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AGILE & OPEN INNOVATION FOR CROWD ENGINEERING IN NEW PRODUCT DEVELOPMENT APPLICATIONS

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Rezumat. *Complexitatea crescândă a proiectării și fabricării de produse noi și inovatoare depinde de modul în care organizațiile beneficiază de serviciile unei game largi de experți. Inovația deschisă trebuie să devină mai agilă, iar ingineria „combinată” este destinată să asigure o utilizare eficientă a unui grup extins de actori implicați, de la studenți la cercetători, start-up-uri și IMM-uri inovative. Acest articol vizează o revizuire actualizată a literaturii de specialitate privind modalitățile optime de combinare a tehnicilor de management, vizând îmbunătățirea aplicațiilor de dezvoltare a produselor noi. Un studiu de caz practic, aplicat pentru o firmă inovativă în colaborare cu o organizație publică de cercetare, a dezvăluit caracteristici utile pentru etapele care trebuie urmate, atunci când se analizează performanțele unui model / algoritm îmbunătățit pentru dezvoltarea unui nou produs.*

Abstract. *The increasing complexity of designing and manufacturing of new and innovative products depends on how organizations benefit of a wide spectrum of experts. Open innovation should become more agile and "crowd" engineering is destined to organize an efficient and effective utilization of a wide set of workers, from students to researchers, start-ups and smart SMEs. This paper targets a detailed and upgraded literature review of the specificities and optimal way of combining management techniques, targeted to improve new product development applications. A practical case study, applied for an innovative company in cooperation with a public research organization, revealed useful characteristics for steps to be followed when analyzing the performances of an improved model for new product development algorithm*.

Keywords: Agile & Open Innovation; Crowd Engineering; New Product Development

1. Introduction – open innovation & new product development

The essence of the open innovation paradigm is: introducing adapted, transformed and enriched ideas, taken from external sources, to the market, trying harder to capture their customers' knowledge and abilities, in the generous framework of "crowdsourcing communities". However, social crowd integration has not reached

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full potential yet, only some groups of digital industries are much interested in supporting to develop products and configure them individually, depending on participants' willingness to take appropriate actions. In the near future, we estimate that companies will increasingly collect data from multiple sources and synthesize them into something that offers new perspectives. Nowadays, intrinsically and extrinsically motivated consumers are willing to share ideas and content on the Social Web, highlighting the potential of integrating the social crowd in various stages of the New Product Development (NPD) process. However, as this kind of external creation and implementation is still in its infancy, is necessary a more in-depth research on how companies' social crowd integration will nourish the open innovation paradigm on the Internet [1].

On the other hand, Web 2.0 has created both challenges and opportunities for companies who implement open innovation (co-create) with customers. In order to help see these challenges and opportunities in a more structured way, a two-dimensional typology of co-creation, which classifies co-creation practices according to whether they target individuals or mass-market (related to output) and whether the co-creation activities of firms and consumers are differentiated or integrated (related to input). By clearly identifying the particular type of a co-creation activity, it becomes possible to devise strategies enabling to motivate contributors, and minimize the costs.

By creating innovative communities around them, firms can act as a "hub" and convey even more roles (e.g. examining ideas, improving coordination and enforcement) to the community of consumers. In any case, technologies such as 3D printing will enable even more co-creation opportunities, and the future competitive advantage will probably be less about `picking up good ideas here and there', but instead having a stable community of innovators around. Therefore, costs and motivations should be thoroughly understood, but beyond that, the social relations and dynamics within these communities need to be understood [2].

When developing the NPD process, open innovation practices are not very simple, many firms facing strong difficulties when integrating open innovation principles with conventional Stage-Gate methodologies for NPD, because lack of structures and of a systematized process for open innovation. An open Stage-Gate model represents a first step to overcome these limitations and deficiencies, underscoring the need for increased systematization in the process of importing and exporting know-how and technology. The model systematizes import and export of know-how and technology and reminds to the NPD team as well as to the gate-keeping managers to pay attention to the opportunities that may arise from opening up the NPD process. Concluding, an open Stage-Gate model represents a new, more externally aware and dynamic way of viewing the NPD process, and provides a basis for firms seeking to apply the principles of open innovation within their NPD process [3].

