The importance of user analysis before the technical design of an instrument, which presents information to users from a different discipline

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Abstract
Flood risk is increasing due to climate change and the growth of the potential consequences of flooding. Analysing how flood-proof the spatial plan is, therefore becomes more important. Since most spatial planners have limited knowledge concerning flood risk, the Netherlands' Directorate-General for Public Works and Water Management commissioned the creation of an instrument that can be used by planners to gain a better insight into the flood risk. However, this instrument is used inadequately. This research paper explains the approach that was initially used to design the instrument and why this approach resulted in a product that is not adequately used by the foreseen users. This explanation is based on a model that delineates the process of transforming raw data into a desired result. With this model the potential for improvement can be outlined in a structured manner. It is concluded that during the design of the instrument, which was predicted to help specialists from a different discipline, it is important to first know who the foreseen user is, what information they need, and how this need can be covered in the design of the new instrument. In the end, the recommendation is to use an approach structured by the following sequence: (1) find out who has the responsibility for spatial planning that may be affected by flood risk, (2) analyse for what kind of result this user is generally aiming, (3) determine what action should be taken to achieve the result, and (4) what decision is needed in order to start the action, (5) find out what knowledge is required to be able to take the decision, (6) determine what knowledge the foreseen decision maker already possesses, and (7) what information is still missing in order to give the user sufficient knowledge, and (8) find out what data is needed in order to produce that information. After these eight steps of analysis, the following steps can be used to design the instrument. Then the final steps include (9) gathering the data, and (10) producing the information that can be presented to the spatial planners.

Keywords: DIKAR, Flood risk, Information, Knowledge, Multi-level safety, RAKID, Spatial planning

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1 Introduction

Despite the high level of attention given to flood risk, vulnerability is still increasing in the densely populated delta of the Netherlands. This is caused both due to the increasing probability of flooding as a result of the changing climate (which is partially addressed by classical measures), as well as due to the increase of potential consequences due to spatial development which lacked sufficient consideration of potential flooding. For a long time, the focus in the Netherlands was mainly on reducing the probability of flooding. However, a shift towards more attention being given to other aspects in the social and spatial environment resulted in a broader vision of how to reduce flood risk. This shift in focus resulted in more attention being directed towards the reduction of the vulnerabilities and potential exposures that were identified from the 1970s onwards (Correljé & Broekhans, 2014). However, the implementation of this is still proceeding very gradually (Klijn et al., 2015).

In 2009, the concept of Multi-Level safety (MLS) was introduced into the National Waterplan by the Ministry of Transport, Public Works and Water Management (2009). This new concept advocates flood-risk reduction with measures that were placed on three different levels (e.g. reducing the probability of flooding, reducing the potential exposure, or reducing the vulnerability). An important difference in MLS is that the spatial planner needs to anticipate flood risk in an area, whereas this task was previously regarded as solely the task of the flood risk managers.

In 2014, an instrument named MLS Explorer was designed with the aim to assist spatial planners from multiple governmental levels with flood-proof planning (Bouwer et al., 2014). After the user has drawn an area and entered several characteristics of that area, this instrument presents flood-risk information for that specific area. The usefulness of having access to flood risk information during the spatial planning process is evidenced by an example from the Wieringermeerpolder in the province of North Holland. In this polder, Microsoft built a large data centre worth 2 billion euros (Edmonds, 2013). Such a data centre has numerous electric devices that are vulnerable to water. When a flood occurs (with an estimated probability of 1/700), the maximum water depth can reach 4.5 meters. Only one kilometre to the south, in West Friesland, the maximum water depth is calculated to be 1 meter, and also has a lower probability of flooding at 1/1000. This example raises the question of whether the higher risk is acceptable or if the current location is worth that much more than the other, less vulnerable, location one kilometre south? But it is possible that this information was unknown to the people responsible for choosing the location.

