master thesis

VELOCITY & MILITARY INTELLIGENCE

THE TRADE-OFF BETWEEN SPEED AND ACCURACY

report

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Case study commissioned by The Dutch Ministry of Defence

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VELOCITY & MILITARY INTELLIGENCE

THE TRADE-OFF BETWEEN SPEED AND ACCURACY

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How much better to
*get **wisdom** than gold,*
*to choose **insight***
rather than silver.

Preface

To protect what we value: the mission statement of the Dutch Ministry of Value. In a world in which knowledge is power, the importance of intelligence increases. In this research, I hope to contribute to the process of creating such knowledge and intelligence to protect what we value.

I worked on a research in which I have found insights in the effects of information velocity on the trade-off people make between speed and accuracy. Through conversations and observations, I got insights in human behaviour, traditions and common methods of people that operate within JISTARC. By combining these insights with the expertise I gathered during my study Engineering and Policy Analysis, I hope to contribute to the organisation of JISTARC. I hope this research challenges your ideas about big data and that this piece of work creates insights in how we as people deal with our surroundings.

My adventure at the Royal Armed Forces of the Netherlands started before the summer of 2019. An organisation I was unfamiliar with opened up and gave me a look inside its traditions, mindset and spirit. I met people that devoted their life to this organisation to contribute to a goal that is greater than ourselves.

I would like to thank Pieter for connecting me to the people of JISTARC and giving me the opportunity to explore an organisation that would otherwise have remained a black box. Many thanks to Rob who took the effort to take me on board of the organisation of JISTARC. He guided me through the organisation and connected me to the right people. Without his experience, network and enthusiasm I would not have been able to create these results as written down in this report. Thanks to Lesley, Rudmer, Peter, Stan, all respondents and all the other people of JISTARC for adopting me into the organisation, guiding me around in ‘t Harde and providing me with insights in their experience. The people of JISTARC gave me an experience that will always be remembered and has coloured my heart forever a little green.

Thanks to my dad that has read thoroughly through more than 150 pages to help me to dot the i's and cross the t's. Thanks to by dearest Thom, who has supported me unconditionally these months through brainstorming, cooking, staying up late with me, telling me to stop working and providing me with confidence to finish this thesis.

Many thanks to Haiko, who has guided me through the process. I appreciate his enthusiasm, approachability and flexibility (especially during my months in The Hague) that have helped me to retain my motivation through the process. I have enjoyed our discussions and he has helped me to bring my thoughts to the next level.

Arline van Maanen,

Amersfoort, February 2020

Summary

With the rise of big data, the velocity of information is increasing. Velocity will affect decisions that are based on information. The question raises whether this increase of information speed, continuity and veracity contributes to an increase in the decision quality of decision-makers in organisations. Such decision quality can be addressed by addressing the trade-off between speed and accuracy that is made by agents within the decision-making process. To create an understanding about the effects of information velocity on decision-quality, the effects of velocity on speed-accuracy trade-off are addressed by this research. The context of this trade-off is analysed within the context of the decision-making process.

Existing work

Current work about the rise of big data and its impact on decision-making processes of organisations is available. These studies describe big data by all four of its aspects: volume, velocity, variety and veracity; although, research about the specific impact of velocity on these processes is not available yet. This research contributes to an understanding of the concept of information velocity and the effects of this velocity on the decision-making process. This issue will be approached by describing the effects of information velocity on the trade-off between speed and accuracy. Current literature about velocity, the speed-accuracy trade-off and the decision-making process are used to provide a direction for this research.

Methods

To address the effects of information on the trade-off between speed and accuracy, a grounded theory approach is used to iterate between existing literature and gathered data to construct a theory about the effects of information velocity on the speed-accuracy trade-off.

A model based on a model of Da Silveira and Slack (2001) is developed to address the effects of velocity on how trade-offs between speed and accuracy are made. This model is adjusted to be suitable for situations in which behaviour of agents influence the trade-offs that are made during a process. By the use of this model, the next factors within the process are identified: requisites, the change one objective brings to the other objective, the efficacy of the capacity and the choice of agents how to balance the trade-off. To identify these factors, empirical research is used to address this issue since agent choices can be observed and questioned. The empirical research is conducted within a case study: an intelligence process within an organisation of the Dutch Ministry of Defence. Two methods of empirical research are used: ethnographic observations and interviews. Interviews are used to understand the perceived trade-offs that are made by agents and to create insights in factors that lead to these trade-offs. During the ethnographic research, the actual trade-offs that are made by agents between speed and accuracy are found. The results of the data gathering processes are combined into a model that addresses the effects of information velocity on the trade-off between speed and accuracy.

Conclusions

From the data gathered by the empirical research methods, a model is constructed about the effects of velocity on the trade-off between speed and accuracy which can be found in figure S.1.

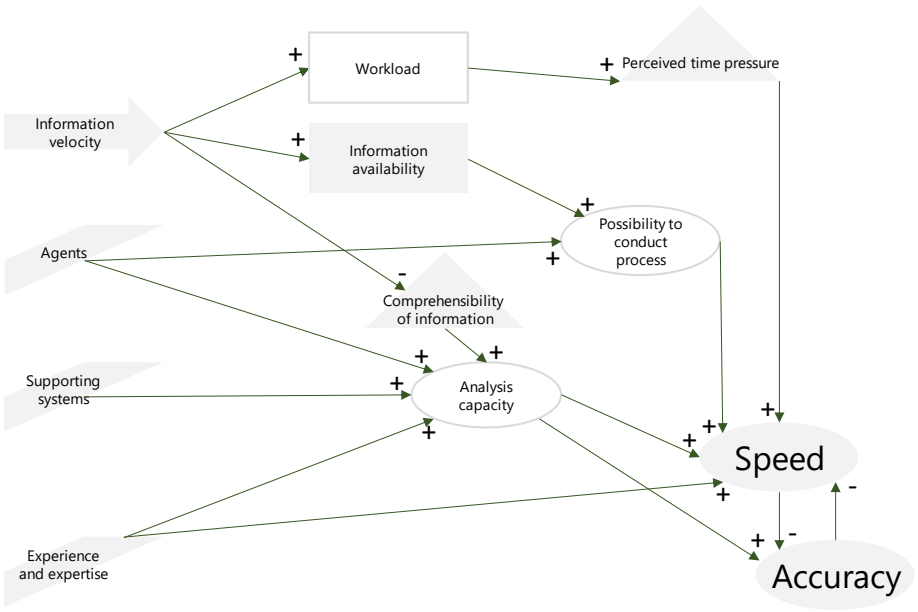

Figure S.1: Model about the effects of information velocity on the speed-accuracy trade-off

This model is constructed by the analysis of data that is collected within a context in which the empirical research is conducted. This context is influenced by contextual factors: the rule that all received information should be analysed, sharp deadlines are defined to deliver results, specific agents have specific tasks within the process and information is mainly shared through reports.

The effects of information velocity can have both negative and positive effects. The positive effects include increased information availability, although this effect is only apparent when no information is available to conduct the analysis process. Negative effects include the decreased comprehensibility of information that decreases the analysis capacity and lowers speed and accuracy. Also, the increased workload that is caused by high information speed requires higher levels of speed of agents when deadlines are fixed. This effect leads to lower levels of accuracy of the outcomes, which is often not desirable within situations in which decisions can entail high risks for human lives.

Although information flows faster when velocity increases, the decision-making process speed is not likely to increase when no adjustments are done to the organisation of the current decision-making process. Also, the accuracy of information that is used to base decisions on is likely to decrease when information speed increases within the given context. Velocity can bring opportunities to the decision-making process by increasing information availability, but to cope with the negative impact of velocity changes should be made to the organisation of the decision-making process.

Next steps

During this research, insights are found about effects of information velocity on the speed-accuracy trade-off. The research is conducted within a specific context and the subjectivity of the researcher has influenced the outcomes that are constructed. To validate the results, more empirical research through interviews and ethnographic research should be conducted within different organisations and with multiple researchers and respondents. Also, the developed model based on the model of Da Silveira and Slack should be validated to be suitable for addressing how trade-offs between objectives are made by agents.

Keywords: *Velocity, the speed-accuracy trade-off, military intelligence, decision-making process*

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INTRODUCTION

1 Introduction

1.1 PROBLEM DESCRIPTION

With the rise of big data, the velocity of data increases (Özköse, Arı, & Gencer, 2015; Sagiroglu & Sinanc, 2013; Schrage, 2016). The velocity of data can be described as the speed at which data is generated and captured, but also the speed at which data is delivered or transported between systems and people or within a process (Katal, Wazid, & Goudar, 2013; Russom, 2011). This increasing velocity is caused by improved sensing techniques and an increase of the use of such techniques (Ang & Seng, 2016; Gaber, Zaslavsky, & Krishnaswamy, 2005; Marjani et al., 2017; Zaslavsky, Perera, & Georgakopoulos, 2013).

Decisions are important. Decisions define how people, organisations and governments behave and the direction in which they move. Many researchers promise or imply big data and higher data velocity will improve decision-making quality and therefore the performance of organisations (Economist Intelligence Unit, 2012; Ghasemaghaei, Ebrahimi, & Hassanein, 2018; Kościelniak & Puto, 2015; McAfee & Brynjolfsson, 2012). Other researchers challenge this point of view by assessing the difficulties big data can bring to the decision-making process (Janssen, Van Der Voort, & Wahyudi, 2016; Katal et al., 2013; Shamim, Zeng, Shariq, & Khan, 2019).

Decisions are made within decision-making processes (Hansson, 1994; Snyder, 2017). Within such processes, data and information is gathered and analysed to inform the decision-maker about the consequences of different actions (Saaty, 2008; Simon, 1993). The role of information is essential in making good decisions (Adeoti-Adekeye, 1997; Bowen & Zwi, 2005; O'Reilly, 1982; Porat & Haas, 1969). Before information can be used to support decisions, data is gathered, interpreted, analysed and outcomes are communicated to the decision-maker (Baldassarre, 2016; Huang et al., 2015; Janssen & Van der Voort, 2016; Klievink, Romijn, Cunningham, & de Bruijn, 2017; Philip Chen & Zhang, 2014). Within this process, information flows from the moment data is created until it is used by the decision-maker (Katal et al., 2013) . The information that flows through this process can be characterised by its

velocity. Velocity can be described as the *speed of information* (Chandarana & Vijayalakshmi, 2014; Dong & Srivastava, 2013; Höchtl, Parycek, & Schöllhammer, 2016; Kaisler, Armour, Espinosa, & Money, 2013; Katal et al., 2013; Özköse et al., 2015), as the *continuity of information* (or the *mode at which information flows)* (Chandarana & Vijayalakshmi, 2014; Dong & Srivastava, 2013; Kankanhalli, Hahn, Tan, & Gao, 2016; Russom, 2011; Sagiroglu & Sinanc, 2013) and as the *volatility of information* (or the *speed at which information changes)* (Dong & Srivastava, 2013; Jony, Rony, Rahman, & Rahat, 2016; Kościelniak & Puto, 2015; Sicular, 2013).

Lycett (2013) emphasises the importance of considering changing information velocity for the decision-making process, since it can change the feedback loops within the information flows of organisations. While research is available of such effects of big data (with all of its aspects) on the decision-making process, specific research about the specific effects of velocity on the decision-making quality is unavailable (Dong & Srivastava, 2013; IBM, n.d.; Kaisler et al., 2013). Although the effects are unknown, technical and organisational challenges of data velocity are recognised, like bandwidth (Kaisler et al., 2013; Tsai, Lai, Chao, & Vasilakos, 2015), the speed at which data can be processed (Höchtl et al., 2016), the assessment of which data is important and which is not (Lycett, 2013), the integration of information (Dong & Srivastava, 2013), the need for incrementalism (Dong & Srivastava, 2013), minimising the lead time (Eisenhardt, 1989, 1990a; Oracle, 2014) and the change from a sequential process towards parallel working (Bureau Algemene Bestuursdienst, 2017). The question raises whether information velocity will improve decision-making quality or will challenge it.

