

# Gated Maturity Assessment: Supporting Gate Review Decisions with Knowledge Maturity Assessment

C. Johansson<sup>1</sup>, A. Larsson<sup>1</sup>, T. Larsson<sup>1</sup>, O. Isaksson<sup>1,2</sup>

<sup>1</sup>Division of Functional Product Development, Faste Laboratory, Department of Applied Physics and Mechanical Engineering, Luleå University of Technology, Luleå, Sweden

<sup>2</sup>Volvo Aero Corporation, Trollhättan, Sweden

## Abstract

Lead-time reduction is an important goal for aeronautics where the 7 Day Proposal is an envisioned scenario, where the offer development of an aerospace product is reduced to seven days. This requires the proposal development procedure to change substantially and knowledge support is increasingly important. Knowledge Maturity is about improving the utilisation of knowledge by comparing current knowledge with required knowledge. With a criterion scale, knowledge maturity is assessed to improve confidence in decisions. Gated Maturity Assessment is an example where stage-gate decisions are supported with knowledge maturity capabilities. Teams can reason about knowledge at gate reviews similarly as with results and performance parameters.

## Keywords:

Maturity, Knowledge Enabled Engineering, Decision Support

## 1 INTRODUCTION

Lead-time reduction is constantly in focus for many manufacturing industry organisations' improvement efforts. Reducing lead-time means that products reach markets quicker and the companies can capitalise on opportunities in the markets, earning money, instead of spending, as is the case in the development phase of a product's life cycle. Lead-time cannot be reduced without considering the implications on quality and overall cost.

Aeronautics is by no means different in comparison to any other sector on this point. Companies need to constantly reduce their development cycles [1], where the same amount of decisions need to be taken in a shorter time frame, while maintaining the quality of the process.

As a consequence, the importance of decision-making in a rational manner increases. Understanding the decision base, and predicting the consequences of decisions must be accomplished in a limited time frame.

Before moving on to the core topic of this paper, a brief description of the conditions in the aeronautical industry will highlight the context.

What makes an already competitive situation even more challenging is the fact that the aeronautical business environment is in rapid transition. Contracts between customers (i.e. airlines) and manufacturers are showing an increasing bias towards service provision and total offers. The product detailed in such contracts can be referred to as a Functional Product [2]. A functional product can be summarised as the provision of a service, including hardware (i.e. aero engines) where a function responsibility is targeted. One example is Rolls Royce that together with its partners (e.g. Volvo Aero) provides 'Power-by-the-Hour' offers to their customer. In such an arrangement, the manufacturers remain owners of the aero engine and the airline operator merely pays for the function utilised, i.e. the customers only pay when they use the aero engine.

With this arrangement, the risk associated with managing the product's function provision, throughout its life cycle,

remains with the manufacturer, as opposed to transferring the risk to the customer in a traditional 'time and materials' arrangement, where the customer buy the product and pay for servicing as the need arises throughout the product's life cycle.

Due to the relatively high cost of products in the aeronautics industry, buying a fleet of aircraft is an expensive proposition for most airline operators. Therefore, manufacturers usually subsidise the initial price, by as much as 70% [3], and then bring home the profits on the aftermarket activities by charging for servicing to make the product profitable over the product's life cycle. With this arrangement, spending is quite unpredictable for the customers as maintenance activities can be hard to plan for over a fleet of aircraft, hence, the interest in functional products.

Given the risks and the rather substantial investments needed to develop the products, the manufacturers most often team up in partnerships to share cost and risk – and thus also revenue and profit. These 'risk and revenue sharing partnerships' are also formed on the basis of companies wanting to better utilise their knowledge assets, focus on their core competencies and let other partners contribute with their core competence and knowledge where there is a need.

Therefore, companies begin to team up in 'virtual enterprises' [4] to be able to better perform the projects, by utilising the partner companies' core competencies in an effective manner. A virtual enterprise is a loosely coupled network of partner organisations that form on the basis of a market opportunity that they will be able to produce together in a superior manner. The partners in the virtual enterprise are equal in the sense that they are collectively responsible for integration, and that they have equal stakes and say in the partnership. After project completion, the virtual enterprise usually disbands and the companies leave the partnership.