The example of the data centre is on a large scale. However, at a neighbourhood level, or even for private dwellings, it can be really valuable to explore the flood risk. Previous research has shown that it is difficult to design an instrument (e.g. the MLS Explorer) that helps users from a discipline different to that of the designers of the instrument (de Vries, 2017). The MLS Explorer was designed by flood risk specialists who have sufficient knowledge of flood risk in order to easily understand the output of the instrument. Despite the fact that the instrument was freely available on the internet, it was hardly used. This research paper will explain why the approach that was initially used to design the instrument did not achieve the desired result, and will suggest what could have been done differently. Therefore the central question is:
How can one design an instrument that presents information to users from a different discipline, who need to make decisions based upon that information?

An important aspect to consider is that the designers come from a different discipline to that of the final user. Therefore their knowledge and terminology (jargon) may differ from each other, In chapter 3 of this paper some background information on flood risk and spatial planning will be provided. Subsequently, chapter 4 will explain the main point in this paper, namely that it is important to start the design with a result driven approach. Finally, chapter 5 will offer discussion and conclusions. However, before this, chapter 2 will explain the method that has been used to analyse the quality of the information that is presented by the existing MLS Explorer, and how this was used to recommend another way to design the Explorer.

2 Research Method

In order to analyse how the MLS Explorer was designed and more importantly, how it *should* be designed, a knowledge management model with the name DIKAR was used. The letters stand for Data, Information, Knowledge, Action and Result (Venkatraman, 1996; Ward & Peppard, 2002). The whole process, which is visualized in Figure 1, shows the transformation of raw data into information. This information can become knowledge if the person understands it. That knowledge can make a person more capable of making the best decision. This decision will lead to a certain action, which in turn produces a (desired) results. This whole process is called knowledge management. However, it can be divided into three smaller types of management. Firstly, **'**management of information' concerns the transformation of data into the right information. Secondly, there is the 'management of competencies'. This is the management of both the level of knowledge in the head of the person who needs to take the action, as well as their level of power, commitment and experience. The third type of management is the 'operational management', which helps to ensure that the action does indeed produce the desired result. In between the five stages of data, information, knowledge, action, and result, four different gaps were identified. Firstly, the design gap is a problem with the consolidation of data and its transformation into information. This is often an ICT problem since someone needs to program what calculation consolidation should be performed with the raw data. Secondly, there is the expertise gap, which is often an organisational problem. Some people lack knowledge and/or expertise to interpret the information in the correct way. The third issue is called the leverage gap. This is again an organisational problem whereby those who possess sufficient knowledge, lack the empowerment to start the action. The fourth gap is a business problem in the form of an execution gap. This means that the action is performed, however, the intended result is not acquired. This can be due to mistakes made during the implementation phase that could have been prevented by better project management.

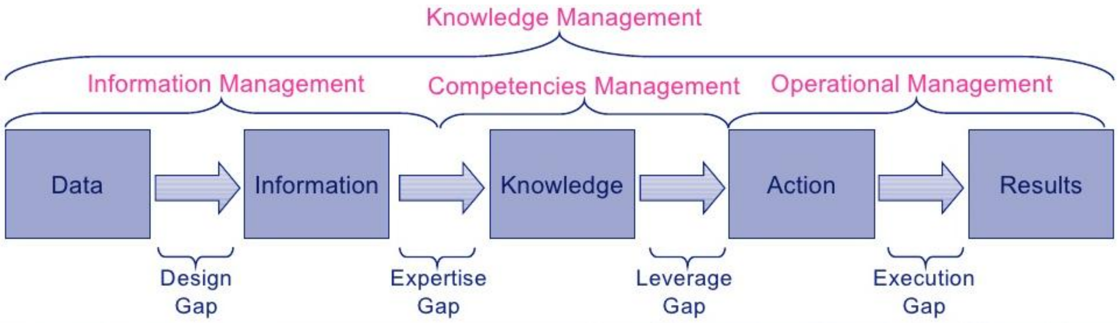

Figure 1: DIKAR stream with possible problems as a gap, and different types of management that can be used to solve the problems (de Vos, 2009).

