specifications earlier set by the design team. Upon the chosen principle solution two similar concepts of lamella design were created with slightly different technical details. Due to the limitations of the paper, authors restrict themselves to introduce only one concept.

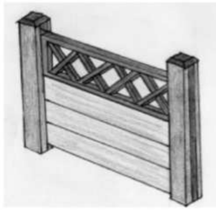
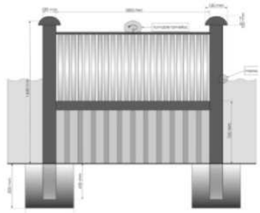
	Permanent Sandbags	Modular Wetfence	Lamella Curtain
Visualization			
Advantages	- low price possible - uses local resources - environmental friendly	- permanent solution - customizable product - see-through option - few parts of procut	- known mechanism - like a normal curtain - open / closed position
Disadvantages	- thick wall needed - time of construction - drying after a flood - very peculiar style	- installation needed - logistics needed	- many part system - complex production - expensive solution

Figure 6: Comparison of dominant concept designs

3.6.2 Lamella Solution Concept

The system applies an array of the eccentric and overlapping lamellas for filling the opening between the posts. The lamellas are connected to each other and are able to pivot around their axes. Lamellas can be flipped together into the upright, horizontal position by using a hand lever, which magnifies force to ease operation. On the tip of each lamella there is a flexible silicone end for proper water sealing between the lamellas. The lamellas could be opened or totally closed according to the wishes of the owner. In opened position the fence is see-through, however, in closed position it provides wind and water protection. The designed fence system is suitable for flood protection around family houses, apartment houses, or companies.

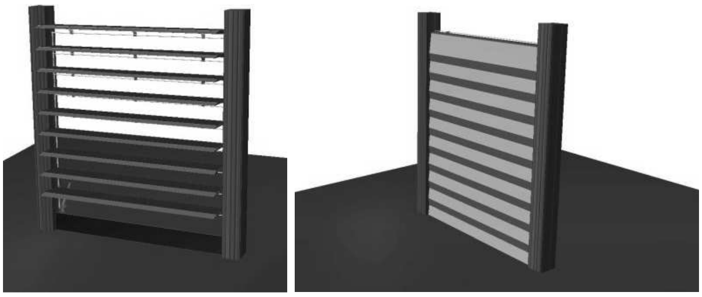


Figure 7: Open (left) and closed positions (right)

The system is easy to be installed by the customer. The posts should be bedded 50 cm deep into the ground. Each lamella sits in grooves inside the wooden posts.

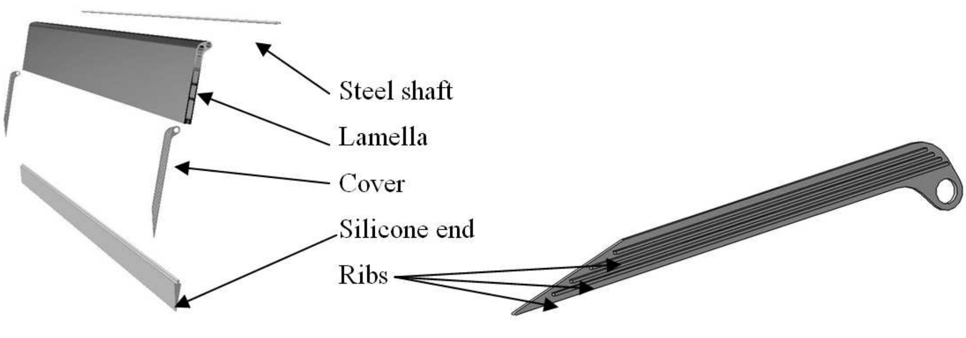


Figure 8: Detailed views of the lamella and its covers

The orientation of the lamella is set thanks to a hand lever that is positioned at the bottom of one of the wood posts. This hand lever actuates the different connecting rods that are connected to the shaft of the lamella. To ensure the pivoting link of the lamella, a threaded spindle is screwed in the lamella for one side and inserted inside the wood post on the other side.

