Characteristics of highly uncertain and complex projects

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ABSTRACT

The purpose of this article is to find characteristics of highly uncertain and complex projects. These characteristics can be used for developing project management theory. The Formal Systems Model is used to identify characteristics of highly uncertain and complex projects. A points of attention model is proposed as an initiation for a tool to support managing highly complex and uncertain projects. Part of this model is a stakeholder value theory. The insights from the Formal Systems Model and the two theories are tested using two cases. One of a highly complex and uncertain project, while the other case is moderately complex and uncertain, for this classification the models of Shenhar and Kuchta & Skowron are used. The paper is meant as initiation of project management theory for complex and uncertain projects.

Keywords

UCA, test flights, demo flights, case study, project management theory, stakeholder values, points of attention, highly uncertain, highly complex, projects

1. INTRODUCTION

A regular way of developing new products; implementing new techniques or introducing new methods is starting a project. A project can be executed in various forms, for example: within an organisation; as a sub-organisation; or outside the company, as a start-up. Another option is a collaboration of multiple parties, consisting of companies, foundations and (legislative) authorities for example. Such projects can be fairly simple, with clear goals and methods. On the other hand, projects can be tremendously complex, with many stakeholders and a complex, uncertain environment.

The field of project management is commonly understood as relatively young and understudied [11][12]. Numerous formal project management concepts exist, however, not every project management concept is suitable for every project [12]. Especially projects in a highly uncertain and complex environment are difficult to manage, everyone can name examples of large projects that failed [10]. The existing literature mainly focuses on frameworks for project classification and management, or analyses enormous projects that have failed or succeeded. These projects are often focused on construction projects [2] or product development [9]. Limited knowledge is available for highly uncertain and complex project management. This paper tries to contribute to theory development for these type of projects by identifying characteristics and proposing tools to support the management of these types of projects.

The paper addresses the following research question:

RQ1 What are the characteristics of highly complex and uncertain projects, where the approach of the project is uncertain?

RQ1.1 Which theories and/or tools can be developed to support the project management of these highly complex and uncertain projects?

The first part of the research will focus on analysing the existing theory and developing new theories. The adapted and newly formed theory will be applied to two cases. The first case comes from a platform, based in Europe, that wants to organise test flights with unmanned cargo drones (*Remotely Piloted Aircraft Systems (RPAS)*). Six stakeholders of the core project team are interviewed to analyse how the project is structured, what the goals are and what the contributions and relations of all stakeholders are. This is a typical example of a highly complex and uncertain project. In addition to a thorough analysis of case one, another case, case two, will be studied in lesser detail. Case one is the main case, the other case is used as a comparison and additional verification. Case two is a project focused on implementing a new *Learning Management System (LMS)* on a university.

The first part of the paper will discuss the method of research. Section three discusses theory, it discusses the classification of project by Shenhar [13] and Kuchta & Skowron [6], the *Formal Systems Model (FSM)* and a points of attention model. Part of the model is the stakeholder values theory. In Section four, the two project cases will be discussed and classified using the two classification systems. Section five focuses on applying the earlier developed theories to check the applicability and validity. The final section, section six, concludes the paper.

2. METHOD OF RESEARCH

The first step in this research is finding existing literature about project classification, which is used to identify how complex and uncertain projects are. The two classification systems of Shenhar [13] and Kuchta & Skowron [6] for projects are studied. By putting both cases in the classification frameworks, it can be shown how complex

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and uncertain the projects exactly are on the given scales. In addition to this, the framework of Kuchta & Skowron also links the different project types to different project management methods [6].

Furthermore, the FSM is used as a basis for theory development. Characteristics of highly complex and uncertain projects are identified, using the FSM structure. Furthermore, a points of attention model is introduced to support the management of highly complex and uncertain projects. Part of this theory is the stakeholder value theory, which is used to create an overview of all stakeholders and their values. The points of attention model can be used next to the FSM. By (further) developing these theories, a first step is set in developing useful concepts for highly complex and uncertain projects. To make sure that the developed theories are of value, they are tested in two cases.

To gather data for the two cases, stakeholder interviews are held. The interviews are held to gain insight into the project workflow and project management from a stakeholder perspective. The methodology of the interviews uses the theory of Cooper & Schindler [1]. The interviews are used as a basis for the application of the abovementioned theories. The two cases are put in the FSM and the deviations are discussed. Furthermore, it is checked for both cases to what extent the points of attention were used and how valuable these were. The new stakeholder theory is tested only in case one because only one stakeholder of case two has been interviewed.

3. THEORY

It is still relatively unknown in the project management research field how to adapt to the diversity that exists in projects. Different project management techniques are used in business, but often not explicitly chosen at the start of the project [12]. Management techniques are for example, Agile; Waterfall; PRINCE2 and PMI's PMBOK [5]. A classification of different types of projects could help link project management methods to classes of projects, but most importantly, it gives a measure of project complexity and uncertainty and makes projects comparable. Two classifications models are discussed, one of Kuchta & Skowron and the other one of Shenhar.