Main reason for continuous rise in collaborative initiatives are increasing innovation and technology dynamics, massively shortened development and product life cycles as well as the aftermaths of the information and knowledge society. On this account, an Open Innovation Ecosystem (OIE) is a huge opportunity for large enterprises to break deadlocked and rigid processes and structures to follow-up on new ideas and implement them more quickly and flexibly. The OIE connects strategic decision-makers and creative thinkers, being also a “free playground” for creative employees and supports the formation of subject specific alliances.

A complete and detailed view of the ecosystem is the key to effectively assessing options and prioritizing opportunities. Based on that, is needed a deeper understanding of the specific goals, approaches, and interconnections of each stakeholder. Furthermore, the relevance of TechShops[1] will be more harnessed, considering Minimum Viable Product (MVP[2]) methods and rapid prototyping. Besides this, the impact of IP rights and the accruing innovation culture are important to be thoroughly capitalized [4].

2. Literature review

It is universally accepted that innovative methods and instruments used to design and manage complex projects for developing new products have evolved considerably over the last 50 years, by increasing specialization and the division of labor in organizations. Also, the time reducing needed to faster reach the markets and customers has led to increased concurrency and multi-disciplinary activity, enforcing the coordination and integration challenges facing managers and systems engineers. Consequently, while product systems must be improved, the process systems for developing new and complex products must be “discovered” and implemented, either formally as standard processes, or informally adapted by the workforce. This framework enables building a “unified model” for a variety of purposes, i.e. project planning (scheduling, budgeting, resource loading, and risk management) and control, and it provides the “basic ground” for knowledge management and organizational learning [5].

[1] https://en.wikipedia.org/wiki/TechShop

[2] https://en.wikipedia.org/wiki/Minimum_viable_product

2.1. Modeling and algorithms in New Product Development

New Product Development has become increasingly important recently due to highly competitive market place and economic reasons. Development and production of new products in the planning horizon require an efficient and responsiveness supply chain network. As new products appear in the market, the old products could become obsolete, and then phased out. A generously persuasive parameter, for new product and developed product problems in a supply chain, is the time in which the developed products are introduced and the old products are phased out [6]. Consequently, the advances in the global environment, rapidly changing markets, and information technology have created new opportunities, one strategy for success being the Collaborative Product Development (CPD). Organizing people effectively is the goal of CPD, and it solves the problem with certain foreseeability. The development group activities are influenced not only by the methods and decisions available, but also by correlation among personnel [7].

More and more, innovative methodologies for New Product Development (NPD) such as Lean Product Development (LPD) and Agile Project Management (APM) are used by innovative SMEs, especially start-ups. Consequently, certain negative influences are encountered by the companies' organizational structure, related to its relationship with suppliers & clients, and their culture and mindset. In this regard, strongly functional and hierarchical organizations (i.e. large companies) deter the application of more "softer ways" of NPD, coupled with rigid and vertical decision making processes. The companies strive to follow the needs of their client's and make use of the products of their suppliers, thus any qualitative modification in this stream needs not only an adjustment of the organization, but also of the entire value chain. Therefore, inertia of these external participants (customers and suppliers) has negative influence in the potential application of LPD and APM [8].

Both Agile Project Management (APM) and Traditional Project Management (TPM) are reliable project management approaches suited to different scenarios. Agile/traditional "hybrid" solutions are today preferable, enabling projects to benefit of "command and control" management style, coupled with agile development advantages, such as adaptability to changing requirements, improved team performances etc. Thus, APM is an extension of the stage-gate phased methodology, rather than a dramatically different way of achieving project-based work. APM can be viewed as a new foundation element that will help support the extension of a TPM platform in such a way as to enable practitioners to more effectively manage projects in an uncertain environment. Despite the great popularity of APM in the software domain, it has not yet been well established in other domains, even though this question is emerging among practitioners [9].

The main differences of the traditional and agile approach can be classified in four groups: requirements & specifications (the level of detail at the beginning of the project), project scheduling (iterations and a rough schedule at the planning phase), team work (self-organized teams, daily meetings), and the client collaboration (the representative of the client is a regular team member) [10].

The complexity in all products and processes increases and the need for operative agility is seen as a key factor of success. Agile approaches are extremely beneficial for situations with high uncertainty and a continuously changing environment. A prototype is seen as a phase-spanning driver of the innovation process, and a prototyping roadmap is used to acquire an agile product development [11].