1.2 RESEARCH INTRODUCTION

The effects of information velocity on the decision-making quality are unknown. These effects will be addressed within this research. The measurement of the quality of decisions can be complicated or even impossible to measure: the effects of the decision cannot be measured in normative terms, the effects of the decision can only be measured in the long run (Sainfort & Booske, 2000) and the outcomes of a decision do not always define the decision quality (Elwyn, Elwyn, & Miron-Shatz, 2009).

An approach to assess the decision quality is to address the information itself that is used by the decision-maker to make an informed decision. The higher the quality of information, the higher the decision quality when decision-makers base and are able to base their decision (solely) on the information (Keller & Staelin, 1987; Raghunathan, 1999). This quality of information can be assessed by the accuracy of the information, although the accuracy of available information is not the only determinant that defines the quality of a decision (Ballou & Pazer, 1985; Förster, Higgins, & Bianco, 2003; Wand & Wang, 1996; Zmud, 1978). The speed at which information is made available to the decision-maker can increase the decision-making speed and therefore improve the decision-making quality as well, especially when timeliness is relevant (Eisenhardt, 1989, 1990b; Perlow, Okhuysen, & Repenning, 2002; Raghunathan, 1999; Robert Baum & Wally, 2003; Wenger, O'Toole, & Meier, 2008). Such speed of the decision-making process and the accuracy of the information that is delivered to the decision-maker is considered a trade-off (Drugowitsch, DeAngelis, Angelaki, & Pouget, n.d.; Franks, Dornhaus, Fitzsimmons, & Stevens, 2003; Rae, Heathcote, Donkin, Averell, & Brown, 2014). This trade-off exists because in many decision-making processes more data and information can be gathered, and more time can be spent on the analysing process before a decision is made. By doing this, the accuracy of the information that can be used to make a decision can be increased, but the speed of the process is decreased as well (Donkin, Little, & Houpt, 2014; Franks et al., 2003; Rae et al., 2014). The measurement of the trade-off between speed and accuracy can be used to address the decision quality (Chittka, Skorupski, & Raine, 2009; Raghunathan, 1999).

Within this research, the decision quality will be addressed by measuring the effects of velocity on the trade-off between speed and accuracy that is made during the process of information gathering and

analysis within the decision-making process. The information that is created during this process is delivered to the decision-maker that can base his/her decision on the available information. The process in which information for the decision-maker is gathered and created will therefore be the focus of this research.

1.3 CONTEXT

This research about the effects of velocity on the trade-off between speed and accuracy is done within a certain context. Decisions are made within organisations in which rules and culture influence the decisions that are made (Goll & Rasheed, 1997; Hough & White, 2003). These influences can be described as the *institutional context* in which decisions are made. Part of the institutional context of this research is the decision-making process in which the information is created for the decision-maker and the organisation of the client for who this research will be conducted. This client is introduced within next paragraph 1.4.

1.4 CLIENT/CASE

To analyse the effects of velocity on the trade-off between speed and accuracy, a case study will be conducted at a client: an intelligence organisation of the Royal Dutch Armed Forces called JISTARC. JISTARC is the organisation that is responsible for creating intelligence during missions abroad by gathering information in the field. Their main task is to conduct the intelligence process to support decisions of commanders. Such military intelligence is needed during abroad missions to create awareness and understanding about the environment in which the unit is located. Based on knowledge about this situation, decisions about the direction of the mission are made by commanders. JISTARC conducts the creation of information within the decision-making process of the military during missions abroad.

JISTARC consists of multiple squadrons that each have their own expertise by type of data that is gathered and analysed. Each of these squadrons deals with different data and with different levels of data velocity. A new squadron within JISTARC will be the Technical Exploitation squadron (108). This squadron will handle a new type of data that was not handled yet by one of the other squadrons. The data that will be gathered by this squadron is collected from DNA, material, attributes and traces (DMAT). This DMAT will be gathered in the field by collectors, investigated and exploited by specialists and analysed by analysts.

This type of data is handled by the military policy (Marechaussee) too, but the focus of the military police is different than the focus of military intelligence. While the Marechaussee needs a high level of accuracy within the process to be able to prosecute people or organisations, military intelligence has a higher focus on creating fast results, so actual information is available for the commanders that needs to make decisions about the course of the mission. Still, information should be accurate and reliable, because decisions that involve risks for human lives are based on this information.

1.5 SOCIO-TECHNICAL CONTEXT

The scope of this research can be classified as a research within a socio-technical context. Technological innovation interacts with society and is changing societal contexts (Weijnen & Herder, 2018). Velocity can be defined as the technological change and innovation that interacts with the societal context in which speed-accuracy trade-offs are made. A further description about the technical and social element of this research can be found in appendix B.

1.6 RESEARCH OBJECTIVE AND PROBLEM STATEMENT

This research is initiated by the observation that information velocity is increasing, as described in paragraph 1.1. The information velocity is therefore the independent variable of this research. The

concept that will be analysed is 'the trade-off between speed and accuracy that is made within the decision-process within organisations', which is the dependent variable of this research. The aim of this research is to address the effects the independent variable (velocity) will have on the dependent variable (the trade-off between speed and accuracy). To analyse these effects, the following research question will be addressed:

What are the effects of information velocity on the trade-off between speed and accuracy in the decision-making process?

A conceptualisation of this research question can be found in figure 1.1.

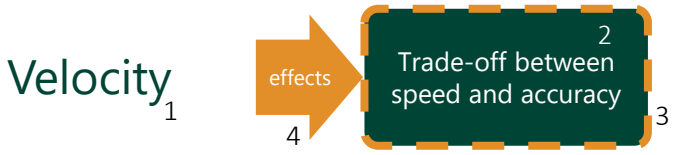


Figure 1.1: Research question conceptualisation

1: independent variable: velocity
2: dependent variable: trade-off between speed and accuracy
3: context in which the trade-off is made (decision-making process)
4: outcomes of the research questions

The observation of increasing velocity is acknowledged, and therefore the independent variable of the research will be *information velocity* (1). The effects of velocity are examined on a dependent variable: the *trade-off that is made between speed and accuracy* (2). This trade-off is made within a certain context. The context that is used as the scope for this research will be the context of the *decision-making process* (3). As the outcomes of the research, an analysis of the effects of velocity on the speed-accuracy trade-off will be described (4). To understand the effects, a certain approach or methods of research will be used. These methods will be discussed in paragraph 1.8.

1.7 RELEVANCE

This research about the effects of information velocity on the trade-off that is made between speed and accuracy within the decision-making process should be relevant within the academic research, within society and for the client at which the case study is conducted. The relevance within these three perspectives will be discussed in next paragraphs.

1.7.1 Theoretical relevance

Within academic literature, the increasing information velocity is acknowledged and mentioned often within the context of the rise of big data (Chardonnens, Cudre-Mauroux, Grund, & Perroud, 2013; Daas, Puts, Buelens, & van den Hurk, 2015; Dong & Srivastava, 2013; Gandomi & Haider, 2015; Janssen et al., 2016; Jifa & Lingling, 2014; Kaisler et al., 2013; Kankanhalli et al., 2016; Özköse et al., 2015). The effects of big data on the decision-making process are addressed (Höchtl et al., 2016; McAfee & Brynjolfsson, 2012; Power, 2014; Schrage, 2016) and approaches are designed to construct a decision-making process based on big data (Baldassarre, 2016; Huang et al., 2015; Klievink et al., 2017; Philip Chen & Zhang, 2014; Sagiroglu & Sinanc, 2013; van der Voort, Klievink, Arnaboldi, & Meijer, 2019). The specific effects of information velocity on decision-quality and the speed-accuracy trade-off within the decision-making process are not addressed within academic literature yet. The aim of this research will be to contribute to academic theories by addressing the effects of information velocity on the trade-off between speed and accuracy by which the effects of velocity on decision quality can be assessed.

1.7.2 Societal relevance

The role of data and information within society is increasing and the impact of this information and changes within this impact are relevant for society (Behnisch, Hecht, Herold, & Jiang, 2019; Graham & Dutton, 2019; Helbing et al., 2018; Liu & Ma, 2019; Lloyd & Wilkinson, 2019). Especially this impact within the decision-making processes is relevant, since many decisions are made within the public and private sector that affect the everyday life of citizens and developments within politics and markets (A. M. Evans & Campos, 2013; G. Evans, Biles, & Bae, 2019; Feng, Fan, & Bednarz, 2019; Krishen & Petrescu, 2019; Ma & Chen, 2019; Prodanova et al., 2019). How increasing velocity will affect these decisions and affects decision quality will therefore affect society. Another aspect the increasing velocity will bring to society is the change it will bring to the organisation of companies and governments. Increasing velocity will change the way of working and the role of people within processes (Bureau Algemene Bestuursdienst, 2017; Sagiroglu & Sinanc, 2013).

Charles Wijnker, Director of Labor Market and Socio-economic Affairs at the Ministry of Social Affairs and Employment, discusses the impact of big data as the fourth industrial revolution that will affect the way of working within organisations and governments. The role of technology becomes bigger, but the role of humans remains important. Organisations should adapt to deal with upcoming technology and people should be able to operate with such new technologies (Based on Bureau Algemene Bestuursdienst, 2017).

Example 1.1

1.7.3 Clients relevance

The research will be conducted at a client, JISTARC, which is an intelligence organisation of the Dutch Ministry of Defence. This client conducts (a part of) the decision-making process. The client must deal with the increasing velocity of information by external effects. JISTARC is also incorporating new techniques that will increase the speed of their data gathering processes. There is often time pressure in conducting their processes, while the outcomes of the process should be reliable and accurate, since decisions will be made based on the knowledge that is created by their process. These decisions can involve risks for human lives.

By understanding the effects of velocity on the speed-accuracy within the client's process, a well-considered and better decision can be made about how this speed-accuracy trade-off should be made and how to achieve maximum decision quality by providing the best information in time. The aim of this research is to contribute to the understanding of the effects of velocity on the speed-accuracy trade-off and to advice the client about this phenomenon.

1.8 RESEARCH CHARACTERISTICS

To address the stated research question, a research will be conducted. This research will have the characteristics of *grounded theory* and a *case study*. These methods will be introduced in next paragraphs.

1.8.1 Grounded theory

To answer the research question as stated in paragraph 1.6, a theory should be developed about the effects of velocity on the trade-off that is made between speed and accuracy in decision-making processes.

1.8.1.1 *The grounded theory approach*

Grounded theory is useful as a research method to develop theories, based on an iterative integration of existing theories and empirical data. From the chaotic and unstructured daily practices within an organisation, there is an aim to identify patterns and to develop a structured understanding about these practices and patterns (Glaser & Strauss, 1967). By combining these patterns with existing theories in

an incremental way, a theory about the effects of velocity on the speed-accuracy trade-off can be explored and validated, which is the aim of this research. Grounded theory is a way to combine inductive with deductive research (Heath & Cowley, 2004).

Grounded theory consists of several elements. At first, relevant concepts should be identified that will guide the research. These concepts should be explored and substantiated by existing theories and literature (in line with Strauss approach; Heath & Cowley, 2004). Based on this fundament of theory, empirical research can be designed to gather empirical data to address the research question. Based on these existing theories and empirical data, a theory to address the main research question can be constructed. This theory should be validated by theory and data to consolidate the theory. The different elements of this grounded theory approach will be addressed in next paragraphs.

1.8.1.2 *Concepts*

To give the research a direction and base to build on, relevant concepts are identified that will lead to addressing a foundation from theory about the effects of velocity on the trade-off that is made between speed and accuracy. These concepts are described by Blumer as *sensitising concepts*. Sensitising concept should give a "*general sense of reference and guidance in approaching empirical instances"* (Blumer, 1954). Prior knowledge and academic research should be identified and mapped for further use within this research.

Sensitising concepts that are identified and considered relevant to address the main research question are *velocity* and *the speed-accuracy trade-off*. These concepts are the main dependent and independent variable of this research. Regular activities that will be used to conduct literature research are the use of search engines like Google Scholar and Scopus, the identification of relevant journals and authors and back- and forward snowballing (Wohlin, 2014).