Kuchta & Skowron published a paper in 2015 about the classification and selection of management concepts of R&D projects [6]. In this paper, they elaborate on the goals and methods matrix of Turner & Cochrane from 1993 [14]. The matrix consists of four types of projects with a well- or under-defined goal and/or method. Kuchta & Skowron link these four types of projects from the matrix to different project management concepts, such as *APM (Agile Project Management)* for projects with only a well-defined goal or method, *xPM (Extreme Project Management)* for projects with an under-defined goal and method and *TPM (Traditional Project Management)* for projects with a well-defined goal and method [6].

Shenhar developed a conceptual model to classify different projects [12][13], which can be found in Figure 1. The model uses two dimensions, namely uncertainty and complexity. Shenhar considers three levels of complexity: Assembly; System and Array. The other dimension of Shenhars classification model is uncertainty. The four levels of uncertainty from the classification model are: Low-Tech; Medium-Tech; High-Tech; Super High-Tech.

3.1 Formal Systems Model

A useful model to get insight into the characteristics and organisation of a project is the FSM. The model was developed by Bignell & Fortune [3] and can be found in Figure 2. It consists of three layers, the system, the wider system and the environment. The system consists of the project team, with three subsystems, decision-making; carrying out transformations and performance monitoring. The project team is supported by the wider system. All relations between these different systems are indicated in the model.

The first thing that becomes clear when looking at the model is that it has three 'layers', the environment, the wider system and the system. For complex projects, this is often not as simple. With stakeholders, everyone who has something to do with the project is meant, so the core project team, but also the people affected by the project. Uncertainty is often caused by something that is not known, a stakeholder that is missing for example or changed behaviour of a stakeholder [15]. Complex projects ask for stakeholder dedication, but not all stakeholders have this, therefore, some stakeholders might switch between the different levels during a project and withdraw from the project. This cannot be represented in the model, which is static and does not evolve over time and thus does not represent the changing states of stakeholders.

The FSM has a link between the decision-making subsystem and the two other systems within the system boundary, with the text "makes known expectations". This link is often not (strongly) represented in the model of a highly complex and uncertain project as the exact expectations are not known. Highly complex and uncertain projects where Super High-Tech Array systems are developed have unclear expectations, the end-goal is roughly known, but not precisely identified [12]. The possible outcomes depend on the process, expectations are formed, changed and further specified during the project. Furthermore, strong expectations cannot always become true as there are not always binding contracts between different stakeholders. One stakeholder cannot demand of another stakeholder to perform certain work if the resources are not available in case of in-kind contributions. Pushing a stakeholder too much is risky, it can make a stakeholder decide to withdraw.

There is another "makes known expectations" link, between the wider system and the system. This link can also be missing or be very weak in the FSM of a highly complex and uncertain project. As argued above, the wider system is often more of a support and not a guiding instance. The stakeholders in the wider systems have expectations for the project, but these will also differ per stakeholder. Furthermore, the expectations are not clearly defined, as this is impossible because the project is highly complex and uncertain and thus the exact path and results of the project are unclear. In addition to this, in case of in-kind contributions, the same risk of pushing stakeholders holds as mentioned above, too much pushing can result in stakeholder withdrawal.

One of the three systems within the system is the Performance monitoring subsystem. This system is focused on monitoring performance, such as progress or KPI's. Especially within highly complex and uncertain projects, this is important to use, to show that progress is being made, even in periods that are difficult and where progress is slow. However, because of the often limited resources, little is invested in a performance monitoring system. The scarce resources are needed for the project tasks, a performance monitoring system is easily seen as unnecessary overhead without priority. But a performance monitoring system can be used to measure and ensure project continu-

(a) Four types of technological uncertainty

Project Type	A	B	C	D
Name	Low-Tech	Medium-Tech	High-Tech	Super High-Tech
Definition	Using existing technologies	Adaptation of familiar technologies; some new technology or a new feature	Integrating many new, but existing, technologies	Integrating key technologies that do not exist at the time of project initiation
Typical Projects and Examples	Construction, road building, utilities, "built to print"	Derivatives or improvements of existing products; new models in a well-established, stable industry e.g., automobiles, consumer electronics	New systems in a fast-moving industry, e.g., computers, new military systems	New nonproven concepts, beyond the current state of the art, e.g., Apollo, moon-landing project

(b) Three levels of system scope

Scope Level	1	2	3
Name	Assembly	System	Array
Definition	Building or developing a collection of components and modules combined into a single unit, either as a subsystem of a larger system, or a stand-alone product performing a single function	Building or developing a collection of subsystems and interactive elements that perform a wide range of functions or activities	Building, developing, or adding to a large widespread collection of systems functioning together to achieve a common purpose
Examples	A power supply, an antenna, household appliances such as, CD players or washing machines	Computers, radar, buildings, aircraft	National air defense system, building a city, a neighborhood, or the city's public transportation system

Figure 1. The project classification model of Shenhar [12]