This paper explores the use of knowledge maturity, a concept to assess the maturity of the decision base (i.e. the quality of the knowledge used to make a decision), to enable a proposal development team to reduce the lead-

time of the proposal development process of an aeronautics product, in a virtual enterprise. The paper describes the Gated Maturity Assessment approach that uses maturity scales to assess the quality of the knowledge in decision documents in the development process of an offering of a functional product by a virtual enterprise.

## 2 THE VIVACE PROJECT

The work presented in this paper was conducted within the frame of the European project VIVACE (Value Improvement through a Virtual Aeronautical Collaborative Enterprise) [5]. The VIVACE project is a €70M EC-funded integrated project and features participation from most parts of Europe's aeronautics industry, including Airbus, Rolls-Royce, Volvo Aero Corporation, BAE Systems, EADS, Avio, etc.

VIVACE has its roots in ACARE (Advisory Council for Aeronautics Research in Europe) [6], a group representing the European aeronautics industry's research interests, that has devised a strategy for the development of air travel and of the aerospace industry in Europe for the year 2020, i.e. what scenarios are feasible and what changes and improvements are needed to respond to these scenarios.

Parts of these goals include the high level objectives of the VIVACE project. These are to achieve a 5% cost reduction in aircraft development and contributions towards a 50% cost reduction and a 30% lead-time reduction in engine development. This will be achieved through supporting the design of a complete aircraft, including its engines, with the development of a virtual product in a virtual enterprise, which implies a substantial reliance on improved simulation capabilities as well as new ways of collaborating.

To support this, a number of 'Advanced Capabilities', of which Knowledge Enabled Engineering (KEE) [7] is one, has been developed. KEE is the use of Knowledge Management (KM) within an engineering context to support a real business scenario (i.e. a Use Case). This paper describes the development of one such KEE capability, the Gated Maturity Assessment, used in the 7 Day Proposal (7DP) use case of the VIVACE project.

The 7DP use case was created as a challenging scenario where an offer is generated following a gated process in a quite accelerated manner.

## 3 DATA COLLECTION

As described above, the work has been developed around the 7DP use case. Therefore, adopting the work structure in the VIVACE project, the business experts, stating the needs of the use case, have been involved during the development of the solutions presented in this paper. Data has been collected; both in workshops with representatives from business development at Volvo Aero and through project meetings and telephone conferences where representatives of the 7DP use case have provided feedback relating to the solutions developed.

Essentially, the data collection has been performed using participative methods, where qualitative feedback and suggestions have been provided throughout the development process.

## 4 7 DAY PROPOSAL

As mentioned in the introduction of this paper, lead-time reduction is a prioritised area in virtually any industrial sector. The 7 Day Proposal (7DP) use case is an envisioned, future business scenario, where the lead-time for the offer development phase of a business proposition, pertaining to an aeronautical product (i.e. an aeroplane or an aero engine) is substantially reduced. Today, the normal time to get from receipt of a 'Request for Proposal' (RFP) for a "product" development to delivery of that proposal to the customer is from two weeks up to six weeks for fairly straightforward proposal cases having low ambiguity. In the cases where extensive development work is needed and where the ambiguity is higher, the time can be substantially longer, in some cases over a year.

In the 7DP vision, a virtual enterprise consortium, consisting of a number of aeronautics companies working together, develops an offer for a comprehensive aerospace product in seven days while maintaining proper quality.

Hence, reducing the lead-time to seven days requires activities to be performed differently, compared to today. It is not enough to merely 'speed up' the current process. There is also a need for new ways of working and performing tasks, such as making greater use of modelling and simulation capabilities at this very early stage in the product's life cycle. There is also a need for structuring the work performed, especially when there are several companies involved, as the risk is otherwise that different companies have different ways of calculating and developing results, which proves hard to integrate into one solution in the end. Using a structured development process with clearly defined decision points is one way of catering for this need. In the 7DP, a stage-gate process of similar structure (but not contents) to Cooper's Stage-Gate process [8], with stages and gates for decision points is used. In each stage of the process, there are parallel sub-processes with activities performed concurrently to further contribute to the lead-time reduction needed. The decision points provide timely opportunities to catch up with any weak points as quickly as possible, to be able to devise actions to bring the proposal up to a sufficient level. In some cases, rework is needed, and the decision points enable decision makers to decide on this as quickly as possible.