The main focus in this paper will be on the design gap and expertise gap. In order to analyse how the design of the MLS Explorer could be improved, interviews were held with various persons from both the knowledge side of the expertise gap, spatial planners, as well as from the information side, the flood risk specialists.

An important distinction to highlight in this paper is the difference between information and knowledge. In order to do this comprehensively, the explanation of data should be added. Therefore, the first three steps of the DIKAR model will be explained, based on the articles of Hey (2004) and Murray (2000).

Data refers to unprocessed numbers and/or characters without any meaning. Data is a resource for producing information. Moreover, it is easily transferrable, discrete, and often available in abundance. An example is the numbers that a digital water level gauge sends to a computer.

Information is data that has acquired a meaning after it was processed. An example is the water level of the river. This is calculated by transforming the measured water level, in combination with the relative elevation of location where it was measured, into a water level in relation to the NAP[1]. In general, multiple sources of data are needed to generate information. The information that is processed is generally easier to read for most users.

Knowledge is a 'personal' (and therefore, subjective) interpretation of information. It has a meaning for the information absorber who understands the information. Moreover, knowledge is not quantifiable, since it is located in the brain of an individual. Knowledge can be acquired by absorbing and seeking to understand different sources of information. An example of knowledge is that a person knows how high a river's water level can rise before people need to be warned. Therefore, this person needs to know the current water level and the circumstances that will influence the situation in the coming hours. They also need to know the process that will be followed, mainly how long it takes, after it is decided that people

[1] NAP stands for the Dutch name Amsterdam Ordnance Datum [Normaal Amsterdams Peil]. This is a vertical reference height (geodetic datum) to which the height measurements are related.

need to be warned. In combination, all these aspects can render a person capable of making decisions about warning people or taking other actions aimed at reducing the possible impact of a flood. A brief overview of the main differences between the first three aspects is provided in Table 1.

Table 1 Main differences between data, information and knowledge

Data	Information	Knowledge
Is objective	Is objective	Is subjective
Has no meaning	Has a meaning	Has a meaning for a specific person
Is unprocessed	Is processed	Is processed and understood
Is quantifiable, there can be an data overload	Is quantifiable, there can be an information overload	Is not quantifiable, there is no knowledge overload

A downside of immediately starting with the DIKAR method is that the desired result is not yet known, which makes it difficult to design a way to transform data into the required information. In most cases the designers will have some kind of implicit result in mind, which is not yet explicit. This can be solved by first of all using the DIKAR method the other way around as RAKID. This result driven approach has already been explained by Murray (2000) and also later by Chaffey and White (2010). RAKID starts with a decent analysis of what the desired result is, who is responsible for taking the decision, and what this user needs to know before he/she can make the decision. This fourth chapter will explain what this means in terms of the design of an instrument like the MLS Explorer. However, before this some knowledge, which is needed to follow the reasoning in chapter 4, will be provided in the next chapter.

3 Necessary background on flood risk and spatial planning

Firstly a literal definition of flood risk will be explained in order to subsequently explain how this definition can be seen in Multi-Level Safety (3.1). Subsequently, a short explanation of the MLS-Explorer and the reason why it was developed will be given (3.2). At the end of this chapter the main differences between realms (or disciplines) of spatial planning and flood risk management will be explained (3.3).

3.1 Flood risk

The definition of flood risk that is used in this paper was adopted from article 2.2 of the European directive on the assessment and management of flood risks, which defines flood risk as '*the combination of the probability of a flood event and the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event'* (European Parliament & European Council, 2007). This definition indicates that there are multiple aspects that influence the flood risk. Klijn et al. (2015) explained that a difficult aspect of dealing with flood risk is the fact that spatial planners and flood-risk specialists prefer different definitions of 'risk' (see Figure 2). The flood risk specialist is often an engineer who strives for flood risk reduction by means of flood protection in the form of keeping the water out. From this perspective, the flood risk can be calculated by multiplying the probability of flooding by the possible consequences, visualised in the first row of Figure 2.