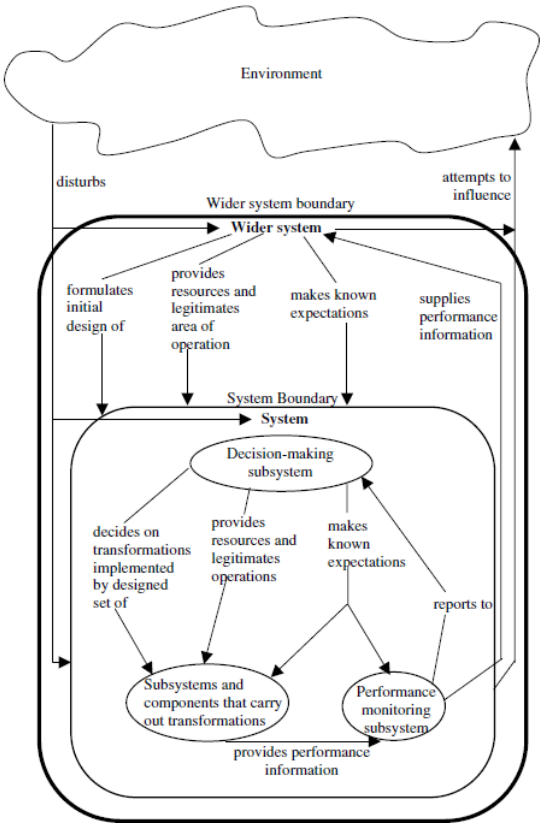

Figure 2. *Formal Systems Model (FSM)* of Fortune & White [3]

ity, therefore it is important to have such a system in place, even in highly complex and uncertain projects. Showing progress to stakeholders supports stakeholder dedication and project relevance.

3.2 Points of attention model

In the previous section, a number of characteristics of highly complex and uncertain projects have been identified. These characteristics require attention when executing a highly complex and uncertain project. To ensure that critical factors are not overlooked, a model with points of attention has been developed, see Figure 3. The model divides a project into three phases, the Starting phase, the Executing phase and the Concluding phase. Furthermore, five tracks that require attention are identified, namely: stakeholders, resources, goal(s), project structure and communication. These five tracks are based on the different parts of the FSM. The first and last phase are done once, from top to bottom while the executing phase is done multiple times, depending on the project.

The stakeholder track focuses on the stakeholders, everyone who is involved with the project. The first step is to identify these stakeholders and build a project team, the core of the project. The next step is to identify all stakeholder values, this is part of the theory explained in the following section. The stakeholder values are also used during the executing phase. If a stakeholder decides to withdraw from the project the gap in stakeholder values should be filled again. Therefore it is important to know all stakeholder values. The concluding phase asks to identify the interest of stakeholders for a successive project, in case this is applicable.

The resources track focuses on all the available resources. Project progress can be delayed if the necessary resources are not available. However, often another stakeholder has resources, for example, budget or knowledge available and this can be exchanged to continue the project. To be able to exchange resources, it is important to have insight into the available resources, this is what the resources track focuses on in each project phase. The third track focuses on the goal(s) of the project. A project is a collection of stakeholders with often diverse goals. However, by fulfilling a project with a common goal, all individual goals can be accomplished. Therefore, it is important to get insight into the goals in the starting phase, as well as agreeing