Coupled with this, 7DP feature a 'support system', which is a specification of the type of model-, tool-, and/or IT-support needed to accomplish the execution of the 7DP process and deliver the proposal on time. While working with the 7DP Process, there are pointers to different support tools in the support system that is needed to complete the activities as intended.

Further, the team producing the proposal needs to make use of downstream knowledge, i.e. to bring in knowledge related to the later phases of a product's life cycle. Knowing more about this in the early stages promises to reduce the amount of rework that would otherwise be needed further down the line. In the case of an offer development process, knowing more early on will enable decisions to be made on a more accurate basis and will contribute to a reduced risk of problems and costs occurring later in the product's life cycle.

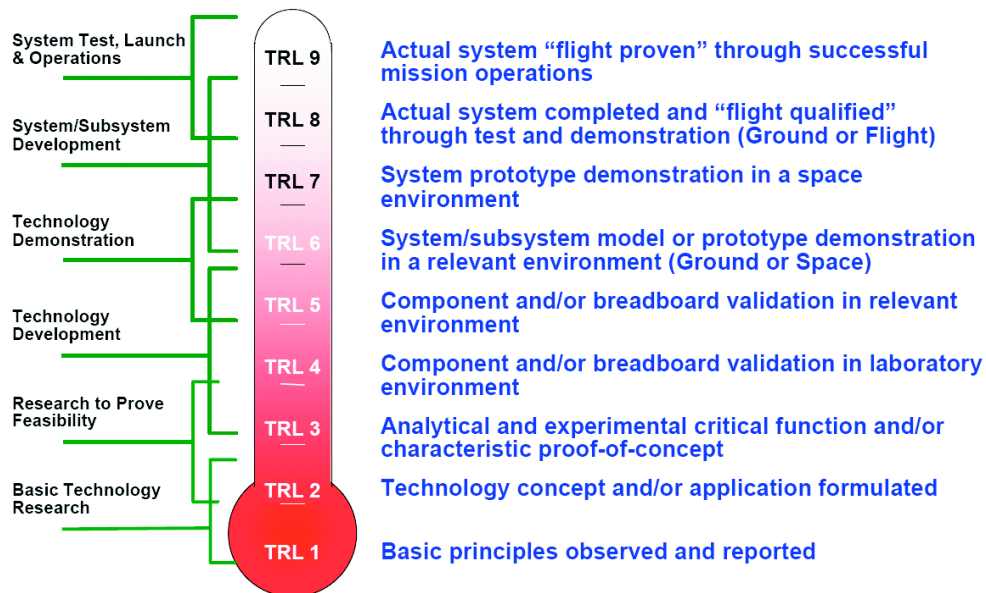


Figure 1: Technology Readiness Level (TRL) from NASA [9].

## 5 MATURITY

There are several concepts on maturity to be found in the literature. This section reports on a few of them that were used as stepping-stones for the results presented in this paper.

Technology Readiness Levels (TRL) [10] is an approach developed by NASA during the mid 1990's to assess flight readiness status by assessing maturity of technologies (i.e. components, systems, etc). This is today a recognised approach to assess technology maturity in many parts of the aeronautics sector. TRL is used both by manufacturers and government agencies (i.e. US Department of Defense) when making technology acquisitions. Manufacturers need to demonstrate a certain readiness, or proven capability, in their technologies and systems to be awarded contracts.

TRL features a nine level scale, illustrated on a thermometer as in Figure 1, to assess where the particular technology is positioned on the scale from basic research to 'flight proven' status.

The scale features criterion definitions based on 'generic' sentences to help decision makers and design teams to define where on the scale their projects are.

An important ingredient is the fact that the technology needs to be proven worthy of a level through tests in different environments, such as a laboratory environment for the immature technologies and (in the case of NASA) a space environment for a very mature technology.

Finally, it should be noted that not all components and systems go through all levels of the TRL scale. As the cost of proving the readiness of the technologies rise with every step and can be quite high in the end, only "mission critical" systems go to level 9, whereas less important components, not in connection with any critical systems, might only be taken to level 6 before being regarded as mature enough.

The Capability Maturity Model (CMM) [11] is a concept in software development where it is used to assess the capability of software development in a company, i.e. how mature the company's software development process is. The Software Engineering Institute (SEI) at Carnegie Mellon University developed the CMM, and is also responsible for the successor model called Capability

Maturity Model Integration (CMMI) [12] that have taken the ideas of CMM further. In a similar way to TRL, CMM is used by government agencies such as the US Department of Defense to assess software contractors and determine whether or not they can deliver software systems on time, on budget and to sufficient quality. Proving a high enough level on this scale is an insurance of sorts that the company is reliable in delivering, which lowers the overall risk for the customer.