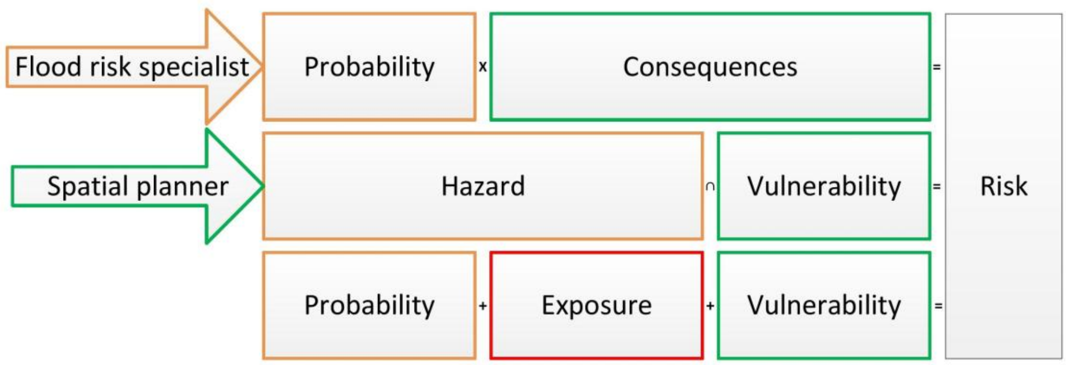

Figure 2: Overview of the differing perceptions of the definition of flood risk. Green is the responsibility of the spatial planner, orange is the responsibility of the flood risk specialist and red is the part that falls between both responsibilities.

From the perspective of the flood risk specialist, the flood risk specialist is responsible for minimising the probability of a flood occurring and the spatial planner is responsible for minimising the potential consequences.

The second perspective preferred by the spatial planner, is visualised in the second row of Figure 2. They divide the risk into hazard and vulnerability. Hazard is the responsibility of the flood risk specialist and vulnerability is the responsibility of the spatial planner. This definition is less easy to quantify since planners generally use social considerations to identify possible alternatives (and preferences are subjective), instead of hard calculations. In addition, the planners state that harm can only occur if there is both a hazard as well as vulnerability. Therefore, they use the intersection sign instead of the multiplication sign.

Klijn et al. (2015) suggested a new element called 'exposure' (red rectangle in the last row of Figure 2) as the element that falls in between the two earlier definitions. According to the spatial planner 'exposure' is part of the hazard, whilst the flood risk manager states that 'exposure' is a part of the consequences.

Elaborating on this flood risk definition, the reason for MLS and its meaning can be explained conveniently. Based on the need for more cooperation in order to reduce the flood risk with spatial planning, a new concept, with the name Multi-Level safety (MLS), was devised. In 2009, the Dutch government introduced this concept and, as the name suggests, it is comprised of different levels. The first level is prevention, and focuses on reducing the probability that a flood will occur (e.g. by building strong dikes or creating more room for the rivers). The second level aims at creating a durable spatial development that will help to minimise the potential (financial) damage when a flood occurs. With such a spatial development, both the potential exposure and vulnerability should be minimised (e.g. houses can be built on higher ground, or made flood-proof by using tiles instead of carpet on the ground floor). The third level focuses on the preparedness of people in order to reduce the number of casualties. Concrete examples include informing people about their risk and explaining how they can prepare for possible floods (e.g. how and where to flee, as well as training emergency services). This MLS appears adequate in theory, however, it was difficult to implement in the real world (van Buuren et al., 2013).