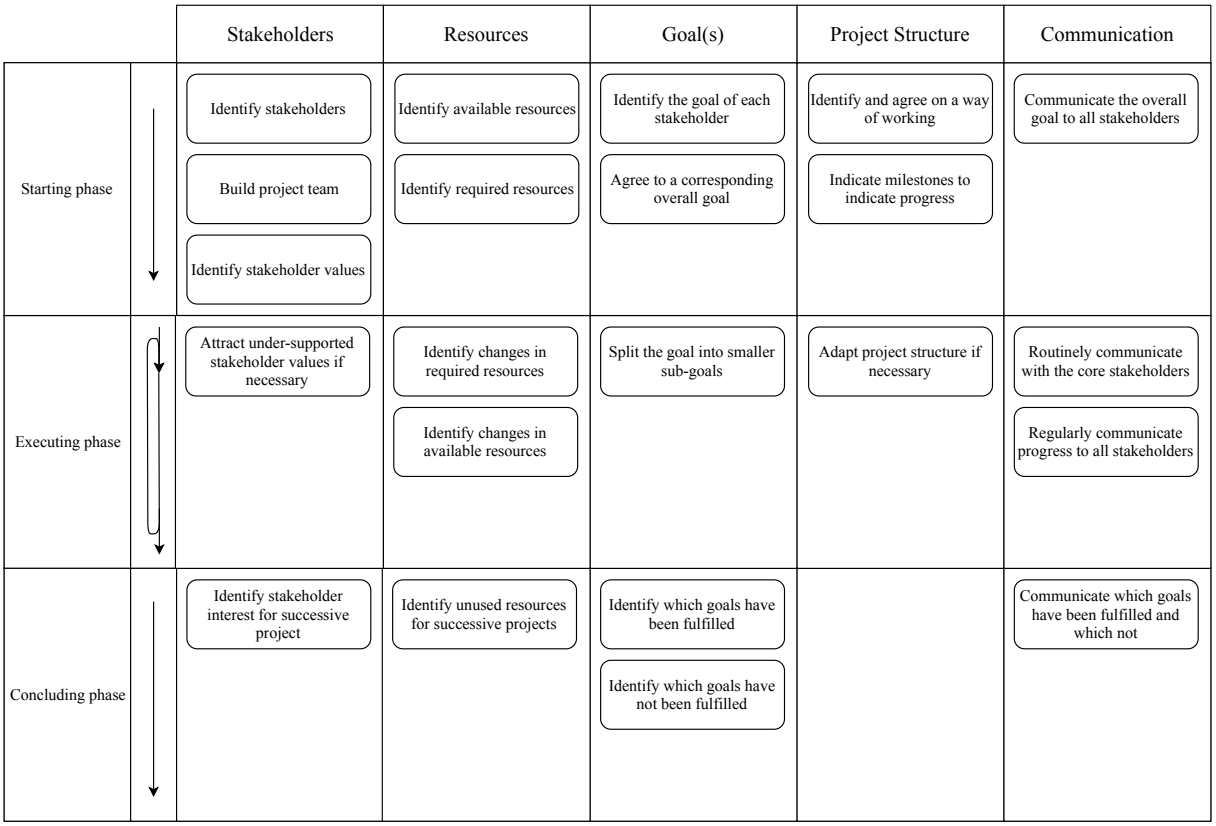

Figure 3. Points of attention model

on a common goal. During the project, these goals can be adapted and split into sub-goals. In the concluding phase, it is important to identify the successes and goals that have not been fulfilled.

The project structure track puts focus on the structure and management of the project. At the start of the project, the stakeholder should agree on a certain way of working. This can be a project management concept, the classification theory of Kuchta & Skowron can be used to identify a suitable project management concept [6]. The way of working can also have a more flexible structure, this fully depends on the stakeholders and the project. During the executing phase the structure can also be adapted, to fully support the project. The last track is focused on communication, especially in highly complex and uncertain projects, this is important since many stakeholders are involved and everyone is focused on its own specialisation. The project should stay relevant for all stakeholders to ensure stakeholder dedication. This asks for clear communication at the start, during the execution and at the end of the project. Especially the core project team should discuss the current status regularly during the executing phase.

3.3 Stakeholder values theory

A theory that is proposed in this paper is the theory of stakeholder values. In this section, the theory is explained, in the following section, it is applied to the two cases. Every project has a number of stakeholders who jointly perform the project. Stakeholder value is the value of a stakeholder for the project, a stakeholder can, for example, bring in a lot of knowledge or a stakeholder could have a commercial interest in the project. Each stakeholder has its own reasons and uses its expertise to contribute to the project.

For a project, a number of stakeholder values should be chosen to represent the full environment. There should be between three and six values to keep the complexity low. Stakeholder values can be found by looking at the end goal and plan of the project and identifying what values are needed to successfully finish the project. Once the values have been identified, they can be mapped in a spiderweb. Each stakeholder is mapped in such a spiderweb, for each value, the stakeholder gets a value between zero and five. This value can be based on a scale that is set up, zero for no contribution at all, five for an expert. Or five for a stakeholder that has the right to give out permits and three for a stakeholder that knows a lot about applying for a permit but cannot give out one. Some stakeholders can bring in a lot of value for one stakeholder value, others bring in a bit of value for multiple stakeholder values.

The spiderwebs are a simple and fast indicator to check if all stakeholder values are sufficiently supported. Weaknesses in the project can be quickly identified. If it becomes clear that not all values are sufficiently represented, it is important to take action. If a stakeholder value is under-supported, the project uncertainty becomes higher, possibly resulting in a standstill [15]. Actions can be taken if a value is missing, for example by adding a new stakeholder.

4. PROJECT CASES

4.1 Unmanned testflights

Case one concerns a project of a European platform that wants to organise test flights with unmanned cargo drones *UCA* [4]. This project is currently executed and not finished yet. The technologies are relatively new and not proven yet, in 2017 the Dutch *Kennisintituut voor Mobiliteitsbeleid* made an analysis about drones in person and

cargo transport [7]. The project is executed by a group of stakeholders that all have an interest in the project. There is limited legislation and regulation available, therefore the project focuses on organising a test flight to show that the concept of an unmanned cargo drone is possible and to gather data and experiences for certifications and regulations. The project has many similarities with the concept of Health Deals of the Dutch government [8], a group with a common interest is put together to initiate innovation. However, this project is not actively supported by the government, but the initiative comes from within the platform. A similarity is that the financial funds are limited, the project mostly runs on in-kind contributions of all stakeholders.