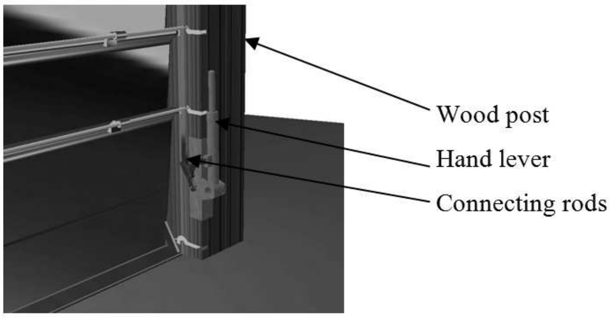


Figure 9: Sub-system enabling the lamella rotation

3.7 Case-study Business Model

The primary customers for the developed solution are households and neighbourhoods in urbanized high-risk-flood areas. In the following, the business plan developed based on the customers of the proposed solution is presented. The revenue streams are direct selling, selling by insurances, or retailing the product. The estimated selling price is about 550 EUR per meter including on-site installation. The selling price is based on a 2x of the costs for the product. Costs for the product are based on an average family house. Therefore, costs, including material and manufacturing, of about 250 EUR per meter are calculated and verified by supplier requests. In order to develop a business case, the following assumptions are taken: Interest rate of 10%, growth rate of 10% and a loan of 2.000.000 EUR for the final development of the solution. Regarding the market size, the business will focus during the first year the three most affected countries in Europe, i.e. Germany, United Kingdom. and Italy. In the second year, the business will be extended to the rest of Europe. Finally, starting from the third year, the business will focus the United States, Africa as well as the rest of the world. As a result of this business plan, the business makes about 440.000 EUR with 76 units in the first year. Finally, in the fifth year, the business makes about 69.830.000 EUR of revenue based on 1609 units. Figure 10 summarizes the business case with the market size in million units (MU), the sales in units as well as the revenue in million Euros.

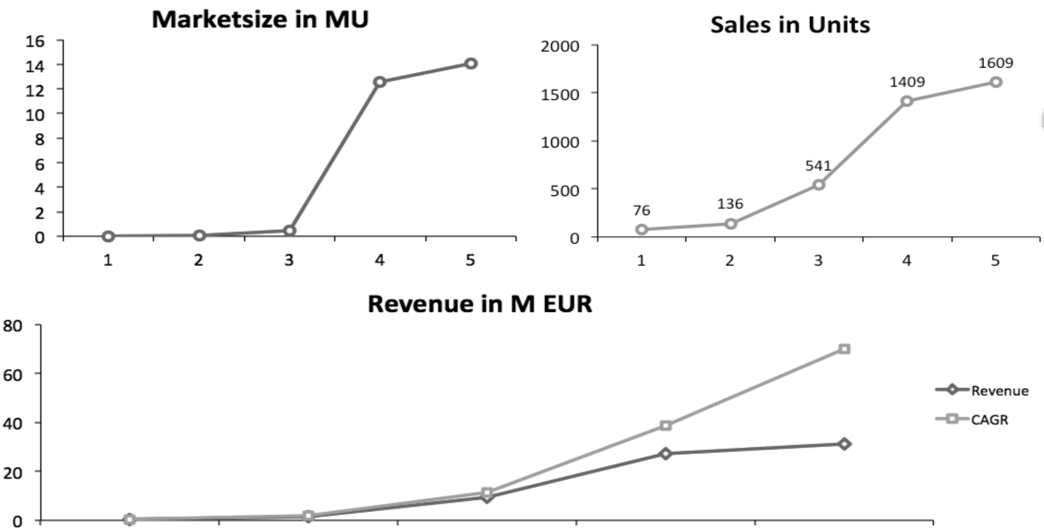


Figure 10: Estimated financial figures

4 PRODUCT DEVELOPMENT PROCESS MANAGEMENT

4.1 Roles and Tasks

The two project team of IPDISS14 were initially formed by the academic supervisors, but it was left to be a democratic and autonomous formation being responsible for its own operation. No special titles were given, although each team had a contact person officially linked to one professor. Rather operative roles were assigned to members, e.g. responsible for methodology, responsible for editing, responsible for meeting minutes, etc. mostly upon free-will basis. The tasks were always derived from interim goals, and they were taken care of either a responsible person or were carried out by all members individually when such manner seemed to be more useful. Previous experience, expertise and motivation were the primary bases of choice for tasks.