3.2 MLS Explorer

In order to stimulate the implementation of MLS-measures the Directorate General for Public Works and Water Management (DGPWWM, [RWS]) commissioned *Deltares*[2] and *HKV-Lijn in Water* to design an instrument that can provide spatial planners with the information they need to be able to take into consideration the flood risk and anticipate potential floods. According to the design-documentation, the foreseen users were policy officials representing municipalities, provinces, safety regions, water boards and the national government (Bouwer et al., 2014). Despite one single interview with a potential user the main approach undertaken by Deltares and HKV was thinking about the information they thought was important to present in this instrument, and also possible to produce with the available data. There are multiple sources of data (e.g. satellite data, water level measuring instruments, planes with laser scanners that fly over the country every two years to produce altitude maps, weather stations and water level measurement equipment, etc.) that can be used to produce information for flood risk assessment. The MLS Explorer provides information in relation to the following aspects (Bouwer et al., 2014):

- Type of flood risk
- Maximum water depth and probability of flooding
- Consequences of flooding in terms of damage and casualties
- Probability of the success of different kinds of measures
- Approximate indication of costs and benefits

[2] Deltares is an independent institute for applied research in the fields of water and subsurface

3.3 Realms of flood risk specialists and spatial planning

The reason that both disciplines use a different definition of flood risk stems from their roots. Both disciplines have a long history because of two characteristics of the Netherlands; it is a low-lying flood-prone country with a high population density. This makes it important to carefully organise the scarce space. There are differences between these two realms that have been traced in the literature. The Flood risk managers are more technically oriented and make 'hard' calculations that result in objective 'best solutions'. However, spatial planners deal more with subjective opinions and therefore are more socially oriented, meaning that often, hard calculations are insufficient to decide which alternative is most desirable. An overview of several characteristics that describe the different realms is given in Table 2.

Table 2: Differences between the realms of flood risks managers and spatial planners, based on De Bruijn and Ten Heuvelhof (2010) and de Graaff et al. (2009)

Flood risk management	Spatial planning
Technical emphasis	Social emphasis
Technocratic decision	Democratic decisions
Only a few stakeholders play role	Many different stakeholders
Static	Dynamic
Project management	Process management
Best alternative can be objectively calculated	Choice for 'best' alternative is subjective

These differences lead to difficulties in the cooperation. For a long time these two realms operated quite independently from each other, but from the 1970s onward there has been a slow move towards a higher desire for cooperation (Correljé & Broekhans, 2014; Wiering & Immink, 2006). Spatial adaptation receives more attention in the Delta programme of 2016, which offers opportunities for new approaches in flood risk reduction.

4 Why it is important to start with RAKID instead of DIKAR.

Now with the information from the previous section in mind it will be explained why the design process, framed as DIKAR, should be preceded with a RAKID analysis in order to design an instrument like the MLS Explorer. The process can be explained with use of Figure 3, which shows the DIKAR process in a left to right funnel shaped process.

The process starts with lots of data (blue rectangles) that is gathered by the flood risk specialist in order to transform it into information (green rectangles). Several sources of information are used to form knowledge in the brain of the spatial planner. This knowledge (purple rectangle) is a combination of previously acquired information (e.g. the specific characteristics of the location), experience and skills (e.g. from earlier projects), and the flood-risk information that should be added in order to form the total package of knowledge. This total package is needed to make the decision about the best course of action (red rectangle) to reach the (desired) result. As demonstrated in Figure 3, the MLS Explorer (yellow rectangle) is at the boundary between the realm of the flood risk specialist and the spatial planner. More precisely, the part that is visualised on the computer screen forms part of the realm of the flood risk specialist, and the person who is reading it is part of the spatial planning realm. The focus is on this boundary between the flood risk specialist and the spatial planner, which is centralised around information. Therefore the next paragraph will explain how information quality can be assessed.