Climbing the CMM scale is not something that is done quickly by targeting the top level directly. In this case, the team will incrementally move through the scale, proving their worthiness of the particular level by mastering a number of key process areas that are defined within each level.

Figure 2 below depicts the CMM scale, with the 'flight of stairs' illustrating that the team needs to climb them to reach the highest level.

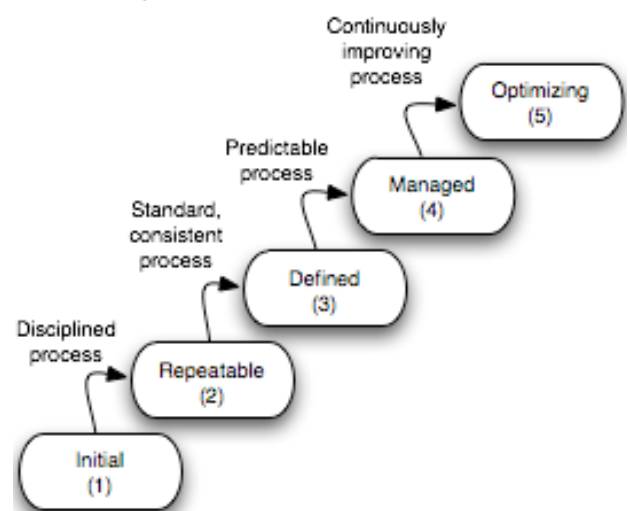


Figure 2: Capability Maturity Model (CMM) adopted from Paulk et al [11].

Even though the TRL and CMM models are the most widely accepted frameworks applied in industrial sectors, there are other concepts that have brought forward some interesting ideas in this area.

Knowledge Management Maturity Model (KMMM) is a term that has been used on numerous occasions. The General KMMM framework [13] is an attempt to summarise most of these attempts and produce a concept that unifies the ideas. The KMMM concept is basically about assessing an organisation's capabilities pertaining to knowledge management, in a similar way to the CMM assessing software development. It is about assessing the organisation's processes for knowledge management and how different support systems – such as expert systems and repositories – are implemented and used. The perception of this model is that the focus is, as with knowledge management, on an organisational level – meaning that the assessment is on how the organisation can best manage their knowledge assets.

Research & Development Degree of Difficulty (R&D<sup>3</sup>) [14] is a concept by NASA that is related to TRL. It describes the effort needed to reach a certain level on the TRL scale. In some cases, the technology may only be a derivative from another component or system, i.e. an interpolation, where the difficulty is relatively low, as similar efforts have already been undertaken. On the other hand, in some other cases, the effort may be quite substantial with fundamental research projects and breakthroughs needed to achieve the particular TRL for the component.

Knowledge Readiness Level (KRL) [15] is an idea that is also brought forward by NASA. In this case, it is about assessing the amount of knowledge that is available and accessible to the team. At one extreme of the scale, it is about getting the right people together, whereas at the other end this is not enough. Here, a fundamental research programme is needed to fill the void. Chiamonte and Joshi (2004) [15] write, "...the cost of the 'answer' is related to the KRL. Low KRL's are relatively inexpensive, while high KRL's require substantial research funding" (p. 36) [15].

## 6 KNOWLEDGE MATURITY

As described in the section about the 7DP, making use of knowledge from downstream phases is essential to reduce lead-time without losing quality in the 7DP process. Today, in offer processes, much time is lost because wrong information or not enough information and knowledge is available at gate reviews when decisions are due, resulting in rework.

The main idea behind the concept in this paper is to support the creation and utilisation of this knowledge by assessing the maturity of the knowledge that is created and/or utilised (i.e. shared, used etc.) in the proposal versus the knowledge defined to be necessary from the beginning.

Knowledge maturity is about knowing what is known. Echoing the famous HP quote "If only HP knew what HP knows..."(p. 47) [16], it is about providing the design team with a means to assess what they, or others in the company or virtual enterprise, might already know about a certain activity or artefact.