1.8.1.3 *Context*

The research to the effects of velocity on the trade-off between speed and accuracy takes place within a context. These effects will be researched within an institutional context and within the decision-making process of the client. The context should be described and discussed as well besides the sensitising concepts to be able to conduct empirical research.

1.8.1.4 *Research approach*

Figure 1.2 presents an overview of the grounded theory approach. Within this approach, at first the research question is constructed which is done in paragraph 1.6 and sensitising concepts are identified. Based on these concepts a literature research is conducted to identify and explore existing theories. These theories provide the foundation for the data gathering method. This method is put in the context of a case study which will be further discussed in next paragraph. Based on the existing literature and the data that is gathered within a case study, a theory can be constructed that will address the main research question.

Figure 1.2 is based on Wagner, Lukassen, & Mahlendorf (2010). In contrast to their description, figure 1.2 is simplified by integrating the 'grounded theory' layer with the 'joint coding and analysis' layer that have resulted in the 'constructing theories' layer. Within this layer, the process starts with a research question after which relevant concepts are identified. Another adjustment is the moment at which literature is consulted. In this approach, displayed in figure 1.2, literature is consulted directly after identifying concepts from research question and is used as first input for the theory to be constructed. This method is based on Strauss' approach, in contrast to Glaser's approach which is used as input for Wagner, Lukassen, & Mahlendorf (Heath & Cowley, 2004).

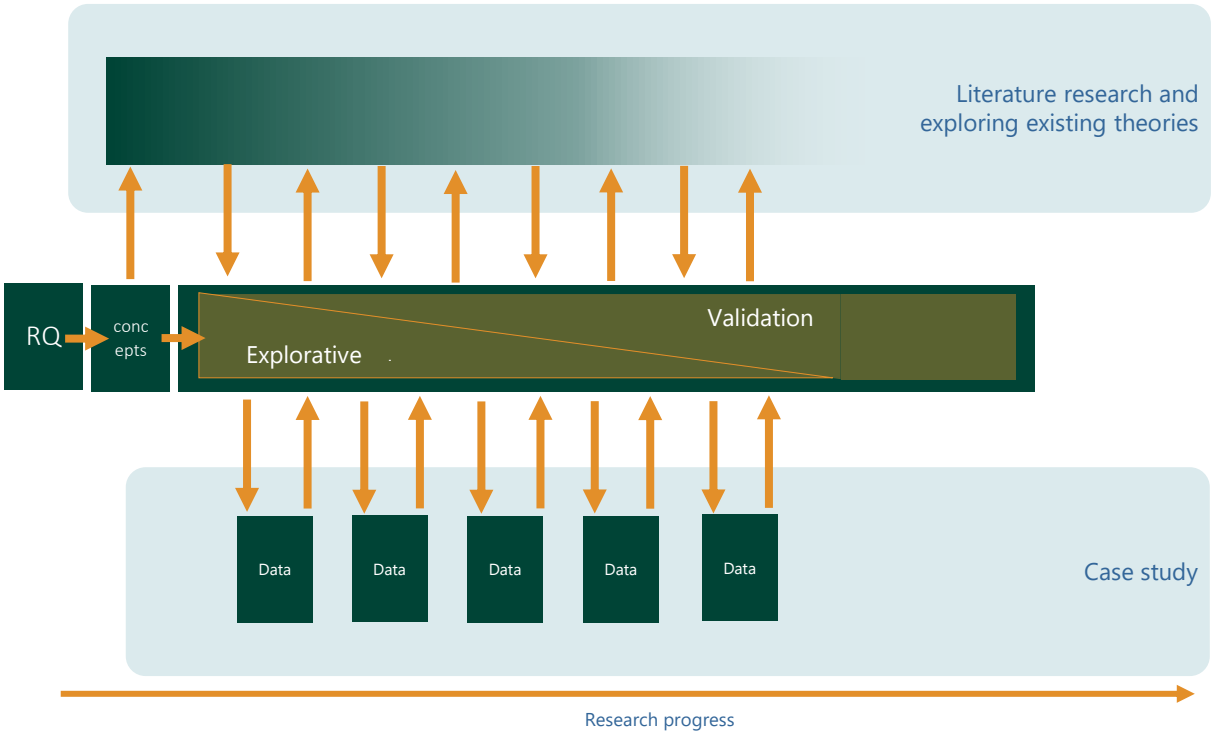


Figure 1.2: Grounded theory research approach

1.8.2 Case study

To understand the effects of velocity on the trade-off between speed and accuracy, empirical research can enrich the understanding of these effects. This research is conducted within the context of a decision-making process of the client. Within a case study, the effects of velocity can be investigated within a real-life context of the decision-making process of a specific organisation (Yin, 2017). This makes a case study a useful method to gather data that provides input and substantiate the theory that will be constructed. Therefore, a case study is suitable for doing research to the effects of velocity.

1.9 RESEARCH FLOW DIAGRAM

Although a grounded theory approach is iterative and incremental as can be seen in figure 1.2, to structure the activities a sequential overview of the research process is given in figure 1.3.

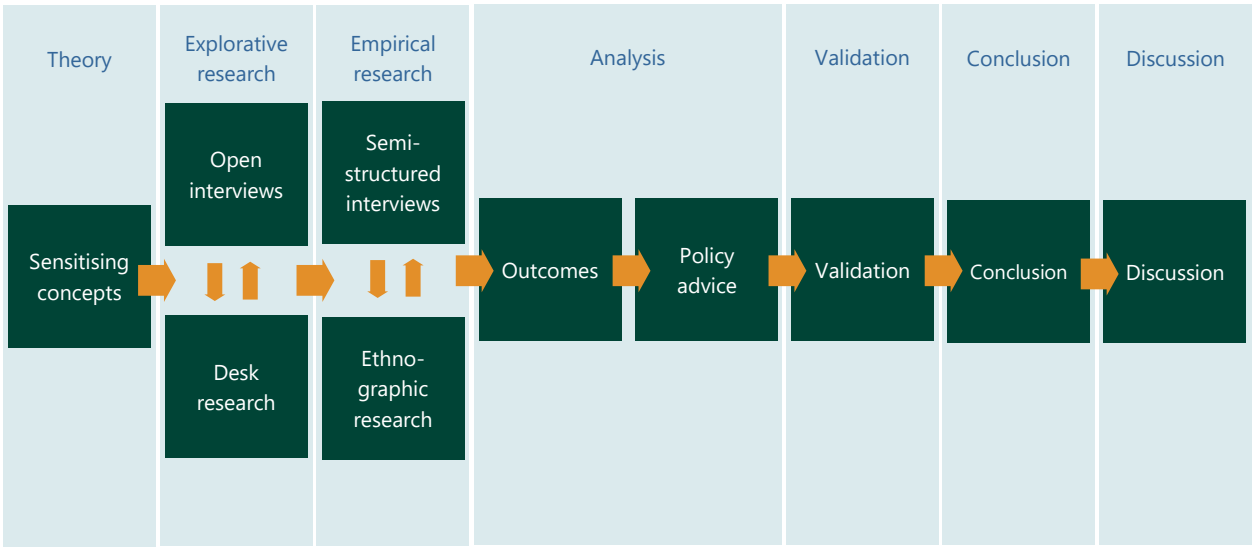


Figure 1.3: Research flow diagram

1.10 READING GUIDE

Within this chapter 1, the research subject, the research question, the client, the research relevance and the research characteristics are introduced.

In next chapters, at first existing theories and academic literature will be discussed in the section 'Theory'. The sensitising concepts are discussed by academic literature in chapter 2 and 3. Within chapter 4 the context in which the research is conducted will be described by theory as well. Within chapter 5, a framework is discussed based on the discussed theories for use within the further research. After this foundation of existing theories, the case is discussed in section 'Case'. In chapter 6 a research approach is given. In chapter 7, the case context is described by an example from the daily news. In chapter 8 the client is introduced, and its processes are described in chapter 9. In the next section, 'Results', the results of the empirical research at the client is discussed is chapter 10 and a policy advice is given in chapter 11. In chapter 12, the given results are validated. In the last section, section 'Conclusions', conclusions are given in chapter 13 and discussed in chapter 14. An overview of this reading guide can be found in figure 1.4.

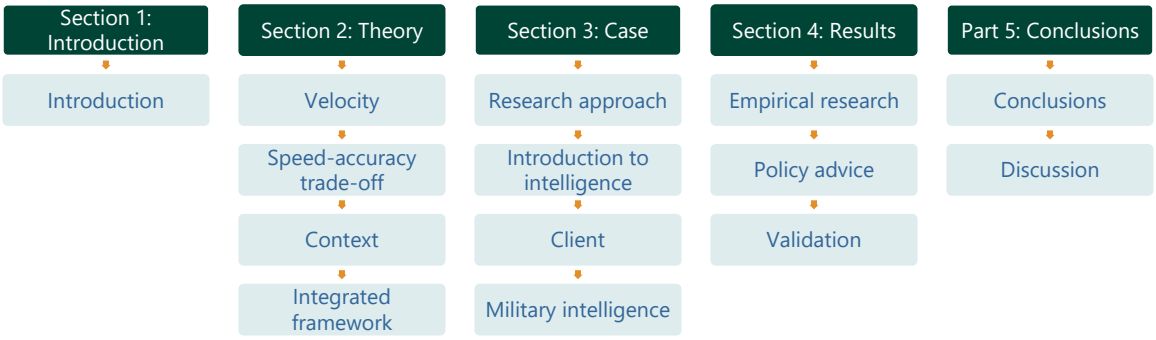
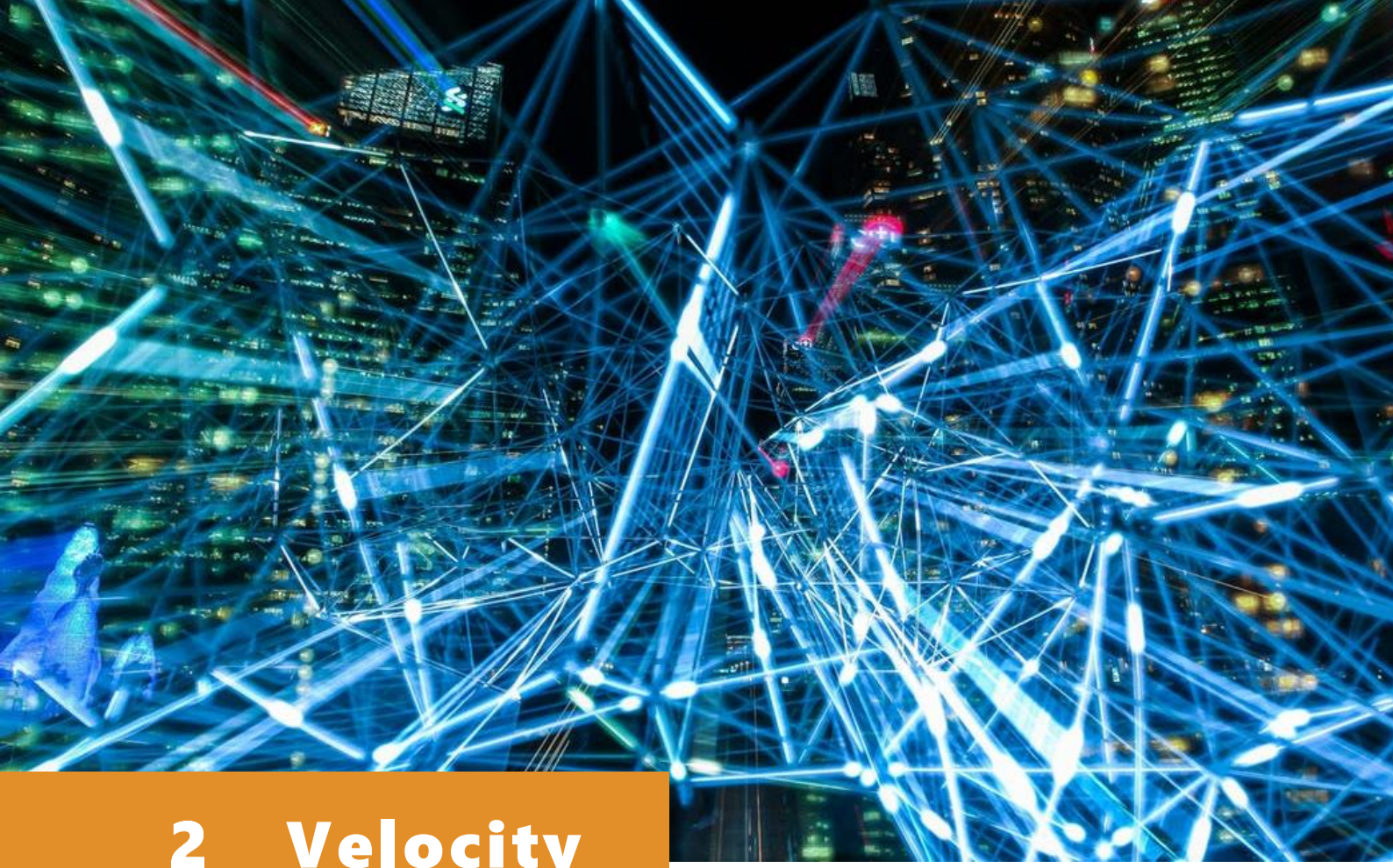