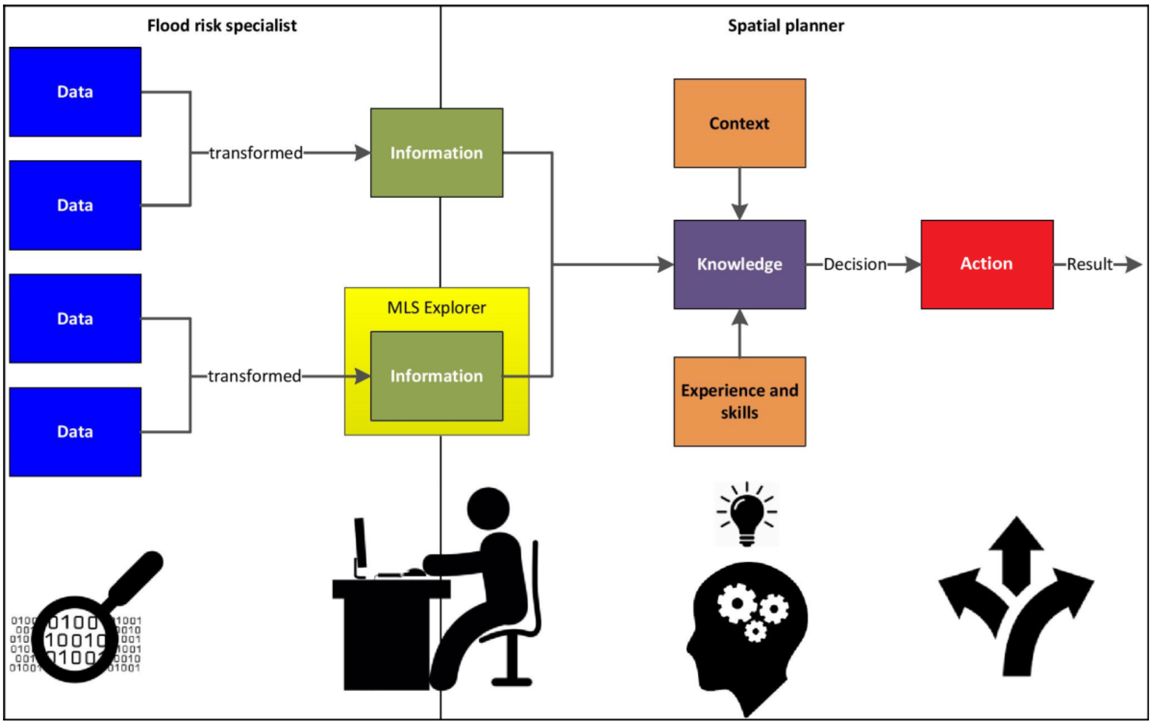

Figure 3 DIKAR process visualised with the MLS Explorer.

4.1 Assessing the quality of information

Quality of information can be assessed using different aspects. Information quality is described by English (1999) as the function of three input variables: (1) Data quality: if the data that is used as source for the information is incorrect then the information quality will be low since it is not based on reliable data. (2) Definition: the definition of the information item must be clear to the user so that he/she knows what it means. (3) Presentation: the presentation must be understandable to the user. Besides these three attributes, three more attributes concerning pragmatic information quality can be added: (4) Relevance, (5) availability and (6), timeliness. In this situation, timeliness (being up to date) is less important since the subject is about spatial planning, which often takes 5 to 10 years before it is realised and subsequently stays in place for a further 5 to 10 decades.

1. If we use the five remaining attributes (timeliness excluded) to assess the quality of information that is presented by the MLS Explorer, it can be stated that despite the fact that the majority of the data quality seems to be sufficient, the transformation of the data into information is not always correct. This was evidenced by the fact that some locations, which are located inside a dike-ring, were presented as an outer-dike area. This is because the algorithm behind the MLS Explorer uses map layers with a certain resolution that influences the outcome of whether a location is inside or outside a primary dike. If the user draws an area inside the dike, but close to the dike, and the area crosses one pixel that is partially located outside the dike, the instrument classifies the total area as outside of the dike. This could be solved by changing the resolution or adjust the coding in the algorithm.
2. The second attribute, that of information quality, means that definitions must be clear to the users, so that the meaning is consistently clear. This is not always the case in the MLS Explorer. During interviews it was discovered that two abbreviations, LIR[3] and LSG[4], were unfamiliar to almost all the spatial planners. Another example of difficult definitions is the probabilities that are presented to the spatial planners. An event that is expected to occur once every 100.000 years is difficult to comprehend for a person who does not regularly work with these types of probabilities. In this case it might be easier –and

[3] LIR is the Dutch acronym for Local Individual Risk [Lokaal Individueel Risico]
[4] LSG is the Dutch acronym for Local Damage Hazard [Lokaal Schade Gevaar]

more useful- for the spatial planner to explain the probability in another scale, e.g. the probability that flood will occur in the coming 50 years.