Hence, knowledge maturity is about providing design teams with insights about which areas they have sufficient knowledge and information in, and highlighting the areas where more knowledge and thus work is needed. Therefore, the team can take action to correct any area where knowledge might be too poor to provide a base for a confident decision. Being confident that decisions are made from a solid knowledge base is what the concept of knowledge maturity attempts to reach; i.e. assuring confidence for decision makers and design teams.

It is about putting the knowledge at the centre of attention, and examining what the team knows about a certain result, instead of just looking at the facts and figures. What is essentially an assumption can be mistaken for being much more truthful than is actually the case, in effect undermining the decision base, just because team members do not back up the results on the basis of the knowledge behind the numbers.

As this work is centred on the 7DP process, the knowledge maturity concept needs to support decision-making in stage-gate processes.

O'Donnell and Duffy (2005) [17] writes about a feedback loop used in assessing and analysing design performance. In this work the assessment loop (see Figure 3 below) is quite similar, with the main difference being that it is not the design performance being considered, but rather the knowledge that builds up the performance. Performing work in a business process (i.e. 7DP process) the team use criteria to assess the knowledge in the process. Thereafter, especially when too little knowledge is available, the team needs to analyse why that is the case and how they can best manage this. Thereafter they decide on actions (i.e. rework or tweaks to the coming stages) at the gate.

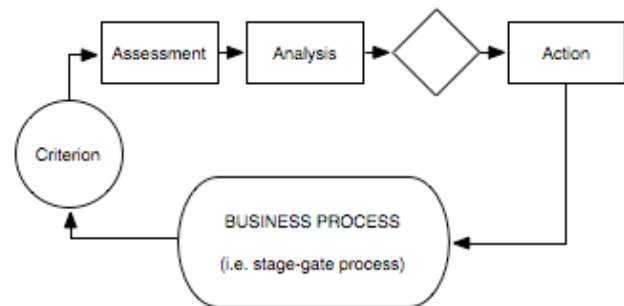


Figure 3: Assessment loop.

## 7 GATED MATURITY ASSESSMENT

The Gated Maturity Assessment (GMA) is an example to demonstrate and test a possible implementation of the thoughts and ideas behind the knowledge maturity concept, and how this can support a situation in a proposal development process in industry. The GMA technique has been developed to support the 7DP process that was described earlier in this paper.

The idea is to support decisions in a stage-gate process by providing an instrument to assess and evaluate the level of knowledge that builds up the material (i.e. content and rationale) that is used to support the decisions.

The GMA relies on three components to decide the knowledge level in a decision base, namely:

- Quality of input data,
- Quality of the method (and/or tool) used to produce the contents, and finally
- The experience and expertise of the people that has produced the proposal.

To describe these in a bit more detail, 'input data' is about the information that comes into the team, from external sources such as suppliers, customers or other departments. 'Method' represents the way a task is carried out, with what tool and to what accuracy the method permits the task to be done, i.e. a FEM (Finite Element Method) analysis can be performed with different meshes and fidelity depending on the amount of calculations that are feasible. 'Experience and expertise' deals with the people doing the work. Sometimes access

to the most knowledgeable experts is not possible, or perhaps sometimes the key person might just be ill at the wrong time. Sometimes 'gut feeling' is all that is available - for instance, at an early stage of the process when little work has taken place - and that quality and confidence is reflected in the decision base through this factor.

To be able to assess the maturity of each part in the decision base, a set of criteria (i.e. metrics) is used to assess the outcome of the process activities.

The initial development of the GMA criterion scale has borrowed ideas and taken inspiration from many of the concepts of maturity described earlier in this paper. Essentially the GMA concept is built up from a criterion scale in a similar way to how the Technology Readiness Levels are constructed. As the decision base is in many cases a document, which can be seen as an artefact, TRL is used as an inspiration for the GMA concept. The fact that the contents of a decision base is also a result of a development process, and thus is reflected by that process, the CMM concept is also influential in the development of the GMA scale.

Table 1 below, depicts the initial development of the GMA scale with keywords representing the end levels and middle level. At this early stage, levels 2 and 4 have been omitted and are used as intermediate levels between the others as 'steps on the way' levels.

5	Excellent:	Proving, confidence	optimising,	known
4	Good:			
3	Acceptable:	Standardised, repeatable,	defined, controllable	stable,
2	Dubious:			
1	Inferior:	Ad-hoc, person-dependant,	heroic efforts, no focus,	unstable, no formal support/methods

Table 1: Initial criterion scale.