The use of Makerspaces facilitates the iterative prototyping within the innovation process of physical products. The prototypes objectives are segmented into four main categories: explorative, communication, usability and design, and verification. Explorative prototyping aims at making ideas comes alive, act as a proof of concept for ideas and give unexpected insights about an idea. The purpose of prototyping for communication is demonstrating the product to customers, investors, or using it as a model for product photos; for this appearance is given priority. Usability and design prototyping focuses on receiving feedback from users through analyzing interactions with the prototype. Verification prototyping aims at verifying product specifications such as the functionality and ability to manufacture and assemble the product. Prototyping is a point of integration or rather consent during the whole innovation process and is an integral part of an open minded process [12].

Consequently, when product development involves many uncertainties and changes are much likely, agile approaches are valuable. They integrate customers into the development process frequently and explore what satisfies them best. For that, the development team builds working prototypes, demonstrates their functionality and receives feed-back being incorporated into the next iteration. Thus, the developing team collects validated learning and reduces risks more early. However, building physical prototypes frequently is difficult, expensive and time-consuming [13].

The use of the scrum framework, i.e. a specific set of agile principles and practices for self-organizing cross-functional teams in software development projects, is currently being expanded to other types of organizations and knowledge management processes. Integrating agile methods and principles for interdisciplinary collaboration requires a high degree of flexibility and a “learning by doing” approach. Taking into account the specific characteristics applicable to research in academic and scientific areas (as a separate context from software development processes, where the APM framework was developed and is widely used), the adoption seems successful overall in that it facilitates the generation of new dynamics of collaboration, benefiting from some APM principles and practices in various ways. In this sense, the scrum framework constitutes a methodological framework that can be counterproductive if it is too ambitiously or rigidly implemented in some contexts, as indicated in the literature on the utilization APM outside of the software development sector. When adopted by academic participants and experts familiar with research or evaluation methods, the scrum framework seems to be an easy concept to transfer and experiment with, even though specific tailoring to the idiosyncrasies of collaboration and personal motivations may be required when adapting APM. Also, as attested by the literature on agile software development, characteristics such as team size and specificities such as the on-line tools required for operating in distributed contexts seem critical.

Studies on agile management have demonstrated the benefits to be gained with respect to fostering trust and cohesion in teams. Empirical evidence points to a correlation with differing levels of shared leadership, team orientation, cross-functionality, internal learning processes and team autonomy. This seems to be the case as well in the specific research context studied at CECAN[1], and also when contrasted with perspectives from other researchers who are familiar with agile methods. As well as the constraints perceived as inherent to the tradition of academic institutions and the lack of new management practices in scientific activity, or difficulties in adapting to digital tools by senior researchers, some other complexities of adopting agile methods for research are obvious [14].

2.2. Customer orientation in New Product Development

Along with the increasing intensity of market competition, quickly introducing new products to market is becoming essential to firms, so different dimensions of customer orientation could help shorten time-to-market of new products, with a better understanding of how customer orientation affects this process. Therefore, customer orientation investments would implement a time-based NPD strategy.

Nowadays, IT implementation also enhances customer driven capabilities of shortening time-to-market of new products. Thus, managers need to invest in IT systems in order to minimize time-to-market of new product through customer involvement and timely communication with clients; even if competitors can imitate the customer orientation, they will not be able to gain competitive advantage from this imitation if they do not implement IT systems as well.

[1] https://www.cecan.ac.uk/

However, firms cannot achieve shorter time-to-market of new products only through IT implementation, thus is necessary that executives should weigh carefully the risks of investing in IT systems. Risks associated with IT implementation are associated with suboptimal implementation or poorly developed supporting resources [15].

2.3. Crowd Engineering. Hackathons & Scientific Research

Product development organizations are increasingly using crowdsourcing for design-related activities such as idea generation and evaluation, and solving difficult problems. In order to effectively use crowdsourcing within engineering systems design, it is important to systematically design these initiatives by considering conflicting goals such as maximizing participation and the quality of outcomes within cost constraints. There is currently a lack of holistic frameworks that help design engineers in depicting crowd-based initiatives, specifically, framing problems, choosing the right type of crowdsourcing mechanisms, and sketching incentives.

Another challenge in design problems arises from the complexity of human decision making. It is well known that humans deviate from such idealized models because of information processing limitations. Therefore, it is important to first understand the effects of such assumptions on the outcomes, and then to account for the deviations from rationality for more accurate models. One way to understand such deviations is through behavioral experimentation. Other research challenges include the presence of (i) networks of decisions in design processes, and (ii) learning effects along a design process.