4.2 Project Management

Figure 11 provides an overview of the planned team efforts compared to the actually deployed efforts. It became quickly clear that both time constraints and workload could only be tackled by massive activities parallelisation.

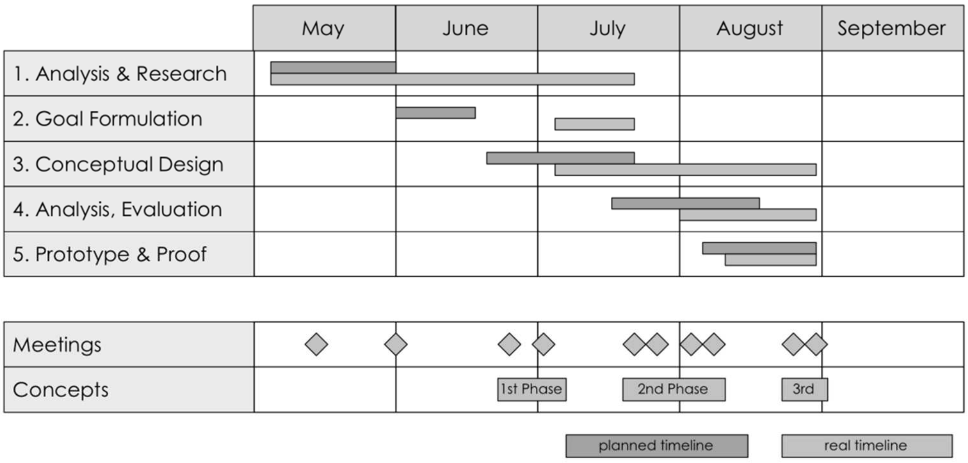


Figure 11: Project run-off (planned and realized)

The primary platform of team communication and management were the virtual team meetings. To enhance the effectiveness of team meetings the team used a variety of tools to support project management, such as Gantt charts, document management system with versioning, internet-based polling system, working documents, meeting minutes, etc. Management tasks and deadlines were handled dynamically and flexibly, basically for availability reasons. The IPD aspects of the development project were mainly discussed at the meetings and were represented in the decisions made.

4.3 Virtual Collaboration

The team development project could not have been done without the extensive use of different remote collaboration tools. From the synchronous applications, the team used Google Hangouts to hold meetings, Google Docs for real time document editing and sharing, Skype for desktop sharing and video meetings as well. Out of asynchronous tools, e-mail, messaging applications, Google Drive for document management, and calendar applications were used.

5 CONCLUDING REMARKS

The paper introduces a solution developed by one of the teams of IPDISS14 to solve the design problem of flood protection. It both presents the methodological and management aspects of the project as well as it outlines the development path the team followed. Moreover, the paper sheds some light on the complexity of an Integrated Product Development project carried out in a collaborative and virtual environment.

In this setting it was found that from the point of the team (i.e. project) success e.g. age, gender, nationality, cultural background, domain specific knowledge, expertise, designer skills are of lower importance. On the other hand, ICT skills, ICT access, internet bandwidth, procedural knowledge, fluency in the communication language, personality, motivation, and availability are of significant importance for effective integration.

Nothing illustrates the importance of collaboration in the success of teamwork better than a famous quote from Henry Ford: “Coming together is a beginning. Keeping together is progress. Working together is success.”

ACKNOWLEDGEMENTS

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