Figure 1.4: Reading guide

THEORY



2 Velocity

2.1 INTRODUCTION

Velocity can be described as *"the speed at which something happens or moves"* (Cambridge University Press, 2019). Information is created at a specific moment. From that moment, the information is communicated between people and systems. The speed at which this information is created and communicated can be described as the *velocity of information*. Velocity and speed are not the same: velocity can be measured by the rate at which something changes position within a direction (a vector quantity), while speed is measured by how fast something moves which is also defined as the magnitude of the velocity (a scalar quantity; Hibbeler, 2010; Verkerk et al., 2004). Within the context of data and information, the direction of data is complicated to identify. Therefore, within this research the direction of data/information will be ignored. Velocity and the speed of information and data will therefore be considered the same concept.

Over the past decades, sensing technologies became further developed and available. More data can be generated by sensing techniques and more data is available to collect through open and/or social resources (Lohr, 2012; Symon & Tarapore, 2015). Within society, the information flows have increased and also computation capabilities grew exponentially (Hilbert, 2016; Philip Chen & Zhang, 2014). These developments can be classified as the rise of 'big data'. With the rise of big data, the velocity of data is increasing. More data is created at a higher speed and more information is communicated between people and systems than before. Velocity becomes both a larger opportunity and a larger issue; high velocity information could contribute to a more effective and efficient decision-making process but comes along with technical and organisational challenges (Baldassarre, 2016; Cai & Zhu, 2015; H. Chen, Chiang, & Storey, 2012; Jagadish et al., 2014; Klievink et al., 2017; Kwon, Lee, & Shin, 2014; Labrinidis & Jagadish, 2012; Özköse et al., 2015; Sagiroglu & Sinanc, 2013).

To understand the effects of information velocity on the trade-off that is made between speed and accuracy, the concept of velocity should be understood. The different aspects of velocity will be introduced in next paragraph which will be discussed in subsequent paragraphs.

2.2 VELOCITY ASPECTS

Different theories can be used to identify different aspects within information velocity. Three aspects are identified in literature: 1. The speed of information (Chandarana & Vijayalakshmi, 2014; Dong & Srivastava, 2013; Höchtl et al., 2016; Kaisler et al., 2013; Katal et al., 2013; Özköse et al., 2015), 2. The mode at which information flows (Chandarana & Vijayalakshmi, 2014; Dong & Srivastava, 2013; Kankanhalli et al., 2016; Russom, 2011; Sagiroglu & Sinanc, 2013) and 3. The speed at which information changes (information volatility; Dong & Srivastava, 2013; Jony et al., 2016; Kościelniak & Puto, 2015; Sicular, 2013).

These three aspects of velocity of information can be found in table 2.1 and will be discussed in the following paragraphs.

	Aspects	Unit	Paragraph
1	Speed	[Information]/[Time]	2.3
3	Continuity	Movement type (flows or batches)	2.4
4	Volatility	[Change in information]/[Time]	2.5

Table 2.1: Aspects of information velocity

2.3 SPEED OF INFORMATION

The speed of information can be described as the speed at which information moves or is transferred through a system or as the speed of data flowing from sources (Katal et al., 2013). The velocity of data can be measured by the speed it is created and handled, for example every millisecond, minute, hour or day (Zaslavsky et al., 2013). The higher the rate at which data is created, the higher the velocity of data. It is estimated that in 2018 around 2.5 quintillion ($2.5 \cdot 10^{30}$) bytes of data were created and gathered each day (Domo, 2018). A higher data creation and gathering velocity implies a higher amount of information that is created in total: the data volume.

Velocity can be defined as the speed of data generation, but also of the speed at which data is processed, analysed and communicated (Katal et al., 2013), which defines the speed of information within the process as a whole.

Information flows can have different speeds. These speeds are often defined by the speed of processing (Baldassarre, 2016). Of the 2.5 quintillion ($2.5 \cdot 10^{30}$) bytes of data that are created and gathered all over the world each day, only a small part is actually processed (Philip Chen & Zhang, 2014). The velocity of the data generation is often higher than the velocity of data processing.

To maximize the value of information that has a high velocity, the processing time of data should be reduced so decisions and actions within organisations can be made with a higher speed (Fan & Bifet, 2013; Hofmann, 2017).

Direct issues raising from high data velocity are the bandwidth by which data can be handled and processed (Kaisler et al., 2013). Often data is collected by different sensors and processed by different systems; different information flows can be distinguished. Often, such different systems have a different speed of processing data which leads to information streams that have a different speed (Kaisler et al., 2013). The combination of information streams that operate with a different speed leads to challenges. Figure 2.1 provides a visual representation of such challenge.

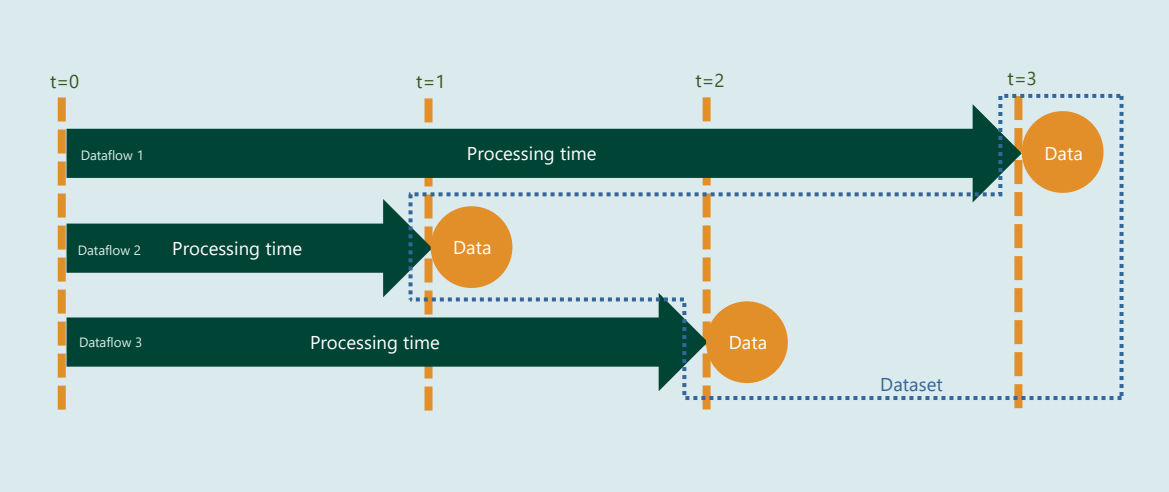


Figure 2.1: Different data processing speeds

At t=0, data is gathered. This data is put through 3 different processing systems than handle data at different speed. At t=1, the second dataflow is processed and put in the database. At t=2, the third system is ready processing the data, which is also put in the database. At t=3, the final system is done processing the gathered data and this data is also put in the database. At t=3, the dataset of the moment t=0 is complete, but at t=1 (or t=2), the dataset only contains the data from dataflow 2 (and 3) and is therefore incomplete. If the data is analysed at t=1 or t=2, the outcomes can give a false representation of the situation at t=0. The choice can be made to only analyse data that is gathered at $t_{current}$-3, so the dataset contains data from all data flows. This entails a total processing time of 3. In this case, the processing speed is as fast as the slowest process. Different processing speeds can also lead to an incorrect connection from data streams to each other, for example when a dataset is created from the three data flows at t=1 (Janssen et al., 2016).

2.4 INFORMATION CONTINUITY

The mode at which information is gathered and processed is another part of the definition of information velocity. This can happen in batches, in real-time or near real-time (Russom, 2011; Sagiroglu & Sinanc, 2013). The velocity mode of information, or the mode at which data flows through the system, is often defined by the mode of data gathering or data processing, which is done occasional, frequent or real-time (Zaslavsky et al., 2013). If the mode of gathering or the mode of processing is occasional, the velocity mode is batch-wise. Although processing of data can be done real-time, if this causes (significant) delays the velocity mode will be near real-time.

The relation between the mode of velocity and the mode of gathering and processing can be found in table 2.2.

Mode of gathering	Mode of processing	Delays	Velocity mode
Occasional	Any type	Any delay	Batch
Frequent	Any type	Any delay	Batch
Real-time	Occasional	Any delay	Batch
	Frequent	Any delay	Batch
	Real-time	Yes	Near real-time flows
	Real-time	No	Real-time flows

Table 2.2: Velocity modes

Many data sources, such as social media, are not stocks of data but ongoing data flows (Davenport, Barth, & Bean, 2012). In figure 2.2, a visual representation of data streams versus data batches can be found. Figure 2.2a shows how data is captured into a dataset, represented by the semicircle. The full circle represents the further use of data, which is done batch-wise; (a piece of) the dataset is gathered for further use. In the meantime, more data is collected and stored in the semicircle until this data will be used for further purposes. In figure 2.2b data is captured by a barrier (the semicircle) which slows down the speed of the information, but the flow of information is ongoing. At any time, information can be further used, but the information has a delay. In figure 2.2c, information moves through the process instantly. This last mode is real-time data processing. At the moment data is gathered, data can be instantly used.

Many processes within organisations are based on processing batches of information instead of streams of continuous information (Sagiroglu & Sinanc, 2013).

Figure 2.2a: Batch-wise information flows

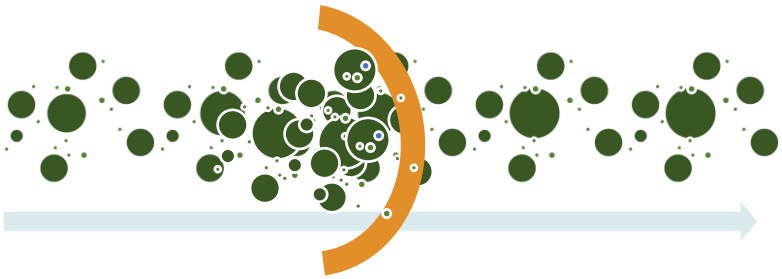


Figure 2.2b: Near real-time information flows

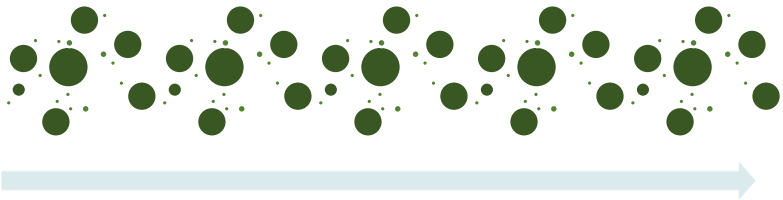


Figure 2.2c: Real-time information flows

Within this research, the increase of velocity is defined as the move from batch-wise information flows towards real-time information flows.

2.5 INFORMATION VOLATILITY

The third and final aspects of information velocity that will be discussed is the speed at which information changes over time. This aspect can also be described as information volatility.