There are also challenges associated with integrating existing systems engineering practices with crowd-based processes. Organizations deciding how to use crowdsourcing in systems engineering processes, must decide what information they are willing to reveal about their problems, because the information may reveal the organization's strategies to their competitors. Organizations must decide how to split problems into sub-problems that can be crowd-sourced and sub-problems that must be solved in-house. There is an analogous issue from the perspective of the individual contestants also. In order to respond to a contest, individuals must completely reveal their design (and intellectual property) to the organization. This poses a significant barrier to using crowdsourcing in design.

Conclusively, crowdsourcing in design can be viewed as an economic transaction in information. Information as an economic good has some unique properties - generation of information is costly, but if someone receives the information, its marginal cost of reproduction is almost zero. Similar approaches that allow evaluating design concepts without revealing detailed design information can greatly reduce the barrier in using crowdsourcing as a core strategy in product development, and can improve the participation of individuals in design crowdsourcing [16].

Scientific research plays a key role in the advancement of human knowledge and pursuit of solutions to important societal challenges. Hackathons can be a means of enhancing collaborative science by enabling peer review before results of analyses are published by cross-validating the design of studies or underlying data sets and by driving reproducibility of scientific analyses. Traditionally, in data analysis processes, data generators and bio-computer-specialists are segregated and do not collaborate on analyzing the data. Hackathons are a good strategy to build bridges over the traditional isolation and are potentially a great agile extension to the more structured collaborations between multiple investigators and institutions. Hackathons can be useful throughout the life cycle of projects, e.g., at the start of projects for skills development and transfer, before data are generated in order to have computational pipelines in place for processing the data, midway through a project to derive a common version of processed data for analyses by a consortium, and toward the end of the project for analyzing and comparing results and sanity checking. Another post-project application of hackathons could be to replicate results from a publication analysis [17].

3. The statement of the problem

A relevant complex case study (see [7]) for optimizing the organization of a manufacturing process, in a relative large company, refers to a new type of impeller for a pump, which is a complex product, with some special surface parts and a complex geometric and functional configuration. In the development of an effective manufacturing process for this new impeller, tasks like designing, processing and testing are carried out by designers, manufacturing and testing engineers, i.e. a relative numerous and specialized professional team. By judging the activity correlations among this personnel and grouping them into collaborative "working sub-spaces" is important for the optimal development of a "Collaboration Space Division" (CSD) program, the task being divided, in this specific case (impeller manufacturing), into numerous (eighteen) sub-tasks, which are aimed at performing different specific characteristics (i.e. hydro-mechanical performance, aesthetic performance, kinetic performance, toughness, other performance, fairing, machinability, machining efficiency, surface quality, load of tools, processing cost, processing deformation, collision and interference, machining error, geometric moving error, program calculation error and calculation principal error). So, for "solving these difficult subjects", the engineers can collaborate synchronously or asynchronously in performing these eighteen objectives. As an original proposed optimization methodology, it were analyzed all steps necessary for implementing a Genetic Algorithm (GA), as part of a relative complex mathematical modeling, targeting the grouping of the staff into teams in an optimal manner, strongly supporting to overcome many of the difficulties inherent in organizing the personnel, which is a severe challenge in NPD process. Just for offering a "flavor" upon utilization of biology's "gene-chromosomes" theory, "…after repetitious crossover, mutation, selection and multiplication, a robust chromosome was found, which can be decoded into an optimal collaboration space...".

Today, product life cycles are getting shorter and companies are working to shorten development of new products and ramp-up of production, and based on increased customization, the production volume is reduced, too. In view of the magic triangle of production optimization, companies are "forced" to reduce (1) costs and (2) time while ensuring consistent (3) quality (see [18]).

Thus, the introduction of Crowd Engineering (CE) can support companies in their task of improving their product development approaches, by integrating professionals as well as nonprofessionals in the product development processes. Well-designed products with reduced utilization of human resources are possible, but some major requirements and challenges should be addressed:

- Whom does the crowd to be addressed consist of?

- How can development tasks be outsourced to the crowd and how can the results be reintegrated into internal processes of the company?

- Which areas can be co-worked by the crowd?

Consequently, companies must identify their core issues in engineering in order to manage efforts judiciously (i.e. American Company Local Motors[1]). With the definition of tasks for the community, it is required to identify appropriate interfaces to provide space for open innovation through the crowd. The tasks should focus on areas without relevance for competition, thus avoiding making intellectual property rights publicly available.