Assessing maturity using the GMA technique is essentially about comparing the 'as-is' level with a predefined 'pass profile' (i.e. 'to-be') on the components that are being assessed. This pass profile is decided in advance to be the required level of the particular case. Figure 4 depicts a tentative pass profile where components B and D would require substantial improvements to reach a confident level, while A and C are 'nearly there'.

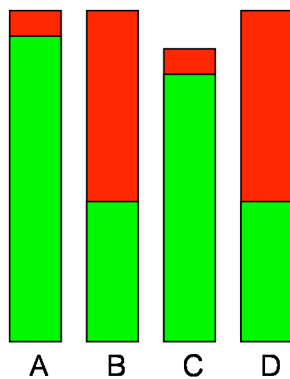


Figure 4: Tentative 'pass profile' with four components.

### 7.1 Support Tool

Complementary to the concept and the criterion scale, a support tool developed in Microsoft Excel is intended to support the assessment of maturity in the stage-gate process. When working in the proposal process, workers

can input progress made and in a similar manner see progress made by others. This provides a 'helicopter perspective' on the project that enables action to be taken on issues having too low a knowledge maturity. Figure 5 shows a screenshot of the support tool.

		GATE LEVEL: 2							
TITLE		Responsible	1	(2)	3	(4)	5	Sum Maturity	Sum Maturity
Cost Calculation	Method		█	█	█	█	█	█	█
	Input		█	█	█	█	█	█	█
Market Need Assessment	Exp.		█	█	█	█	█	█	█
	Method		█	█	█	█	█	█	█
Generic #1	Input		█	█	█	█	█	█	█
	Exp.		█	█	█	█	█	█	█
Generic #2	Method		█	█	█	█	█	█	█
	Input		█	█	█	█	█	█	█
Generic #3	Exp.		█	█	█	█	█	█	█
	Method		█	█	█	█	█	█	█
Generic #4	Input		█	█	█	█	█	█	█
	Exp.		█	█	█	█	█	█	█
TOTAL:									

Figure 5: Screenshot of support tool.

## 8 CONCLUSIONS AND DISCUSSION

The objective of this paper was to explore the use of knowledge maturity to contribute to lead time reduction by assessing content and rationale in decision material (explicit and implicit).

The GMA technique is a concept for assessing the maturity of information and knowledge in decision material by using a criterion scale to assess the contents and rationale with.

Using the GMA, the teams have an instrument to reason about knowledge as a core result in a similar manner as performance is presently assessed and analysed. The team members can start to discuss knowledge – or in the worst case, lack of knowledge – in a similar way as they discuss thrust, weight and fuel burn of aero engines.

The usage of 'pass profiles' provides an interesting aspect to this concept, as they enable comparison of pass profiles for different offers with a view of 'carrying over' knowledge (i.e. components) from a previous project to the current one, to make better use of previous knowledge.

The knowledge maturity concept shows promise of actually supporting how a team deals with assumptions. Especially early in a process, assumptions are quite frequent. The problem is that people can tend to believe that in the interest of self-preservation it is bad behaviour to visualise uncertainty in the knowledge base. On the contrary, what is needed is just this sort of uncertainty to be visible and this visibility is needed as early as possible in the process. For instance, knowing that a value of a parameter is somewhere between 10 and 14, depending on the uncertainty of a number of factors, and hence, not exactly 13 makes a huge difference to how that parameter is approached in many areas. Having this extra amount of knowledge is extremely valuable to the design team when they are to decide on actions such as rework and planning of future activities and phases. Initial feedback from industry representatives in the VIVACE project shows promise in supporting this with the knowledge maturity approach.

This is an important aspect, especially in a business offer context, as the kind of precision that is mandatory in the technical domain, regarding for instance weight, thrust, and fuel burn in the aeronautical domain, is harder to realise in the business domain.

## 9 FUTURE WORK

This paper reports on the initial development of the Gated Maturity Assessment technique and the ideas behind knowledge maturity, but there is more work to come.

First, the development of the GMA technique is ongoing with evaluation and validation in a business process context being underway.

Then, as the concept should work in virtually any stage-gate process context, it is a future wish to bring the ideas forward and test them in a wider (functional) product development context, where new challenges and issues can be found.

## 10 ACKNOWLEDGMENTS

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