With data moving fast, information can be volatile and dynamic (Dong & Srivastava, 2013), which means information changes fast over time and data only has a temporal validity; the timeliness of data is short. When it takes a long time to process data after collection, the recency of data decreases at the time of use. The low data recency negatively affects credibility of the conclusions (Cai & Zhu, 2015). High recency of data at the moment of conclusion- or decision-making, means the velocity of the data in the whole data process should be high to maintain information validity.

Figure 2.3a: High volatility of information

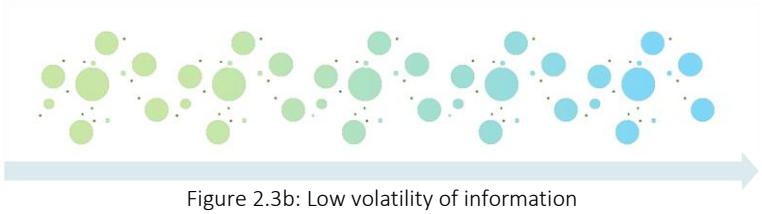


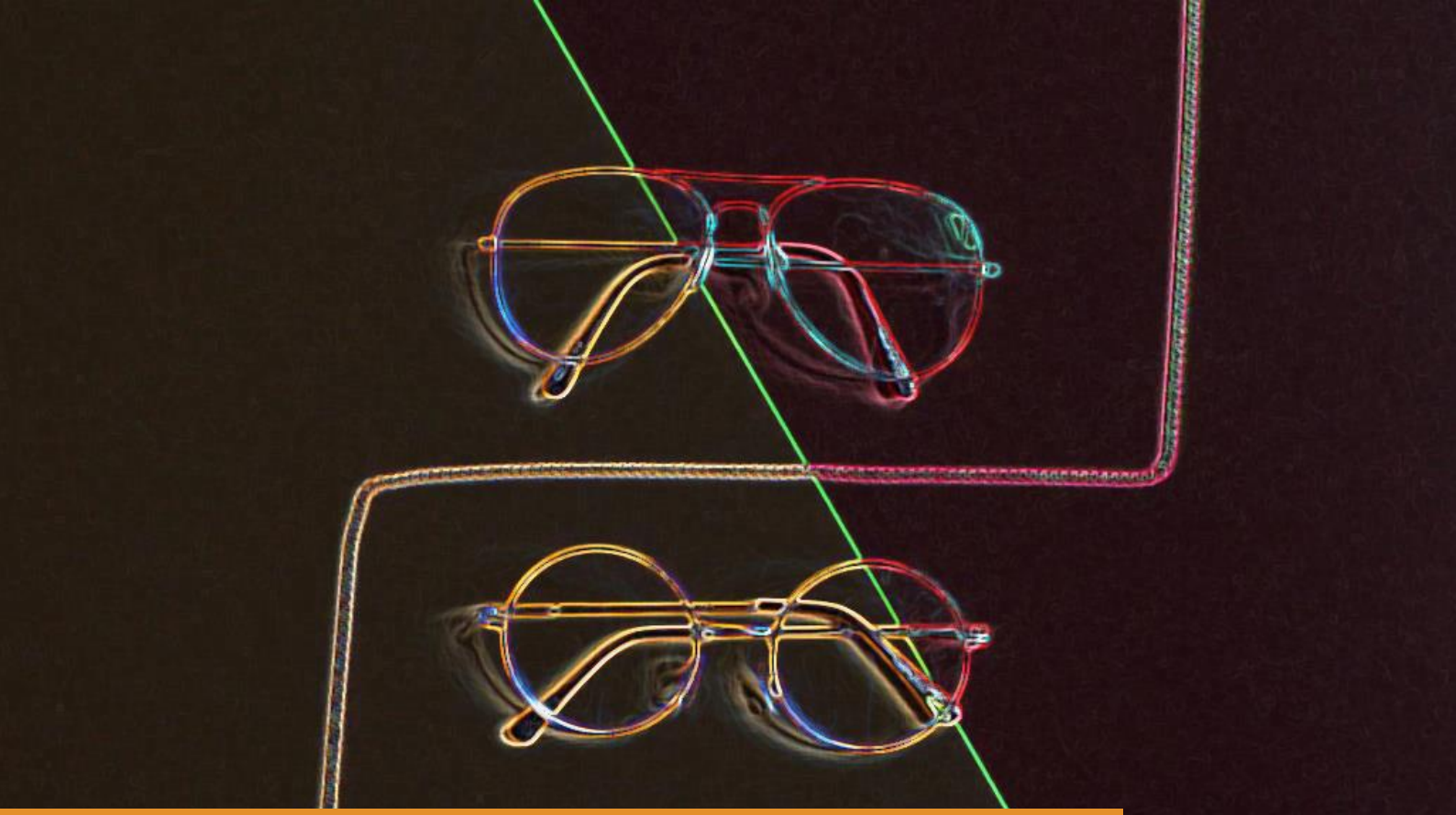
Figure 2.3b: Low volatility of information

2.6 CHALLENGES VELOCITY CAN BRING TO ORGANISATIONS

The rise of high information velocity causes challenges for organisations. High velocity information can contribute to faster decision-making speed, which can lead to higher decision quality (Eisenhardt, 1989). Although, when data comes into the process at high speed in a real-time way, the processing speed at which an organisation operates is often too low to maximise the value of the fast, real-time data (Safaei, 2017). When decisions can be made real-time, the high volatile information can lead to a short validity of decisions. Also, challenges arise when data has to be understand within its context while information moves fast through the decision-making process (Janssen et al., 2016). When information is shared continuously within a process of an organisation, organisations that are organised in departments will be challenged in cooperation between the different departments, since information silos need to be broken (Kim, Trimi, & Chung, 2014). Also, the organisation of processes into sequential steps can be challenged when information flows through the process instead of shared within batches. The successiveness of processes can change by the influence of increasing velocity (Bureau Algemene Bestuursdienst, 2017).

2.7 CONCLUSION

Velocity of data is increasing. Information velocity can be described by three aspects: the speed of information, the information continuity and the volatility of information. These aspects influence organisations: it can bring value but also can also challenge the current processes of organisations.



3 Speed and accuracy

3.1 INTRODUCTION

The second sensitising concept that will be discussed is the trade-off that is made between speed and accuracy. The aim of this research is to describe the effects of velocity on the trade-off between the speed of a process and the accuracy of the outcomes of the process. To create insights in the effects of velocity, the concept of a trade-off, specifically between speed and accuracy, should be substantiated by literature and theory.

Velocity is e.g. described as the speed of information[1]. Within this chapter, another concept that is related to speed is introduced as well, which is the speed at which processes are conducted. The speed of the process defines the lead time of the process. This speed of the process is the element of speed within the speed-accuracy trade-off. The speed of the process should be distinguished from the speed of information, which are two different concepts during this research.

Within this chapter, at first the definition of a trade-off will be discussed and conceptualised towards a model in paragraph 3.2 and 3.3. After this, the trade-off between speed and accuracy is discussed in paragraph 3.4.

3.2 TRADE-OFFS

3.2.1 Definition

A trade-off is a decision of an agent, which can be a decision that is made within a process. Skinner (1969) defines the trade-off concept as multiple objectives that are conflicting (or 'competitive objectives'; Da Silveira & Slack, 2001). Trade-offs are relevant in many optimization industries, economics and finance (Clifton, Leon, & Wong, 2001), but also occur in nature where species develop

[1] See chapter 2

traits at the cost of developing other traits (Garland, 2014). A definition is that a trade-off is *a decision that is based on compromises* (Da Silveira & Slack, 2001). The trade-off can be a conscious decision that is made by an agent that is aware of the alternatives, but it can also be a decision that is made unconsciously and intuitively (Da Silveira & Slack, 2001; Förster et al., 2003; Keramati, Dezfouli, & Piray, 2011; Marshall, Dornhaus, Franks, & Kovacs, 2006).

Because multiple objectives are relevant within the decision, a trade-off is a type of a multi-criteria decision (Bonissone, Subbu, & Lizzi, 2009). In a multi-criteria decision, multiple objectives are relevant for the outcome of a decision. Different values can be assigned to these criteria. An example of a trade-off represented as a multi-criteria analysis is represented in table 3.1. In this example, two actions within the trade-off are defined that lead to different outcomes of the objectives. In reality, the trade-off consists of multiple or infinite possibilities because the balance between two objectives can be defined as a ratio on a continuous scale (Pachella, Fisher, & Karsh, 1968; Wickelgren, 1977).

	Objective A	Objective B
Optimisation of objective A	Positive effect	Negative effect
Balance between objective A and B	Neutral effect	Neutral effect
Optimisation of objective B	Negative effect	Positive effect

Table 3.1: Multi-criteria analysis of a trade-off decision

A trade-off is often visualised within a graph, like in figure 3.1. Within this graph, it is visible that objective A decreases at the cost of objective B and vice versa.

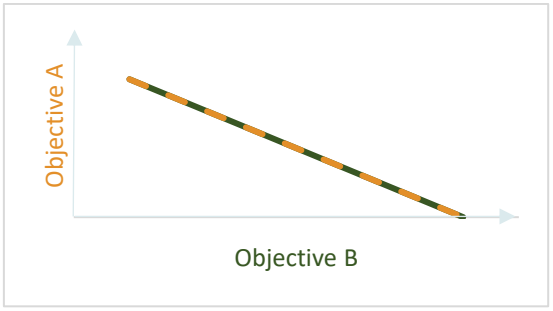


Figure 3.1: Graphical representation of a trade-off

In table 3.1 and in figure 3.1, two objectives are considered within the example trade-off. Such trade-off can also exist for three or more objectives. Within the speed-accuracy trade-off, only two objectives are considered: speed and accuracy. Therefore, only the trade-off between two objectives will be discussed in this research.

3.2.2 Optimum of a trade-off

An optimum can be identified that defines the distribution between the objectives that is most optimal for the specified situation (Jonkman, Vanure Gelder, & Vrijling, 2003). Such optimums can be defined intuitively, but can also be defined by extensive calculation (Da Silveira & Slack, 2001; Förster et al., 2003; Keramati et al., 2011; Marshall et al., 2006). Such an optimum can be found based on information but does not include different perspectives on the position of this optimum. Within organisations, the challenge arises within this approach to identify the optimum within a trade-off and to carry out this decision (Da Silveira & Slack, 2001; Skinner, 1969).

3.2.3 Trade-off as an agent's choice

In a trade-off decision, a ratio is chosen between two or more objectives by an agent. Often, for this ratio an optimum cannot be found when this optimum is unknown and different agents within the process have a different perception about the position of this optimum (Pendse & Wyckof, 1974).

A process in which a decision is made can consist of multiple steps that are executed by different agents. Each agent has its own influence in the trade-off that is made during the process (Klijn & Koppenjan, 2016). Agents that operate within an organisation; cooperation and interaction between agents leads to a joint trade-off between objectives (Enserink, Kwakkel, Bots, Hermans, & Thissen, 2010; Klijn & Koppenjan, 2016). To understand how a trade-off is made by agents, a model will be introduced in next paragraph 3.3.

3.3 CONCEPTUALISATION

To identify the effects of velocity on a trade-off, a model can be used to identify factors that lead to a trade-off. Da Silveira and Slack have defined a model in which factors are defined that identifies factors that lead to a trade-off between objectives. The model of Da Silveira and Slack consists of three factors, which are the *base,* the *sensitivity* and the *pivot* (2001). In figure 3.2, these elements are visualised.