4.1.1 Classification

The project operates with new, unproven concepts, such as RPAS. Some of the drones that are going to be used do not even have permission to fly yet. Furthermore, experiences with similar technologies are very limited. Therefore, the project can be categorised as Super High-Tech, the highest level of uncertainty in the model of Shenhar [12]. The level of system scope is Array, the project develops the whole array for a test flight, ranging from the drone to the communication and control operations. The project has Project Type D with Scope Level 3, see Figure 1. Thus this project scores on the highest level of both concepts and therefore it can be called highly complex and uncertain according to Shenhar [12].

Kuchta & Skowron look at the goal and method of a project [6]. This case does have a well-defined goal, namely a test flight with RPAS. However, the method of the project is not well-defined, as it is difficult to make a plan if the available resources are unknown. According to Kuchta & Skowron, this asks for agile project management. Currently, the project does not follow this management concept. However, a lean startup method was proposed by one of the stakeholders in the interview: "Innovation projects are complex projects with a lot of uncertainties ... in the world of start-ups, the lean startup method is the standard."[1]

4.1.2 Stakeholders

In the initial phase, the project was formed with a group of stakeholders that had joined the platform. More knowledge was added by inviting stakeholders that had not joined the platform yet. This combination of stakeholders forms the core project team. Whenever new knowledge is missing or available, stakeholders can join the core team. The core stakeholders in this project work in multiple disciplines, for example, a company; a government institution/foundation; as self-employed or as a former employee.

The project and platform can be divided into three levels of stakeholders. The first level is the core project team, consisting of a group of stakeholders that gets in touch regularly (about every three weeks) via a telecon. The second group consists of stakeholders that have an indirect contribution, they are often connected with the project via one of the core stakeholders. The third group consist of stakeholders that have passively joined the project, they are part of the platform and do not have an active contribution to the project itself. However, they have the opportunity to join the quarterly meetings of the platform to get informed about the project. Besides these three levels, there is also the environment.

[1] van Schooten R.W. (2019, May 27). Interview with Stakeholder 3.

4.1.3 Project structure

There is no clear structure in the project, almost all stakeholders joined based on goodwill. The budget is very limited and most contributions are in-kind. This is also one of the major difficulties, it is difficult to set up a project plan. Setting and following a plan requires efforts from all stakeholders, however, this can not be enforced because of the lacking resources. This is one of the reasons that there is not a clear project plan available. In addition to this, there is no performance management system and the goals of the project are not explicitly stated. There is some structure in the communication, although this is not based on a general project structure.

4.2 Implementing LMS

The second project case concerns the implementation of a new LMS on a university. The project started with a tender and finished with a successful transition. A new tender had to be started because of national regulation, a new supplier was chosen and the contract with the old supplier was ended. The project concerned the choice of solution, the technical implementation and giving support to all the users during the transfer. The system is used by all students and teaching staff on the university and is connected with other systems of the university infrastructure. The project was supported by the management of the university and sufficient funds and knowledge were available.

4.2.1 Classification

Concerning the uncertainty, the project is a Medium-Tech project, an existing SaaS solution of the software supplier is implemented with additional programs in the existing architecture. Thus the project is an implementation of familiar, existing technologies with some new futures that the old program did not have. The complexity of the project, is a system, the solutions forms - together with the other programs - a collection of subsystems that offers all the necessary functionalities to the users. It is a Project Type B with Scope Level 2, see Figure 1. Thus, this project is not as complex and uncertain as case one.

In the classification model of Kuchta & Skowron [6], the project is having a clear goal and method. The goal is implementing a suitable system, taking into account certain demands from the stakeholders. The method is also clearly described, as the project was lead by an experienced leader, using the university's own management method, based on PRINCE2. The management concept that follows from the classification of Kuchta & Skowron is TPM [6]. This fits with the concept that is used.

4.2.2 Stakeholders

Most of the stakeholders come from within the university, for example, the director of the educational support department; the ICT department; multiple (student) focus groups; the faculty deans; the suppliers of the software products and education specialists. The project consisted of a core project team with a project leader that worked with all the stakeholders. Every stakeholder is focused on its own interest, students, for example, wanted an easy to use and simple solution. Teachers wanted enough functionality to set up their courses and a quick grading system. For the ICT department, it was important that the system could be implemented in the existing architecture. The educational stakeholders focused more on innovation.

