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INCREASING DESIGN PROCESS ROBUSTNESS IN THE CASE OF DURABLE CONSUMER GOODS

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Abstract: *Designing and manufacturing consumer products, especially durable goods that are foreseen to have a rather long lifecycle, is increasingly difficult due to the frequent changes of trends, preferences and requirements of the customers or end-users. If previously, the main functionality of the product had to be defined and the details could be worked out through successive iterations, in the world of Industry 4.0 and smart products, the focus has shifted towards products that have to be successful from the beginning (form the first attempt) and should also be capable of adaptability to changing circumstances. The current paper presents a case study that addresses these issues in the furniture industry, where software enhanced products are not an easy solution to the requirements for flexibility, and as such robust design approaches based on risk management and contingency planning should be employed.*
Key words: *robust design, durable goods, risk management, furniture*

1. INTRODUCTION

Product design and development (PDD) is a high-risk endeavor that is as complex and troublesome as it is necessary for success [1]. Competition on the market, especially in the case of consumer goods with a low or moderate tech level (i.e. no software, apps or operating system), is very difficult and resource consuming. Not many companies are willing to commit to this process especially in a developing economy.

The technological transformations and the market pressures have increased significantly over the past decade, in the Industry 4.0 era and in a time of full-fledged globalization. From localized markets in which small companies were used to manufacturing simple and uncomplicated products, we arrived at global virtual market places in which products like fast fashion, smart furniture, smart lighting or intelligent bicycles are common place and are highly sought by customers.

In this context, the PPD process should be supported and boosted with know-how, tools and techniques, and best practices, to be able to generate enough added value in a timely manner, which we equate in this paper with the robustness of design, that should be capable of dealing with changes in customer preferences. Many companies in Romania are limiting themselves to manufacturing based on external designs and are fighting for resource efficiency, quality and on-time delivery. However, the ones that are also creating new products, and then designing them and planning the adequate production processes and support mechanisms, actually multiply their workload and their exposure to failure.

The aim of this paper is to develop an integrated approach for robust product design and provides a support infrastructure for assessing, managing, alleviating and eliminating risks along the product lifecycle. The procedure can be implemented in parallel and in interconnection with the traditional tools used during the design process, such as Failure Modes and Effects Analysis (FMEA) for management and mitigation and Fault Tree Analysis (FTA) for technical solutions to failures. Also, it can complement methods and models in the field based on the increasingly present standards that propose risk management approaches - ISO 9001 or ISO 31000 [2] or other management methodologies such as agile development [3] or lean manufacturing [4].

2. CONTEXT

The specialty literature related to risk management deals extensively with the need to create better approaches for accurately measuring the exposure to failure in certain industries or stages in the product lifecycle, with customization being addressed for each area in particular (software, food, consumer goods, industrial products, etc.). The current article can be integrated in a trend that contains similar models that have been published recently and are targeting business services [5], precision manufacturing [6] and automotive engineering [7].

The main experience leveraged for the proposed demarche is related to new product development for a small furniture start-up, which included the authors as part of a large R&D team of over 20 persons. The goal of this project was to develop both PDD capabilities and concrete results (i.e. furniture products) as part of the long-term development strategy of the company that has received EU structural funding. Due to the nature of this situation, the process ran into a considerable number of difficulties, ranging from nuisances to possible catastrophes and as such, the need to address risks and increase resilience and robustness has become apparent.

Due to a collaboration between the company itself, the industrial cluster to which it belonged and the university, the topic became of general interest to many other stakeholders and has prompted the valuation of other experiences and the employment of specific managerial and software tools. Also, in the context of the transition to the implementation of ISO 9001:2015 instead of ISO 9001:2008, the companies became deeply invested in the success of the undertaking and the connection between process vulnerabilities and product nonconformities became clear.

3. METHDOLOGY

In order to achieve the mentioned goals, the PDD process has been modeled using flowcharts and discrete event simulations with the help of the SigmaFlow software. Qualitative and quantitative risk management has been performed upon the results coming out from this simulation and a mix of measures has been proposed falling into these categories: redundancy measures, fail-safe zones, error-proofing techniques and wild-cards methods. The measures are characterized and exemplified in such a way that their employment and aggregation is fostered.

The SigmaFlow simulation analyzes, as a complete process, the stages and activities included in PDD (maintaining a high degree of portability) with the purpose of identifying threats associated with certain activities and pinpointing bottlenecks and deficiencies, focusing on their elimination or, at least, minimization, thus improving the overall flow and the end result. There are many approaches that aim to define the phases of the PDD process, but it is not within the current scope to discuss them. However, a sequential approach is common and so the studied situation was structured into 6 steps and the analysis was carried out over a period of two years (simulation time: 104 weeks). This was deemed adequate to collect relevant information and uncover the major failure possibilities.