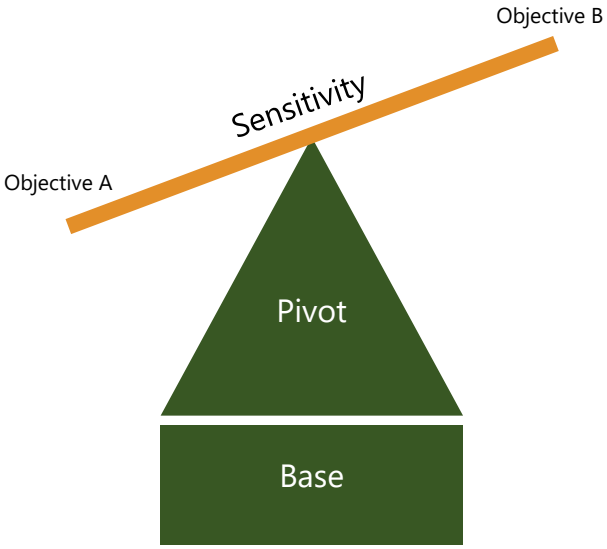


Figure 3.2: Factors of a trade-off

The three factors of the model of Da Silveira and Slack influence the height of the objectives that can be achieved in a process, as can be seen in figure 3.2. The base within the model defined by Da Silveira and Slack consists of the resources and capabilities that are available during the process. The pivot consists of the attributes that define the capacity to use the available resources and capabilities towards a contribution to the set objectives. The change that an increase in one objective brings to another objective is the sensitivity of the trade-off. This sensitivity is often constant within an organisation, according to Da Silveira and Slack. Further description of these three elements of the model of Da Silveira and Slack can be found in appendix C.

The model is constructed by making use of cases within the manufacturing sector. The trade-off model as defined by Da Silveira and Slack (2001) can be useful to understand factors that influence the outcomes of a trade-off decision. Although, some elements require some adjustments to employ the model within this research. The model of the trade-off that is described does not include the influence of the behaviour of an agent, although this element is relevant within many trade-offs (Scheutz & Sloman, 2002) . The model of Da Silveira and Slack should be adjusted to be applicable and employable for the research to the effects of velocity to the trade-off between speed and accuracy[2]. This specific trade-off between speed and accuracy will be introduced first.

[2] See paragraph 5.2.1

3.4 SPEED AND ACCURACY

3.4.1 Speed

The speed of the process defines the lead time of a process, which defines how much time it takes from the moment of data capture until the use of the outcomes of the process. Speed of the process should be distinguished from information velocity, which is the speed of information.

3.4.2 Accuracy

Accuracy can be described as the degree to which something is exact or correct (Cambridge English Dictionary, 2020). Within the context of an information process, the accuracy of the outcomes can be defined as the exactness and the precisions of the outcomes of the process.

3.4.3 The speed-accuracy trade-off

A common trade-off within processes that are executed by agents is the trade-off between the speed of the process and the accuracy of the outcomes (Beilock, Bertenthal, Hoerger, & Carr, 2008). An agent can make a choice to trade increases in speed for decreases in accuracy and vice versa (Wood & Jennings, 1976). This trade-off exists because of limited cognitive human capacities; it takes time for a human to process information that can lead to more accurate actions (Bogacz, Wagenmakers, Forstmann, & Nieuwenhuis, 2010; Heitz, 2014). If an agent speeds up the process, the accuracy of the outcomes of a process is likely to decrease. If an agent wants to execute a task with high accuracy, it is likely that this task will take longer compared to using a low level of accuracy. When the speed within a process is considered more important than the accuracy of the outcomes of the process and therefore is emphasized, it is likely that this emphasis on speed goes along with decreased focus on the accuracy of the outcomes of the process. If the emphasis of a process that is executed is on the accuracy of the output of the process, it is likely that this emphasis on accuracy goes along with decreased focus on the speed of the process (Zakay, 1993). How and why this trade-off is made is an area of research that has already been researched for a long time (Woodworth, 1899). The trade-off within a graphical representation is visualised in figure 3.3.

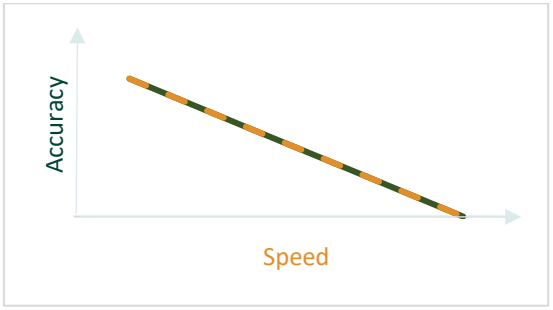


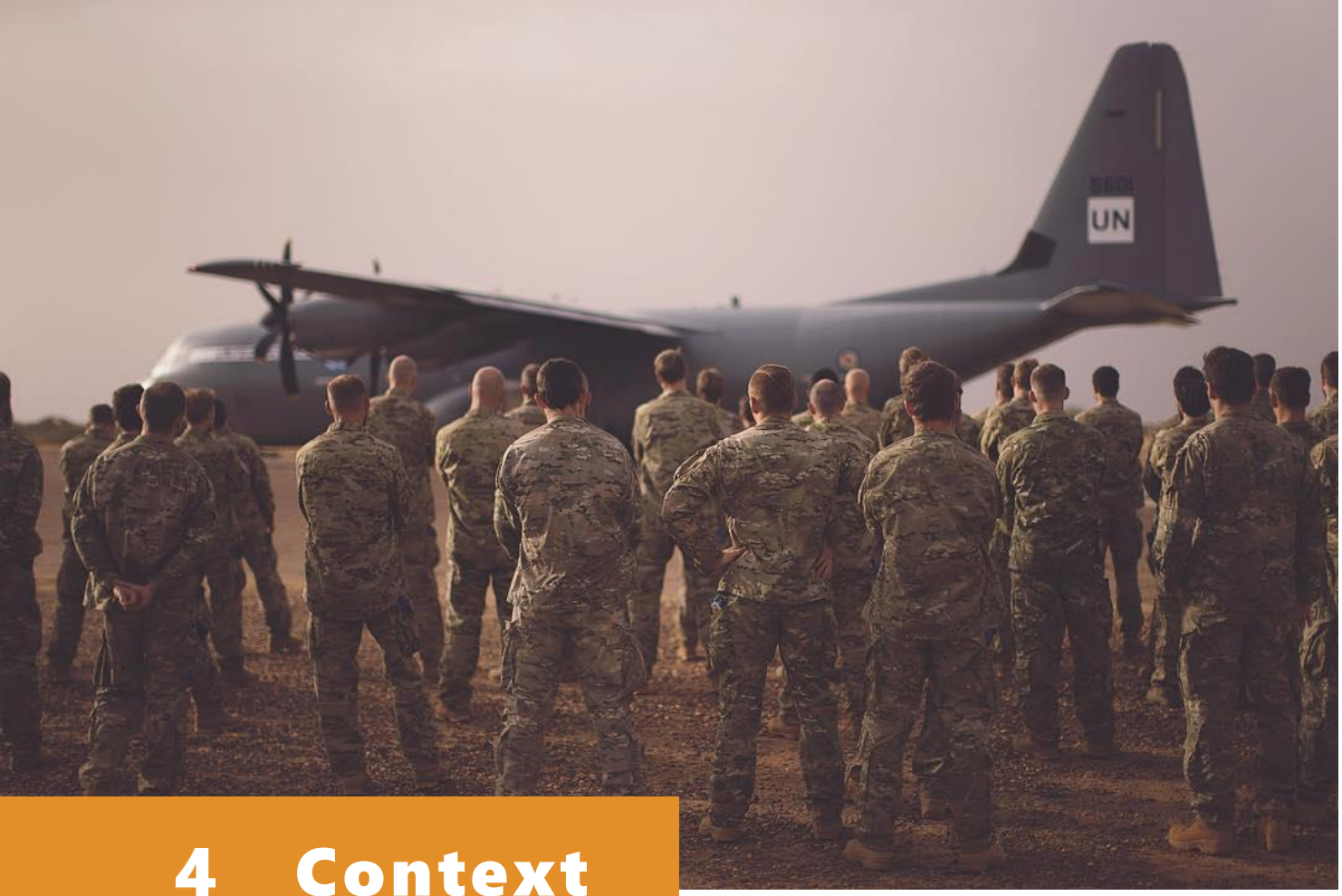
Figure 3.3: Graphical representation of a trade-off between speed and accuracy

Factors influence how a trade-off is made. Factors that are identified that influence a trade-off are a base, a sensitivity and a pivot (Da Silveira & Slack, 2001)[3].

3.5 CONCLUSION

Within a process, an agent makes a decision about a ratio between speed and accuracy to use within the process. Within a process, it is likely that speed can be increased at the cost of accuracy and vice versa. This decision can be approached by a model that consists of multiple factors that lead to a ratio between the objectives and a sum of the total height of the levels of the two objectives: speed and accuracy. These factors are the sensitivity, the pivot and the base.

[3] See paragraph 3.3. These factors will be further discussed in paragraph 5.2.1.



4 Context

4.1 INTRODUCTION

The trade-off that is made between speed and accuracy is made within a context. Within this chapter the institutional context will be introduced and the process in which decisions are made will be discussed. The specific contextual factors of the client will be further discussed in the section 'Case' in chapter 8 and 9.

4.2 INSTITUTIONAL CONTEXT

The institutional context is the definition of contextual factors that influence the choice of the agent within the process (Hodgson, 2006). Within the context of this research, the institutional context is defined by the decision-making process in which trade-offs are made and the organisation, which is the organisation of the client.

The decision-making process is the process in which information is gathered, processed and analysed to support the decision that is made by a decision-maker. In this decision-making process, constantly trade-offs between speed and accuracy are made that define the lead time of the process and the accuracy of the information that is used by the decision-maker. The institutional context of an agent influences the decision an agent makes. This context defines e.g. legacy and rules: formal and informal (Hodgson, 2006). Such legacy and rules can be described as e.g. a job description, operating procedures, deadlines, or the method of information-sharing between agents that influences the transparency (Klijn & Koppenjan, 2016).

4.3 THE DECISION-MAKING PROCESS

4.3.1 Decisions

A trade-off is a decision. According the Cambridge Dictionary, the definition of a 'decision' is a choice that is made by an actor after considering multiple options (Cambridge Advanced Learner's Dictionary

& Thesaurus, 2019). Such a decision is considered a choice which is made by an actor which is aware of at least two different actions that can be taken (alternatives), can make a prediction of the consequences of the different actions (expectations) and has an idea of the value of the expected outcomes (preferences). Decisions can be conscious choices, but many decisions are also made unconsciously and intuitively (Simonson, 2005). The trade-off an agent makes can be defined as the behaviour of the decision-making agent (Lewin, 1939).

4.3.2 Information

To define a decision-making process, it is necessary to define the concept of information which is created during the decision-making process. A definition that is constructed by Mason & Mitroff based on Ackoff is '*the knowledge for the purpose of taking effective action*' (1973). Information can be described as the foundation of knowledge which should support the decision-maker in deciding.

There are different methods to approach the decision-making process. Within this research, the rational and the non-rational perspective will be discussed. Within a rational approach, the decision that is made by the decision-maker can be reasoned back to the available information to the decision-maker (Elbanna, 2006). Within a non-rational approach, the information can influence this decision of the decision-maker, but other factors are influencing the decision-maker too. Within this perspective, each agent has its own point of view, interests and perceptions about the decision to make. With a perspective of a non-rational decision-making process decisions are not just defined by the information that is created in the decision-making process, in contrast to the rational approach (van der Voort et al., 2019). Both perspectives to decision-making will be discussed within next paragraphs.

4.3.3 Rational Decision-Making

The decision-making process is a process in which information is gathered, analysed, communicated to inform decision-makers. Within a process approach, the decision-making process can be divided into steps. Multiple papers have described the process from data gathering to decision-making into multiple different steps. Some of the methods emphasize the use of automatic algorithms, like Sagiroglu and Sinanc (2013), others emphasize the participation of the public (Renn, Webler, Rakel, Dienel, & Johnson, 1993), others on the optimisation of the outcomes (Wang, Huang, & Dismukes, 2004). Many researchers defined the decision-making process within the context of (large) datasets; five of these will be discussed and used as a base for conceptualising a decision-making process that will be used as a starting point for this research. The agent-dependent perception of the decision-making agent is not considered in the rational decision-making approach.

Philip Chen & Zhang (2014) have defined the decision-making process from data to decision-making into five steps, as can be found in table 4.1. Huang, Lan, Fang, An, Min & Wang (2015) have definen similar steps but add a prior step: 'formulation of question'. Klievink, Romijn, Cunningham & de Bruijn (2017) show a different perspective of four steps. Janssen, Van der Voort & Wahyudi (2016) define similar steps as Klievink et al., in contrast to Baldassarre (2016) which has defined seven steps: he splits the data analytics process into three subprocesses and adds 'automating the analysis' as a final step to the process. Although, this last step is part of the meta-process and will therefore not be further discussed. The different perspectives are listed in table 4.1.