4.2.3 Project structure

The project is structured using parts of the PRINCE2

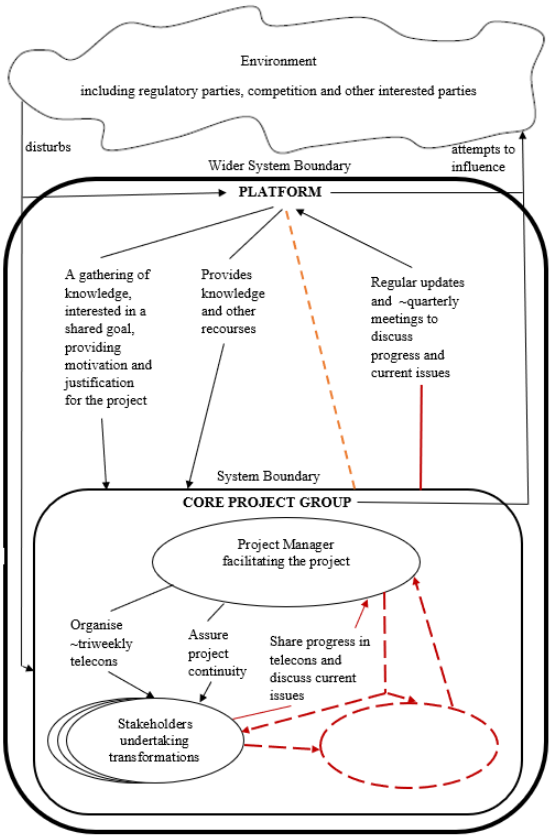

Figure 4. Filled in *Formal Systems Model (FSM)* for case one, based on Fortune & White [3]

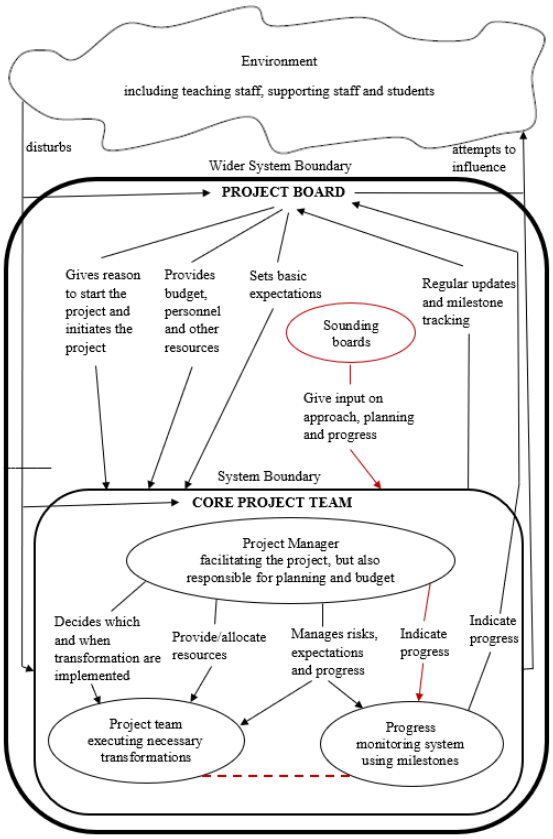

Figure 5. Filled in *Formal Systems Model (FSM)* for case two, based on Fortune & White [3]

method. A detailed planning was made for the project and methods to identify and tackle disruptions were in place. The project manager saw himself as a facilitator for the project. The progress, approach and planning were regularly discussed with focus groups to ensure full support of all stakeholders. The project team itself had a weekly meeting in the starting phase, once the project was running smoothly this was scaled down to every two weeks. Furthermore, the project team made monthly progress reports that were sent to the supervisors. A Sharepoint was set up for the team to share information and the Gitlab tickets system was combined with this. Furthermore, the team communicated with everyone using its website where regular updates were posted.

5. APPLYING THEORY

In this section, the earlier developed theories are applied to the two available cases. The first step is to put both cases in the FSM and check if the deviations match with the developed theory. The FSM for case one can be found in Figure 4, the FSM for case two is shown in Figure 5. The biggest deviations from the original model are marked in red. Striped components mean that the part is missing, components that are red but not striped are extensions of the model. Furthermore, the two cases are checked with the points of attention model. Part of the points of attention model is the stakeholder value theory, this theory is applied to case one and is also discussed, see Figure 6.

As mentioned earlier, the FSM is clearly divided into three layers and static. For case one there are more layers of stakeholders. Within the platform, there is a group of stakeholders actively contributing to the project and a group that is only looking at the project. The stakeholders have been identified using the steps of the points of attention model. Stakeholders from the platform have built a project team and attracted new stakeholders to supplement the existing values. The values of all stakeholders for case one have been identified in Figure 6.

Five different values have been chosen for this case to represent the full environment: commercial (e.g. sponsors); regulatory (e.g. the government); connecting (e.g. the platform itself); technical (e.g. the RPAS owner); knowledge (e.g. university), based on all the insights that are required for this project. As can be seen in the spiderwebs, the backgrounds of the core stakeholders vary, but all five aspects are represented. However, it becomes clear that the regulatory value is not strongly represented. There is only one stakeholder that contributes to the value regulatory. This can also be linked back to the answers of the stakeholders that were interviewed, three of the six participants indicated that they would like to see another stakeholder with a regulatory value, see Table 1. The points of attention model gives a solution to solve this, namely by attracting a new or extra stakeholder to close the gap. However, for this case, the project manager did not see stakeholder withdrawal as a high risk: "There are stakeholders that we absolutely need, but I think the subject and project are big and ambitious enough to make it illogical for stakeholders to withdraw."[2]

Another point that becomes clear in the FSM of case one is the missing link between the project manager and stakeholders/performance management system is the "makes

[2]van Schooten R.W. (2019, May 29). Interview with Stakeholder 1.

known expectations" link. The theory says that the reason is that the goal of the project is unclear. The project manager of case one mentions: "The cooperation shows that the goals are sufficiently aligned, we discussed what each of us wants to accomplish. There are different goals, but they come together in the project."[3]. However, this is still on a general level, the exact way of reaching the end goal is still unclear, which indeed makes it impossible to have clear expectations. Furthermore, in this case, everyone operates based on its own goal, therefore the power of expressing expectations comes from all the stakeholders themselves, not the project manager. The process of clarifying individual goals and identifying a common goal also is represented in the points of attention model. The third track focuses on the goals. As the project manager tells, this case performed the same steps as mentioned in the goal track of the points of attention model.