4. RESULTS

For allowing the process to be correctly simulated, the following assumptions and modeling decisions had to be made:

- practice shows (based on the experience of the authors for managing and being involved in PDD projects), that teams of designers, CAD engineers, production specialists and market researchers are needed for success;
- the coordination by a research director is also necessary;
- the simulation stages are: Ideation, Analysis & Research, Development, Testing, Customer interaction and product validation, and Commercialization & Improvement;
- there are 3 resource “clouds” defined in the simulation, one for every couple of stages, to allow for the study of cross-connections and divergent evolutions;

• in the fifth stage, "Customer interaction and product validation", the customer is defined as a simulation resource, and associated to the activities which heavily depend on its feedback;

• a "pool resource" is also defined, comprising all the resources involved in a particular stage of the activity, representing real-life situations in which members from a certain team can take on tasks that are normally carried out by other teams, but are currently unavailable to do so;

• customers are not included into the pool resource, as they cannot fulfil the job of experienced team members, but their input is essential in the advancement of the PDD process;

• the probability distributions of inputs taken into account for each step when performing the simulation are modeled upon the real collected data during the implementation of the above-mentioned project and are then extrapolated for the purpose of the case study.

Since the complete simulation is difficult to show on paper, we will present in the next figure the process steps layout for one of the stages included in the application, dealing with customer - company relations in the final stages of PDD (Figure 1).

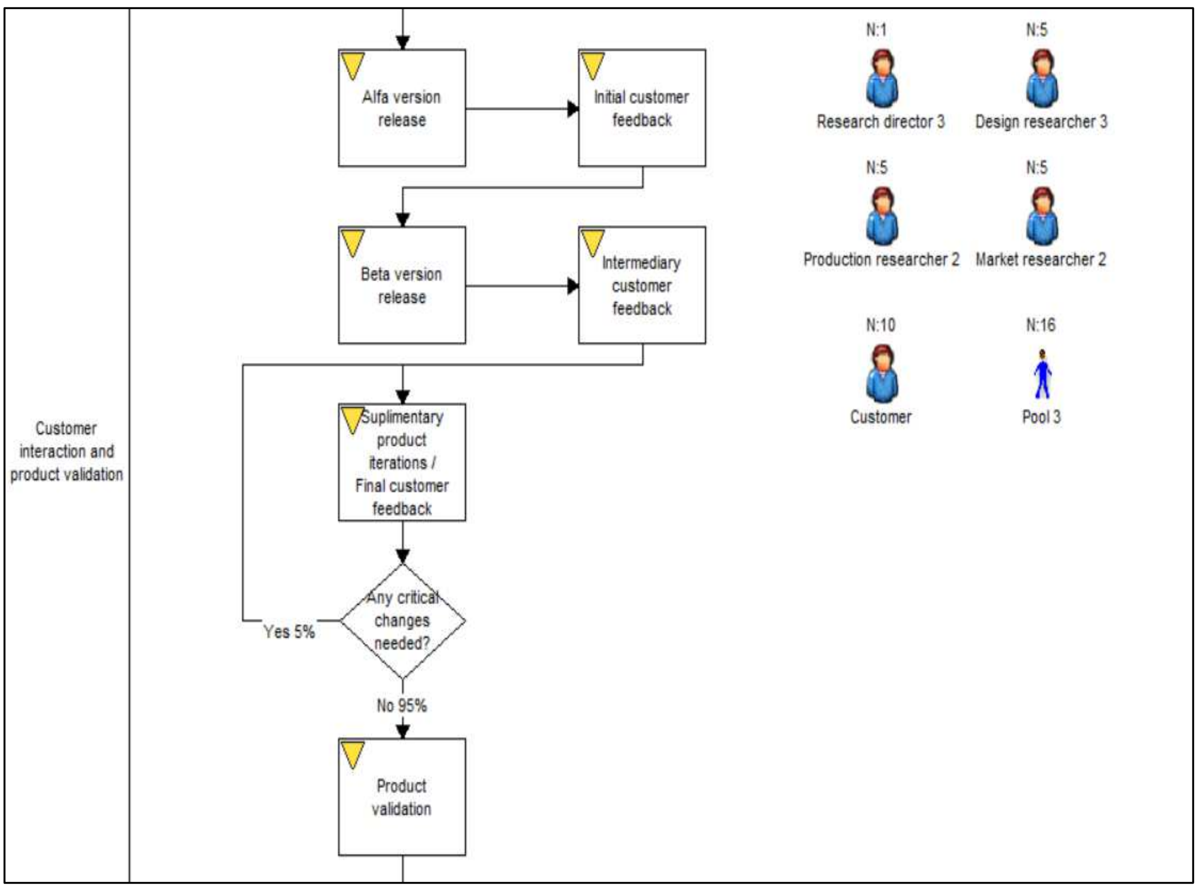
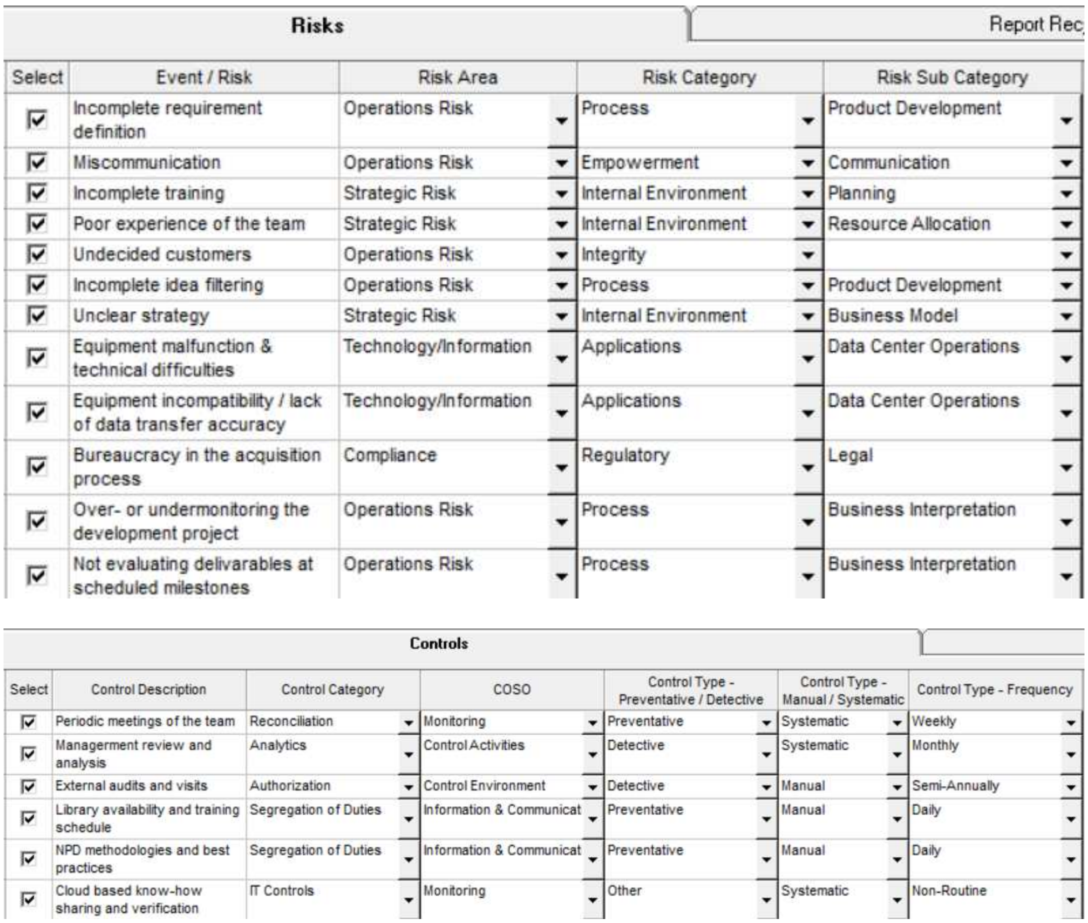