Steps	Philip Chen & Zhang (2014)	Huang, Lan, Fang, An, Min & Wang (2015)	Klievink, Romijn, Cunningham & de Bruijn (2017)	Janssen, Van der Voort & Wahyudi (2016)	Baldassarre (2016)
1		Formulation of question			Research goal
2	Data recording	Data collection	Data collection	Data collecting	Data retrieval

3	Data cleaning, integration and representation	Data storage and transferring	Data combination	Data preparing	Data preparation
4	Data analysis	Data analysis	Data analytics	Data analysing	Data exploration
					Data modelling
5	Data visualization and interpretation	Report and visualization			Presenting results
6	Decision-making	Evaluation	Data use	Decision-making	

Table 4.1: Decision and information process perspectives

By means of table 4.1, six different steps can be distinguished which will be discussed in the next paragraphs. These perspectives will be compared and combined which have led to one comprehensive process of the steps that are visualised in figure 4.1. The steps of the rational decision-making process will be further discussed in appendix D.

Figure 4.1: The sequential decision-making process

4.3.4 Non-Rational Decision-Making

Within many organisations, the decision-making process is defined as a sequential process as described in paragraph 4.3.3. In practice, the decision-making process is often executed differently (van der Voort et al., 2019). In addition to the rational approach to the decision-making process as discussed in previous paragraph, other more political approaches are defined to address and understand the decision-making processes. The rational decision-making process is solely based on objective information, while non-rational decision-making includes the different perspectives and choices of agents (Bots, van Twist, & van Duin, 2000; Coleman, 1990; Enserink et al., 2010; Klijn, 1997; Ostrom, Gardner, & Walker, 1994; Sabatier, 1988; Scharpf, 1997). The actual process in which decisions are made is often not structured and not executed within sequential steps. Multiple models are constructed to get hold of a non-rational decision-making process. Example of such models are the garbage can model (Cohen, March, & Olsen, 2012; Olsen, 2001), the stream model (Pauly, 2001) and the rounds and arena model (Van Bueren, Klijn, & Koppenjan, 2003) which each emphasise the influence non-rational factors can have on decisions that are made within processes.

Within most decision-making processes, multiple actors are involved in executing the decision-making process and contribute to a (sub)process within this process (van der Voort et al., 2019). Agents have different values, different resources and different perspectives within the network in which the decision-making process is executed. These factors lead to different objectives and to different perspectives in how to achieve these objectives (Hermans, Cunningham, Reuver, & Timmermans, 2018). When a decision-making process includes multiple actors with each their own perspective, the process as described in paragraph 4.3.3 is not conducted in a simple straightforward way, but is often an incremental process that includes multiple iterations and decisions are based on perceptions instead of just information (Enserink et al., 2010; Hermans & Cunningham, 2013; Klijn & Koppenjan, 2016; Olsen, 2001).

4.3.5 Speed-accuracy within non-rational decision-making

Within the decision-making process, trade-offs are made constantly about the execution of the process. Speed-accuracy trade-offs can be made by different agents within the same decision-making process. If the process is executed quickly, the lead time is short and a fast decision can be made, but the accuracy of information is low. If information is gathered and processed until a perfect accurate answer, the lead time is likely to be very high. A trade-off between the speed of the decision-making process (or decision speed) and the accuracy of the decision (through the information) is identified (Zakay, 1993). This trade-off can be defined as a multi-criteria decision which is defined in table 4.2.

	Speed of the process	Accuracy of the outcomes
Increase the speed of the process	Positive effect	Negative effect
Increase the accuracy of the outcomes	Negative effect	Positive effect

Table 4.2: Multi-criteria analysis of the speed and accuracy of a process

Creating actionable knowledge with a high accuracy takes time. To create maximum accuracy, a certain amount of time is needed. Velocity could lead to a higher accuracy of information (Hofmann, 2017), but it is not sure whether this velocity contributes to a shorter lead time of the whole information process. In many cases, the speed by which a decision can be made is also relevant, besides the accuracy of the decision (Eisenhardt, 1989). In such cases, a trade-off is made between speed and accuracy. The speed of the information process determines the total lead time of the process.

The decision-making process is a process that is executed by agents. Every agent in the process makes a trade-off about how to execute its task, based on the perception and values of the agent and influenced by the institutional context (Braun & Guston, 2003; Buchanan, 1988; Jensen & Meckling, 1976).

4.4 CONCLUSION

Speed-accuracy trade-offs are made within a context. This context consists of contextual factors that influence how these trade-offs are made. The process context of this research is the decision-making process. Agents that operate within this process make speed-accuracy trade-offs within this process to create fast and accurate results. This decision-making process is often structured within organisation, although the process is often executed less sequential because agents that operate within the process have different perceptions.

5 Research Framework

5.1 INTRODUCTION

Within chapter 2, 3 and 4, the sensitising concepts are discussed. These theories are relevant and give direction for the case study that will be conducted. The subject of research is the influence velocity has on the trade-off that is made between speed and accuracy. This is researched within a context: the decision-making process within the organisation of a client. These contextual factors can be described as the institutional context that influences the speed-accuracy trade-off.

5.2 INTEGRATED FRAMEWORK

Within chapter 2, the concept of information velocity is discussed and described. Information velocity is increasing, and this change affects the decision-making process of institutions and therefore the decision-making quality of these institutions.

As discussed in chapter 2 and 4, velocity is likely to affect the decision-making quality. One aspect of decision-making is the trade-off that is made within the decision-making process between speed and accuracy. The speed-accuracy trade-off is made by agents that operate within (a sub-process of) the decision-making process. This context will affect the trade-off between speed and accuracy, besides velocity, and therefore this context should be understood to understand the effects of velocity within the context.

5.2.1 Translation of model

The model of Da Silveira and Slack as introduced in paragraph 3.3 will be adjusted to be usable for this research; the behaviour of an agent is introduced into the model. Translations are made to de model of Da Silveira and Slack to be usable for addressing factors that lead to the speed-accuracy trade-off, including behaviour. An overview of this translation is presented in table 5.1.

Factors	Model of Da Silveira and Slack	Elements	Translation to Research Model	Characteristics	Examples
Base	Content of the operation	Resources Capabilities	Requisites	- Present or absent - Discrete factor - Can change during the process	Information
Sensitivity	Function	Change one objective brings to the other objective	Change one objective brings to the other objective, including capabilities	- Value of elasticity - Continuous factor - Is constant during the process	Expertise of agents
Pivot	Effectiveness with which the content of the operation is deployed	Attributes	Twofold: - Efficacy of capacity - Choice of agent how to balance the trade-off	- Value of efficiency - Continuous factor Can change during the process	- Concentration of agent - Motivation of agent - Preference of agent

Table 5.1: Overview of research methods and type of data that is gathered

Within the next paragraphs, the introduced model in paragraph 3.3 will translated to be useful for this research to address the speed-accuracy trade-off.

5.2.1.1 *Base*

According Da Silveira and Slack the base consists of the capabilities and resources that are available during the process[4]. Within this research, the distinction between capabilities and resources will be made, since the resources are considered the essential element that is needed to conduct the process, while capabilities can contribute to a higher sensitivity between objectives.

Within this research, the base that leads to the speed-accuracy trade-off will be identified as the elements that are essential to conduct the process and to achieve some speed and accuracy: the requisites. The base is a discrete factor that leads to enabling or disabling the process. If these resources are constant through the process, the base is constant too. If all elements of the base are available, the process can be executed, if not all elements of the base are available, the process cannot be executed.

5.2.1.2 *Sensitivity*

The sensitivity of the speed-accuracy trade-off is the change an increase in speed brings to the level of accuracy and vice versa[5]. The sensitivity defines how much accuracy to the outcomes can be added when speed is decreased and how much time it saves to decrease accuracy. Within the model of Da Silveira and Slack, this sensitivity is presented a fixed relation within an organisation. This means an increase in speed would always lead to a fixed decrease in accuracy, although this implementation does not seem applicable within the speed-accuracy trade-off; analysis capacities may differ amongst processes. Within the speed-accuracy trade-off, the sensitivity defines the speed by which accuracy can

[4] See also paragraph 3.3 and appendix B
[5] See also paragraph 3.3 and appendix B

be achieved. The sensitivity between speed and accuracy is considered to differ amongst different cases (Beilock et al., 2008). This would lead to a definition of sensitivity within this research that is the capacity to create accuracy within time; the elasticity between speed and accuracy. The capabilities that are part of the base within the model of Da Silveira and Slack is translated from the factor base to the factor sensitivity within this research. An example of sensitivity within this approach is the expertise of agents (Beilock et al., 2008). The sensitivity of the speed-accuracy trade-off is considered constant during a process.

5.2.1.3 *Pivot*

The pivot is described by Da Silveira and Slack as the efficiency of the use of resources and capabilities that lead to certain heights in the trade-off. Within this research, the pivot is defined as the deployment of the available resources that are part of the sensitivity and the base into the objectives. A major element of this pivot is the *behaviour of an agent* in the process. The factor pivot is considered to fluctuate through a process; behaviour (which includes choices) of agents can also fluctuate within a process. Such non-constant elements are often subjective to the behaviour of the agents within the speed-accuracy trade-off.

Another aspect of the pivot will be introduced for this research: The balance that is chosen between the level of speed and the level of accuracy which is the choice of the agent, which is made conscious or unconscious (Braun & Guston, 2003; Buchanan, 1988; Di Paolo & Iizuka, 2008; Page, 2008). Therefore, the pivot is twofold: It leads to the balance that is chosen and it influences the change in total levels of the objectives that are achieved in a process.

The pivot of a trade-off is defined by the agent that makes the trade-off. Examples of elements of the pivot are concentration, motivation, preference, etc. The pivot that influences the speed-accuracy trade-off is not considered constant during a process.

5.2.2 Research approach and model

The model described in previous paragraph 5.2.1 can be used to address the effects velocity will bring to the trade-off between speed and accuracy. By identifying the effects of velocity on the factors that lead to a trade-off, the effects of velocity on the trade-off between speed and accuracy can be addressed; the model functions as a provider for intermediate variables to address the trade-off itself. The introduced model and the research question as described in paragraph 1.6 should be integrated to use the model to address the effects of velocity on the trade-off between speed and accuracy. By doing this, the effects of velocity on the factors of the model that lead to the trade-off will be analysed. The institutional context in which trade-offs are made should be addressed too by addressing the context of the elements of the factors of the model. A visualisation of the integration of the research approach as described in 1.5 and the model that can be used to address this trade-off can be found in figure 5.1.

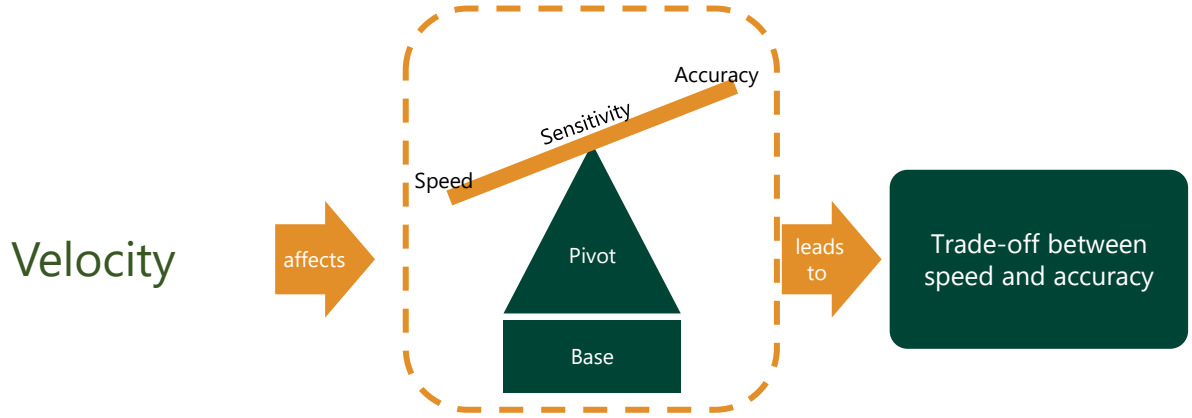


Figure 5.1: Model and research approach

Different elements within this combined research framework can be distinguished. These elements are:

- Velocity of the information of the process
- The institutional context in which trade-offs between speed and accuracy are made
- The trade-off between speed and accuracy
- The model to address how trade-offs are made between speed and accuracy
    - The base within a decision-making process that influences the speed-accuracy trade-off
    - The sensitivity within a decision-making process that influences the speed-accuracy trade-off
    - The pivot within a decision-making process that influences the speed-accuracy trade-off
- The relation of the factors of the model to the trade-off between speed and accuracy
- The effects of velocity on the factors of the model

5.2.3 Elements of research approach and model

By understanding the elements of the research approach, the effects of velocity on the trade-off between speed and accuracy, via the model, can be addressed. Each of the elements will be shortly described.