In case two, the "makes known expectations" link is present, but more focused on managing. Case two is not a highly complex and uncertain project, therefore it is easier to have clear expectations. The project manager also has more power in case two, there is more hierarchy in the project. In the project the goals of all stakeholders have been taken into account, sounding boards were set up for this. In this way, the goal(s) track of the points of attention model has been taken into account. The structure of case two was also clearly defined, the used management concept was the same as advised by Kuchta & Skowron [6]. Furthermore, milestones were identified and set up, as is said in the points of attention model.

In case one, there was no clear project management concept used. One of the stakeholders mentioned: "A good project plan would be the biggest improvement."[4] Furthermore, no common milestones have been identified. None of the steps of the points of attention model of the project structure track has been followed. Another track of the points of attention model that the project of case one could use to improve is the resources track. Half of the interviewed stakeholders indicated a lack of resources as a problem, see Table 1. However, another stakeholder indicated that there was some budget available, but apparently, this was not clear in the project. If the actions from the points of attention model had been followed, the available resources would be clear. The available resources were clear in case two, however, there was just a general shortage of staffing during certain phases, see Table 1.

There is another "makes known expectations" link in the FSM, between the wider system and the system. The theory argues that this is because the wider system is not the deciding instance. The project is executed by the core project team in the system. This is also the case for case one, while in case two this link is represented. In this less complex and uncertain project, the direction is set by the project board while in case one the core project team sets the direction and executes the work.

One of the three systems in the FSM is the performance monitoring system. The theory explains why this system is often missing in highly complex and uncertain projects. In case one, this is also applicable. All stakeholders are focused on the test flight, that is the result that matters to them, no attention is brought to a monitoring system. As one of the stakeholders put it: "For us, it is a very simple project, we want a demo flight within a few weeks. The only KPI that we have is if the demo flight took place."[5] The progress that is made in the project is regularly communicated with the other stakeholders, but there are no concrete deadlines or plan to indicate progress. In case two, there are project goals and milestones formulated, that are used to monitor the performance and show progress. This is also represented in the communications track of the points of attention model, in both cases, progress is regularly communicated with other stakeholders. However, this happens in a more structured way in case two. Communication within the project team is done using telecons for case one with an average frequency of once a month.

A last big difference between the two cases is the role of the project manager. In case one, the project manager is focused on facilitating the project and communicating to all stakeholders. The project manager is not responsible for the budget or planning, this is a responsibility of the whole core project team. In case two, the project leader is also focused on facilitating: "I feel like a facilitator, but I have extra responsibilities, such as a project plan, planning, monitoring issues, a budget and communication with all parties that are involved."[6] This is not the case for case one, as the project leader says: "I am overall responsible for facilitating the demo flights and approaching and informing stakeholders."[7]

6. CONCLUSION

This research focused on identifying the characteristics of highly uncertain and complex projects. Using the FSM, it is described what characteristics and typical deviations of the FSM of highly complex and uncertain projects are. A theory using a points of attention model is proposed as a tool for supporting the management of these highly complex and uncertain projects. Part of the tool is the stakeholder values theory. The theories are applied and tested using two cases. Both cases have successfully been categorised concerning complexity and uncertainty, using the two classification systems. However, the project management concept that Kuchta & Skowron linked to case one was not applicable, for case two the suggested project management concept was actually used.

The main research question was: "What are the characteristics of highly complex and uncertain projects, where the approach of the project is uncertain?" The first finding is that highly complex and uncertain projects also have a complex stakeholder structure. A structure that is so complex that it cannot be represented in the FSM, the model is too static. The second characteristic is that highly complex and uncertain projects often do not have clear expectations. An addition to this is that the expectations often come from within the project team, or even the core project team stakeholders themselves and not from a project board. A final finding is that in highly complex and uncertain projects the Performance monitoring subsystem does not get enough attention. In case of scarce resources, most of the resources are spent on the project itself, not on the organisation of the project. However, monitoring performance is important, for instance, to show progress.

[3] van Schooten R.W. (2019, May 29). Interview with Stakeholder 1.
[4] van Schooten R.W. (2019, May 27). Interview with Stakeholder 3.
[5] van Schooten R.W. (2019, May 27). Interview with Stakeholder 3.
[6] van Schooten R.W. (2019, June 19). Interview with Stakeholder A.
[7] van Schooten R.W. (2019, May 29). Interview with Stakeholder 1.