Motivation for the extension of using CE in NPD and the benefits derived from it are achieved through the following aspects:

- CE enables the integration of different user groups, which today can only provide feedback in beta user tests or even after the launch of the product. With CE, these "voices" are captured and harnessed at an early stage. The expected

[1] https://www.linkedin.com/pulse/co-creation-digital-world-case-study-local-motors-dharmika/

benefit is therefore the reduction of development time and/or increased success of the developed product, as well as a higher acceptance by the customers;

- CE allows the integration of more resources into the development than the conventional methodologies, supported by an interdisciplinary community and since not all community members have the same background, cross industry innovation is possible;

- CE enables a stronger concentration on the core areas of one's own business, being also possible to have several solutions created by the crowd in order to further detail the most suitable solution.

Prototyping can be used in nearly every phase of the innovation process, which makes it a determining element for the application of agile frameworks for the development of physical products. Iterative prototyping can be seen as core element of agile frameworks, and is supported by a Makerspace. So, a Makerspace is characterized as a publicly accessible workshop which provides members with machines and tools and offers access to a creative community. This community can be divided into generalists and specialists regarding the members' knowledge. Generalists have a broad knowledge covering several disciplines, and specialists have gained in-depth expertise in a single discipline. The community of a Makerspace can support several methods within agile frameworks. Members could attend brainstorming sessions, give interviews or can be included in user tests.

Latest researches investigated the use of traditional product development approaches within the agile innovation framework, helping to rigorously characterize the "happy balance" between the systematic approaches and a "trial-and-error" approach. This challenge is determined by the fact that staying innovative implies the capability to becoming agile, and how to stay agile within a product development process was not been explored in detail, yet (see [12]).

Thus, in this paper we have developed, and gave a practical case study comprising of a possible solution to this issue, the adaption of Media Richness Theory[1] from communication research for agile development, and adopting a guiding model on how to choose an appropriate kind of prototype depending on the complexity of communication task. In doing so, we analyzed the illustration of its plausibility with an exemplary case from practice (i.e. LumiNav[2] – see Fig. 4 from [13]). In this respect, for LumiNav, in the first day, the team started to build simple

[1] https://en.wikipedia.org/wiki/Media_richness_theory
[2] https://www.thinkmakestart.com/lumi-nav/

prototypes. Through a survey of about 30 people of different ages and lifestyles, they learned that LumiNav needed to be a removable all-in-one device sitting in the middle of the handlebar. Apart from these design choices, the team learned that the basic features needed on a bike are a bright light, a navigation function and a trip computer including a speedometer (and additional features like a health tracking system). For the first two prototypes, the team focused on design prototypes to explore the desirability of the design with potential user. The complexity of the communication tasks within the team was simple but the media richness kind of high. Since a CAD model has a higher degree of fidelity than a paper prototype[1], Prototype #3 is arranged higher than prototype #1 and #2. Subsequent to an internal team discussion, the casing passed through another design review to become slimmer in width (compare prototype #4). Prototype #5 was mainly focusing on feasibility and technical verification. The functional prototype was embedded in a laser cut housing, since the fidelity of the electronic components was not high enough yet, for the desired casing. With prototype #6, the team also focused on feasibility, but also on usability and design, as well as verification. The team tried to find out which available rapid prototyping machine was adequate concerning manufacturing of a small production series. The CAD rendering, prototype #7, already pictures the final concept with regards to high fidelity. The final prototype (#8) can be seen as a Minimum Viable Product with minimal faults. The team successfully managed to overcome the constraints of physicality by using simple and easy-to-build kinds of prototypes that still transfer a sufficient spectrum and amount of information to the evaluator. However, prototypes #1, #2, #3 and #7 leave potential for improvement.

4. Case study

In this paper, our case study took a Romanian research innovative SME (Daily Sourcing & Research[2]), which has developed a new product (polyols), destined to introduce in the market an industrial application of non-conventional energy used in energy high consuming industry, combined with waste materials recycling used as the raw materials. Following an iterative prototyping process and by using media richness theory, as presented above for LumiNav application, the team of Daily Sourcing & Research, passed all needed steps till the final product, as presented below, in the following table (see Table 1).