Fig. 1. PDD process for creating new furniture products - SigmaFlow simulation (excerpt)

The model shown in the figure displays the process steps, the yes/no proportion for a decision block and two types of resources (individual that work separately on specialized tasks and pool-type, which share capability and availability). Based on the computer simulation, the model has been optimized for effectiveness (low scrap / nonconformities / errors) and efficiency (resource usage and load). Once this phase is completed, the potential failure allocation has been performed based on data resulting from the project implementation. The risks have been analyzed according to the categories available in the software and so have been the possible control mechanisms, to allow for their interrelated understanding and description.

The combination of process simulation and risk management is complemented by innovative contingency and mitigation measures and proposals for their correlated deployment. In this way, the solutions are delivered at the right spot in the process, in due time and with increased chances of success and durability of results, due to being part of an integrated robust strategy. The general overviews are presented in the next section (Figure 2).



Risks | Report Rec

Select	Event / Risk	Risk Area	Risk Category	Risk Sub Category
☑	Incomplete requirement definition	Operations Risk	Process	Product Development
☑	Miscommunication	Operations Risk	Empowerment	Communication
☑	Incomplete training	Strategic Risk	Internal Environment	Planning
☑	Poor experience of the team	Strategic Risk	Internal Environment	Resource Allocation
☑	Undecided customers	Operations Risk	Integrity	
☑	Incomplete idea filtering	Operations Risk	Process	Product Development
☑	Unclear strategy	Strategic Risk	Internal Environment	Business Model
☑	Equipment malfunction & technical difficulties	Technology/Information	Applications	Data Center Operations
☑	Equipment incompatibility / lack of data transfer accuracy	Technology/Information	Applications	Data Center Operations
☑	Bureaucracy in the acquisition process	Compliance	Regulatory	Legal
☑	Over- or undermonitoring the development project	Operations Risk	Process	Business Interpretation
☑	Not evaluating deliverables at scheduled milestones	Operations Risk	Process	Business Interpretation

Controls

Select	Control Description	Control Category	COSO	Control Type - Preventative / Detective	Control Type - Manual / Systematic	Control Type - Frequency
☑	Periodic meetings of the team	Reconciliation	Monitoring	Preventative	Systematic	Weekly
☑	Management review and analysis	Analytics	Control Activities	Detective	Systematic	Monthly
☑	External audits and visits	Authorization	Control Environment	Detective	Manual	Semi-Annually
☑	Library availability and training schedule	Segregation of Duties	Information & Communicat	Preventative	Manual	Daily
☑	NPD methodologies and best practices	Segregation of Duties	Information & Communicat	Preventative	Manual	Daily
☑	Cloud based know-how sharing and verification	IT Controls	Monitoring	Other	Systematic	Non-Routine

Fig. 2. Risk understanding in the context of the furniture start-up - SigmaFlow analysis

Based on the analysis performed and the simulation results, the last step of the approach was to define four classes of interventions and bring up elements than can potentiate each other in the case of the furniture start-up company (Table 1). The focus of the proposed process adjustments is on delivering better products, that have an increased chance of withstanding complex changing conditions during their life cycle.

Table 1

Interconnected mitigation measures and contingency planning (excerpt)

Category	No.	Measure	Characteristics	Examples	Relations
Redundancies	1	Multiple qualifications	Interchangeable skills with integrator events/staff Determining and using a qualifications' matrix	Product designers & CAD engineers have cca. 50% common skills	2, 3

Category	No.	Measure	Characteristics	Examples	Relations
	2	Competing projects	Support for the development of innovation team leaders Customized competitive organizational and PDD culture	Healthcare related furniture vs. sports related furniture	1, 2, 4
Fail-safe	3	Multifunc-tionality	Employ the Kano model to address requirements Layered product structure: base, details, aesthetics	Extendable work desk with cable management and USB connectors	2, 4
Error proofing	4	Product families	Establishing market niches and feature groups Internal negotiation of access to resources for generating results	Office furniture Commercial displays & transparent cases Furniture with complex surfaces (e.g. waves)	2, 3, 6
	5	Peer review process	Communication climate must be open & active Testing facilities should ease the validation of ideas	Weekly work review Cluster level furniture testing, reliability and certification laboratory	1, 6
Wild-card	6	External expertise	Integration in an entrepreneurial ecosystem Long-term partnerships will diminish usual costs	Technology transfer of composite materials Cooperation with smart device manufacturers	3, 4, 5

3. CONCLUSIONS

The approach to PDD robustness discussed in this paper subscribes to the philosophy of preventive and preparatory actions. The space available does not allow for the complete depiction of the simulation results and for pinpointing all the risk - to - managerial controls relationships.

Based on the proposals, the simulation was brought up to 98.07% effectiveness with an average duration of the PDD process of 27.82 weeks and a standard deviation of 6.97 weeks, while estimating an increase of cca. 25% in product sales volumes. This was achieved by reconfiguring the process flow and by fine tuning the dynamic resource allocation.

The methodology has the following limitations: it requires deep knowledge and heavy involvement in the PDD process, as well as commitment towards this approach, it is based on a specific software solution at the moment and has only been tested on one large case study and several smaller ones used for filling in the details and, finally, the resources defined in the simulation are a simplified versions of the real situation.

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Creșterea robusteții în procesul proiectare în cazul bunurilor de consum durabile

Rezumat: *Proiectarea și fabricarea produselor de larg consum, în special a bunurilor durabile, care se preconizează să aibă un ciclu de viață destul de lung, este din ce în ce mai dificilă datorită schimbărilor frecvente de tendințe, preferințe și cerințe ale clienților sau utilizatorilor finali. Dacă anterior, funcționalitatea principală a produsului trebuia definită și detaliile puteau stabilite elaborate prin iterații succesive, în lumea Industriei 4.0 și a produselor inteligente, accentul s-a mutat către produse care trebuie să aibă succes de la început (din prima încercare) și ar trebui să fie, de asemenea, capabile de adaptabilitate la circumstanțe în schimbare. Lucrarea curentă prezintă un studiu de caz care abordează aceste probleme în industria mobilei, în care produsele îmbunătățite prin software nu sunt o soluție ușoară la cerințele pentru flexibilitate și, prin urmare, ar trebui folosite abordări de proiectare robuste bazate pe gestionarea riscurilor și planificarea contingențelor.*

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