Figure 6. Spiderwebs of the stakeholder values, for each stakeholder of case one.

To support highly complex and uncertain projects, two tools were developed, which take into account the above-mentioned characteristics. The points of attention model consists of three project phases, the starting, executing and concluding phase and five tracks: Stakeholders, Resources, Goal(s), Project Structure and Communication. For each phase and track combination, points of attention have been identified. By using these points of attention, management of highly complex and uncertain projects is supported. Part of the model is the stakeholder value theory. This theory can be used to identify gaps in the values of the group of stakeholders. Using the theory it can become clear that a value is under-supported, this is a reason to take action and attract new stakeholders for example.

This research was the first step in developing theories for highly complex and uncertain projects. The two theories have only been tested on two cases, one highly complex and uncertain and one moderately complex and uncertain. The characteristics and theories were applicable to the highly complex and uncertain case and partly applicable to the moderately complex and uncertain case. The points of attention model and stakeholder values theory have not been used in a case yet. Further research could focus on expanding the theories, as well as validating them using more cases. This will strengthen the value of the model and theory. The ultimate end goal is to have suitable project management tools for highly complex and uncertain projects.

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APPENDIX

	Stakeholder 1	Stakeholder 2	Stakeholder 3	Stakeholder 4	Stakeholder 5	Stakeholder 6	Stakeholder A
Stakeholders							
When did you join the project (or Platform)?	2017 (Platform)	2014 (Platform)	November 2016	Start of 2019	2012 (Platform)	September 2018	August 2017
What is your role in the project	Project leader	Focussed on organising the flight (Secretary Platform)	Booster, co-organiser, providing location	Facilitating certain affairs, providing a meeting place, willing to invest	Point of contact with the Defence department of the government	Specialised in aviation regulation and airspace	Project leader
Are you missing any stakeholders or viewpoints within the current project group?		More commercial partners would have been better	A national regulatory partners should be more involved, possibly a manufacturer of drones	A national regulatory partner should be more involved, but unfortunately is not available	No, all levels are covered	National regulatory partner(s) should be more involved	A central point of communication for each faculty was missing
Resources							
What is the biggest obstacle in the project?	Missing Legislations and regulations	No budget available	Missing a drone that can be used, missing legislations and regulations, missing decisive cooperation	Missing Legislation and regulations, certification of drones	The recourses that are available, national certification is lagging behind	Demo flights are only possible based on exemptions, not official permits	Staffing, some stakeholders had employees only partially dedicated to the project
What is the maximum time that the project can take?	Internal: depends on available recourses External: if another party has organised a demo flight		Until the test flight, or if another party comes up	Not important in this phase, at least two or three years	Unlimited, unless I have to stop because someone tells me to	End of 2019, unless the test flight is cancelled because of a technical reason, then Q1 2020	There is no alternative for the project because of contractual reasons, there was a back-up for the Go Live
Goal(s)							
What is your goal of the project?	Get attention for the region	No specific goal, supporting aviation (research) industry	Claim the domain of unmanned cargo aircraft in Europe, as a region with the knowledge and capacity to enable the development	Write world history, proof that the UCA concept is possible	Contribute to the first unmanned cargo flight	Organise a local test flight	Implement new LMS that is more flexible compared to the old system
What is the desired result for you?	Economical activity		Successfully performed flight with an unmanned cargo aircraft from Twente Airport to another location	A business model, as development of urban mobility	Useful data from the test flights	Starting a series of local/regional test flights	Fulfil the goals that were set, both on ICT aspect and broader aspects
Is there enough alignment of end goals to successfully end the project?	The cooperation works, the different goals align, joint success	Yes, the biggest problem is the budget available		Absolutely, individual goals are different but strengthen each other	Yes, but there are different goals, sometimes a consensus needs to be found	Yes, but everyone operates in own interest	All stakeholders were satisfied in the end, but some stakeholders were already satisfied with the old system
When is the project finished?	First demo flight			If the test flight have taken place and the concept is proven		When the first test flights have taken place	There is no concrete ending, but when all tasks are finished
When is the project successful?	If the first demo flight took place and regular (demo)flights start to develop			If the test flight can result in (European) legislation and regulations can	Every step forward is progress	When the first test flights have taken place	When all end goals that have been set are met
Project Structure							
What are the most important moments in the project?	First demo flight	Preparations of flights			The first two flights, organised on the same day with the two available options	If budget comes available, a real flight can be planned, including a risk analysis for ground and airspace operations	Start of the pilots and finished training of student assistants to support teachers with setting up the courses
Communication							
What do you think of the meeting structure?	Telecon every three/four weeks, this works most efficient	Telecon once a month works well	Regularly being updated of what happens in the meetings is sufficient		Regular telecons when information is available work well	Joins a telecon whenever relevant, telecons work, but combined with physical meetings	

Table 1. A selection of the answers of the stakeholders to the interview questions. Missing values have not been (clearly) answered by the stakeholders. Questions selected based on relevance for the paper.