3. The next attribute, presentation, scores sufficiently in most of the visualisations within the MLS Explorer. However, sometimes there are maps with a legend that contains colours that hardly differ. In this presentation it is better to choose colours with sufficient variation so that the differences between areas can be quickly recognised by the user. Also, the overview of all possible measures that is given in the last screen of the MLS Explorer is not the best way of presenting the results. It is a large table with different type of numbers, which is difficult for many spatial planners to understand. The spatial planners that were interviewed explained that they needed more visualisations of the expected situation (de Vries, 2017). Therefore, a map that presents all the numbers, perhaps with the option to shift between different themes or different assumptions, could replace the table.

4. The relevance of information has two aspects. First, all information that is relevant should be presented and secondly, all information that is not relevant should be left out to prevent an information overload. In the current Explorer there is still information missing. This missing information is needed by the spatial planners to conduct an adequate flood risk assessment (e.g. locations with vital objects, borders of dike-rings and possible deviations in the calculations).

5. The last attribute is availability. The MLS Explorer is sufficiently available since the spatial planner only needs a computer and internet access to be able to use the instrument.

With this analysis of the quality of information presented by the MLS Explorer it can be concluded that there is room for improvement. Now the question remains, *how* could it be improved? The next section will explain how the result driven approach, as articulated by Murray (2000) and Chaffey and White (2010), has potential to significantly improve the quality of the MLS Explorer.

4.2 Result driven approach

The design method that was initially used can be identified as DIKAR. This has resulted in an instrument that is barely used. The main problem that was identified in previous research is that the information is not sufficiently understood by the users (de Vries, 2017). If the users had been better questioned prior to the design of the instrument, a better instrument could have been designed. The total process that is recommended can be defined as RAKIDDI: Result → Action → Knowledge → Information → Data-1 → Data-2 → Information. The first part 'RAKID' is the analysis and the second part 'DI' is the design of the instrument (as visualised in Figure 4).

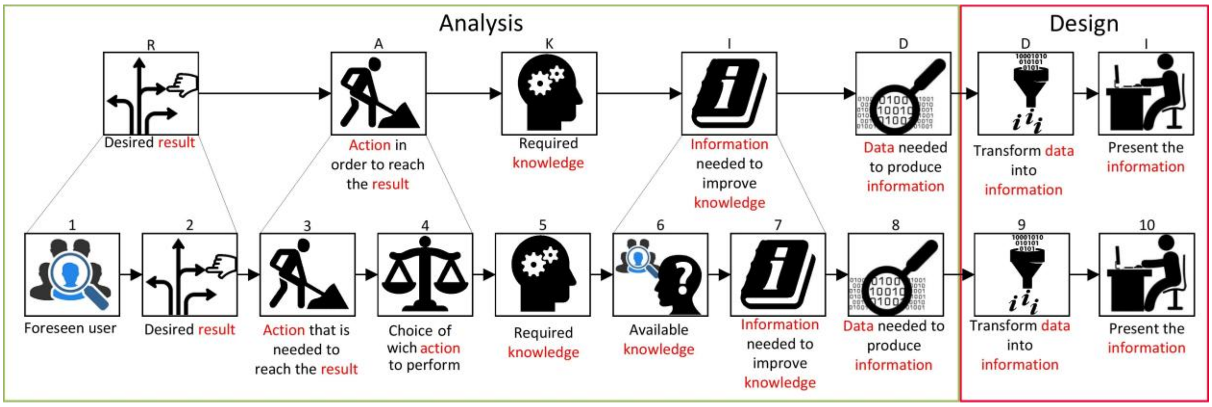

Figure 4: Schematic overview of the suggested approach to designing an instrument like the MLS Explorer. Visualised in the upper part with RAKIDDI that was retrieved from Murray (2000) and Chaffey and White (2010) and adjusted, as well as ten identified steps in the lower part.