[1] https://uxplanet.org/the-magic-of-paper-prototyping-51693eac6bc3
[2] https://www.dailyresearch.ro/en/

Table 1) Prototypes built by the team to design and built (synthesis) of polyols

#	*Prototype description*	*Category*	*Kind of prototype*	*Type of prototype*	*Purpose*	*Evaluator*
1	Industrial application of non-conventional energy in energy high consuming industries combined with waste materials recycling used as raw materials	Desirability	Paper prototype	Design prototype	Exploration	Potential user
2	Representing the prototype of reactor with microwaves heating	Desirability	Paper prototype	Design prototype	Team exploration	Specialized team
3	Working the prototype of reactor with microwaves heating	Desirability (feasibility)	Laboratory prototype	Functional prototype	Exploration	Team (potential user)
4	Working the prototype of reactor with microwaves heating and waste material as the raw material	Feasibility	Laboratory prototype	Technical prototype	Exploration	Specialized team
5	Trials with the prototype of reactor	Feasibility	Laboratory set-up	Functional prototype	Exploration	Team
6	Working with the prototype of reactor and alternative waste materials (PET - polyethylene terephthalate)	Feasibility	Modification of parameters + additives used in polymerization reaction	Functional prototype	Usability and design verification	Team
7	Final version of reactor + raw materials	Viability	Final mock-up	Technical prototype	Validation of concept	Potential user

More details about each step (prototype) are given below.

#1. Industrial application of non-conventional energy used in energy high consuming industry combined with waste materials recycling used as the raw materials

Desirability based on microwave experience in various applications, the team proposed to use it for cleaning or obtaining the polymers or resins in chemical industry. The aim of the team was to use microwaves both for heating system and to recycle the waste materials i.e. PET bottles. The recycle of PET bottles and re-using them in industry has a huge economic benefit, and environment protection, also. Choosing the type of prototype needed few sketches based on the knowledge's of classic reactors with induction heating. Exploration – mixing of knowledge from microwaves science and how they transmit in various physical supports, with knowledge from classic reactors construction, i.e. physicists, technology specialists, mechanics, chemistry engineer. Potential user - the investor.

#2. Representing the prototype of reactor with microwaves heating

Desirability - a reactor can work with unconventional heating. Design prototype graphical illustration of reactor, mentioning the main aspect related to the functional description of it, possible reaction during microwave heating. Team exploration: physicists, mechanics, technology specialists, chemicals researchers in polymers and resins industry from Ploiesti Institute, ICAA institute, chemical researcher in Environment Protection from University POLITEHNICA from Bucharest (UPB).

#3. Working the prototype of reactor with microwaves heating

Laboratory prototype - designed a reactor to be used with microwave heating, and testing it. Identification and drawing of each component of reactor (distillation and reflux system), fixing their spatial position, distance to the reactor, in order to be easy to handle or control. Various trials were done, with reactors heated with microwaves, parameters study, changing the parameters under loading with different materials. Also it was done the setting of the type of reactors possible to be used, for laboratory tests. Team - physicists, mechanics, technology specialists, chemicals researchers in polymers and resins industry from Ploiesti Institute, ICAA institute, chemical researcher in Environment Protection from UPB.

#4. Working the prototype of reactor with microwaves heating and waste material as the raw material

Laboratory prototype of chemical reactor (in UPB – see Figure 1):

Fig. 1. Image of laboratory prototype of chemical reactor

#5. Working with the prototype of reactor and alternative waste materials (PET - polyethylene terephthalate)

Usability and design verification – the whole team + electronics engineer to follow the stages of reactions, with electronic equipment to be checked at every stage of reaction or to identify the possible problems that could appear during the polymerization reaction. Team, including the final beneficiary – he asked to get a final product with rapid time curing in order to have an immediate industrial application.

#6. Trials with the prototype of reactor

Laboratory set-up comprised all chemical trails, changing the mixtures, catalysts, or temperatures of reaction, in order to get the new final products. Based on using the new raw materials or catalysts, recommended by the suppliers, the tests were made according to the purpose to get the final product with the improved characteristics, compared with the actual products in the market. Usability and design verification – destined to modify the parameters of reaction, in order to get a final improved product.

#7. Final version of reactor + raw materials & final product (see Figure 2)

Fig. 2. Final product (types of polyols)

Conclusions

Building physical prototypes is difficult, expensive and time-consuming. Choosing the prototypes, and deciding when and how to carry those out not only depends on the nature of the product being developed, but mainly on the set of skills that the development team and the evaluators possess in order to understand them. The aim of the paper was to contribute to this field, by adapting the Media Richness Theory from communication research for agile development. Therefore, we outlined an illustrative example by using the case of polyols manufacturing and we presented a guiding model on how to choose an appropriate kind of prototype depending on the complexity of the communication task.

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