If we examine the individual steps we can count a ten-step process. So instead of starting with the data and producing information for a wide group of users[5], it is better to start with (1) a choice for the foreseen user of the instrument and (2), by analysing its desired result. Although this may seem obvious, it is an often encountered pitfall in designing a decision-supporting instrument. The chosen user must be specific since a more general group means a more significant variety in prior knowledge, which makes it difficult to design an instrument that can be easily used by all users. The next step is to (3) identify which actions the use of the instrument may assist, and (4) what decisions lead to these actions (e.g. a municipal official deciding to build a new neighbourhood at the south-western border of the existing city). If it is known what kind of decisions are relevant for this instrument, it can be (5) traced to what knowledge is required to be capable of making those decisions. Subsequently, it is important to (6) find out what the user, who was identified in step 1, already knows about this topic. If 5 and 6 are known, the lacuna between those two can be seen as (7) information that is needed to improve the knowledge of the user up to the required level. The last step of the analysis is to (8) distil what data is needed to produce the information. After the RAKID analysis of is performed, the DI-design can start with (9) gathering the data that was identified in step 8 and (10) transform this data into the required information. At this stage it is important to verify if the presented information is indeed understood by the user. If not, the designer should think of ways to improve the level of understanding as it means that the quality of the information is still insufficient. What is not understood must be analysed (step 6) and then steps 7 to 10. This process can be repeated several times until the information, and presentation of the information, has sufficient quality to bring the knowledge level of the user to the required competency to be able to make the decision.

5 Discussion and conclusions

Now the question, of whether it would be better to train the spatial planners so that they have sufficient understanding of the flood risk information, surfaces. In the visual in Figure 3, this can be explained as an investment in the upper green information square. Although this could be a solution to the problem, it is not an efficient solution. It would be expensive as the target group has to be identified and subsequently this group has to be trained, taking into account their previous knowledge.

The first difficulty is to identify the target group. Who should be trained? Is the training only for coastal and fluvial river flooding, or also for pluvial flooding? This then raises the questions of how often civil servants need this specific knowledge? Furthermore, how expensive is it to keep them educated at the desired level? This has high potential to result in inefficient training. In my opinion it would be less expensive, take less time, and therefore be more efficient, to train a smaller group of flood risk specialists in dealing with spatial plans. These specialists can be deployed throughout the whole country and assist spatial planners who have already explored the flood risk in their area.

A second downside of training the spatial planners is that this training has to be designed for all the spatial planners, or at least the ones that have been selected for deployment in places where there is a flood risk. The flood risk situation in the southern province of Limburg, which has upland areas and only deals with flooding from the river or precipitation, differs a lot from the flood risk situation in North Holland, which has low-lying land that is susceptible to flooding from the sea. This would thus make it difficult and expensive to have only one general training. This doesn't mean that the municipalities shouldn't do anything in relation to flood risk. If the spatial planners better understand what risk means and have access to an intelligible instrument that gives them sufficient and understandable information to explore the situation, I believe that these planners may slowly gain a better understanding of the flood risk aspects in their respective regions. This understanding can already be grown by using the improved MLS Explorer, but can also be improved by giving more general 'risk training' throughout the whole county.

The main conclusions can be summarised by the advice to start the design process of an instrument like the MLS Explorer with the analysis of the end user. This can be done by using the result drive RAKID model, and subsequently using the technology driven DIKAR approach, in order to produce a design that fits the

[5] Important to note is that these are not the users of the final result but rather the users of the instrument. These users should base the result on the needs or desires of the people who live in the area.

demands of the end user. In this research paper the scope ran up until the information, which means the suggested design process can be expressed as RAKIDDI. An important point to mention is that this does not mean that the spatial planners do not need any training, but rather that the focus must first be upon the design of the instrument.

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