5.2.3.1 *Velocity of the information process*

The velocity is the independent variable of this research. This variable should be measured to identify the changes within this variable to be able to identify the effects of this variable on other variables. How this variable should be measured will be discussed in paragraph 5.3.1.

5.2.3.2 *The institutional context in which decisions are made*

The institutional context is the context in which empirical research is conducted and data is gathered to create insights to answer the main research question. How to address the institutional context will be addressed in paragraph 5.3.2.

5.2.3.3 *The trade-off between speed and accuracy*

The trade-off between speed and accuracy is the dependent variable of this research that is assumed to be influenced by velocity. How trade-offs are made can be measured by measuring the levels of speed and accuracy, but why these trade-offs are made this way will be addressed by using the factors of the model. How the trade-off itself will be measured is discussed in paragraph 5.3.3.

5.2.3.4 *The model*

The model consists of three factors, which are the sensitivity, the base and the pivot. The data by empirical research will be addressed by making use of the model and its factors. The model will be placed within the institutional context by which the factors are influenced and addressed. The model with its factors within this research is a proxy to address and to understand the actual trade-off that is made by agents. The factors of the model are operationalised in paragraph 5.3.4.

5.2.3.5 *The relation of the factors model to the trade-off*

The model will be used to understand how trade-offs are made. The relation between the model and the trade-off is addressed within theory in paragraph 3.3, paragraph 5.2.1 and appendix C.

5.2.3.6 *The effects of velocity on the factors of the model*

Towards addressing the main research question, the relation between velocity and the factors of the trade-off will be analysed. These effects will be addressed by making use of the model that is used to create an understanding in the factors that lead towards a trade-off. How the effects of velocity on the factors of the model can be addressed is discussed in paragraph 5.3.5.

To analyse the effects of velocity and institutional context on the trade-off that is made between speed and accuracy, the research elements should be operationalised. This will be discussed in next paragraph 5.3.

5.3 OPERATIONALISATION

The effects of velocity on the trade-off between speed and accuracy will be investigated within a certain context by empirical research within a case study. To address the effects of velocity on the speed-accuracy trade-off, the approach as described in 5.2 is used. This approach consists of several elements that each should be operationalised.

5.3.1 Velocity

Velocity is the independent variable of this research. To analyse the effects of this velocity on the speed-accuracy trade-off, the velocity of the decision-making process of the organisation should be measured. The definition of information velocity as defined in this research[6] is the speed at which data and information enters the process of the agent, the mode at which information flows and the volatility of information.

The most accurate method to measure information velocity is to measure the amount of information that comes into the process of the agent per time frame. The identification of the second aspect of information velocity is the identification of the mode at which information enters the process: within batches or as a continuous flow. The process is considered continuous when information is received constantly and the amount of information has the same order of magnitude during the process, while in case of a batch-wise sharing method the amount of information that is received in the process has different orders of magnitudes and most moments no information is received. The last aspect of information velocity, volatility, can be measured by measuring the period the information is valid and relevant that enters the process.

The velocity of information that comes into the process can also be analysed through the perception of agents that operate within a process. By interviewing agents that operate within the decision-making process of an organisation, insights can be gathered about the (perceived) speed of information coming into the process, the mode by which information is shared and the volatility of information. By analysing this velocity by interviews, the outcomes are coloured by the perceptions of the agents. By

[6] See chapter 2

understanding the institutional context in which the agents operate, more insights can be gathered about the velocity of the context of the agent, especially how this velocity is perceived.

5.3.2 Institutional context

To measure the institutional context of an agent that affects the trade-off that is made between speed and accuracy, the relevant elements within the institutional context should be identified. Examples of such elements are the organisational structure in which an agent operates, the identification of values and mission that drive an organisation, the processes by which the organisation operates, responsibilities and scope of the agent and the resources that are available to an organisation that are likely to affect the speed-accuracy trade-off.

5.3.3 The speed-accuracy trade-off

The trade-off that is made between speed and accuracy is the dependent variable of this research and should therefore be measured. This measurement can be done in a quantitative way or in a qualitative way. Both will be discussed in next paragraphs. A quantitative approach and a qualitative approach can re-enforce each other. Outcomes of the qualitative part of the research can lead to insights in things to measure during quantitative results and can bring an explanation or confirmation of the results of the quantitative outcomes. Quantitative results can give a confirmation and validation of qualitative results.

5.3.3.1 *Quantitative measurement*

Speed

The speed of a process can be measured in a quantitative way. This can be measured by the total duration of the process in e.g. minutes, which is the time that is spent on a process. A challenge that arises from this type of measurement within the decision-making process of organisations, is that the start and the end of a process should be defined and be a clear moment in time.

Another method to measure the speed of a process is by empirical observation on an ordinal scale, for example by the method as described by Likert (1932). Within this method, the speed of a process is measured through the perception of the observant and levels are assigned to these perceptions on a scale. A baseline is needed to assign values to the speed that is conducted within a process, the researcher should be acquainted with the average work speed. The speed of a process can be identified through empirical observation. Human action can be identified as very slow (level=1), or as very fast (level=5).

Accuracy

The accuracy of a process can be measured by the numbers of mistakes that are made by the operating agents. By counting mistakes that are made, an appreciation of the accuracy of the process can be assigned to a process. A challenge that arises from this type of measurement is the identification of mistakes by the researcher. The researcher should have a deep understanding of the process and the outcomes of the process to identify and understand mistakes in order to get an understanding of the accuracy of the process.

The accuracy can also be measured by an ordinal scale as perceived by the observant by observing the acts of the subjects. Also, a baseline is needed to assign values to this accuracy. Accuracy can be appreciated by observing agents in their behaviour. The accuracy of a process can be identified through empirical observation. Behaviour can be identified as not accurate (level=1), or as very accurate (level=5).

Trade-off between speed and accuracy

The trade-off that is made by agents within the decision-making process of an organisation can be identified by comparing the quantitative measurements of speed and accuracy.

Trade-offs that are made within different processes should be compared as well to understand how trade-offs are made. One of the challenges of this method of measurement, is that most processes are hard to compare. E.g. the workload of processes can differ, which is a determinant for both the used speed and the used accuracy. Like the measurement of the speed of a process, the number of mistakes should be put into context of the workload of the process as well. This number is often hard to quantify or to compare to the workload of other processes.

5.3.3.2 *Qualitative measurement*

A method to measure qualitatively the speed and the accuracy of a process is through conversation. The role of speed and the role of accuracy within the process can be understood through interviewing agents that have experience in conducting the decision-making process. By understanding the value that is assigned to speed and to accuracy and which value is emphasised by agents, the trade-off within the speed-accuracy can be addressed in a qualitative way. This method of measurement is always conducted through the perception of the agent that is interviewed.

5.3.4 The model: Factors that lead to a trade-off

The model as introduced in paragraph 3.3 and paragraph 5.2.1 consists of three factors: the base, the sensitivity and the pivot. These factors are put within the context of the speed-accuracy trade-off and operationalised in a quantitative and in a qualitative way in next paragraphs.

5.3.4.1 *Base*

The base is the factor of the speed-accuracy trade that consists of the elements that are essential to conduct the process. This base can be identified by identifying the elements that are part of the base. This can be done through interviews with agents and through an observation of the process.

5.3.4.2 *Sensitivity*

The sensitivity as a factor of the model that is used to understand how speed-accuracy trade-offs are made is the speed at which accuracy of results can be delivered. In figure 5.2 a graph of a trade-off between speed and accuracy can be found. The slope of the line can be defined as the sensitivity of the trade-off.

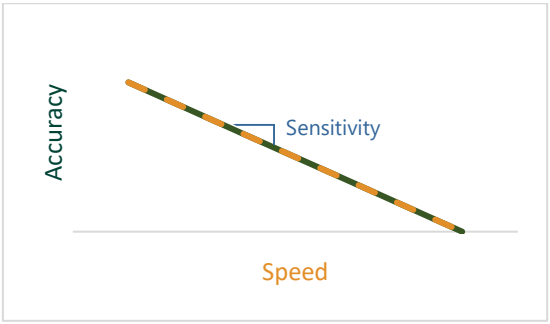


Figure 5.2: The sensitivity of the speed-accuracy trade-off

Levels of speed and accuracy can be mapped and compared to identify the sensitivity of a trade-off. If quantitative data is available about this trade-off, a quantitative measurement of the sensitivity can be done. Such quantitative data can consist of, e.g., measurements of process duration and mistakes that are made within a time frame. Another type of data that can be analysed to identify the sensitivity of a trade-off is ordinal data by data gathering methods such as Likert's approach as described in paragraph 5.3.3.1. The data that is generated by such ordinal methods will result in insights about the shape of the sensitivity bar, while the exact values of the sensitivity cannot be found.

The sensitivity of the speed-accuracy trade-off can also be addressed through the perception of agents by interviewing agents to understand their perspective about the speed at which information can be created to create a certain level of accuracy.

5.3.4.3 *Pivot*

The pivot factor is twofold: the pivot influences the sum of the total of the levels through the efficacy of the analysis capacity, but the choice that is made between speed and accuracy is influenced by the pivot too. The pivot of the model influences the actual heights of the values of the levels of the objectives that are achieved. The pivot of a trade-off is the factor of the trade-off that can differ through the process.

The pivot of a trade-off is hard to distinguish by the agent that makes the trade-off, since it is defined by its own behaviour. Of some of these elements of this the agent is aware, of other elements of this behaviour the agent is unaware. Through conversation by interviewing these agents, the elements the agent is aware of can be found, the elements the agent is unaware of cannot be addressed by such method. By observing agents within the process, the elements that are part of the pivot can be identified, both the elements the agent is aware of as the elements the agent is unaware of.

5.3.5 Effects of velocity on the factors of the trade-off

By analysing velocity, the institutional context and the speed-accuracy trade-off that is made by agents and combining these elements, insights can be created to address the main research question. By combining the insights of the identification of the elements that are part of the base, sensitivity and pivot with the insights into how velocity affects these factors, the effects of velocity on the trade-off can be discussed. These insights will be used to answer the main research question to address the effects of velocity on the trade-off that is made between speed and accuracy. The velocity of information affects the decision quality through the speed-accuracy trade-off.

CASE

6 Research approach

6.1 INTRODUCTION

Within the first part of this report, relevant concepts were discussed for a theoretical foundation for addressing the main research question:

'*What are the effects of information velocity on the trade-off that is made between speed and accuracy within the decision-making process?*'

The discussed sensitising concepts are *velocity* and *the speed-accuracy trade-off.* Also, the context of this research is discussed. To address the main research question, a case study is conducted to create insights in the effects of velocity on the trade-off between speed and accuracy. Data is collected from this case study to contribute to the *grounded theory* that will be constructed from a combination of existing theory and the data gathering. Within this chapter, the research approach to conduct the case study will be discussed.

The trade-off that is made between speed and accuracy is made within a certain context, influenced by velocity and other determinants. The context in this case is the decision-making process in which information is gathered and processed by multiple actors which lead to outcomes. To understand the effects of velocity on the speed-accuracy trade-off, these effects will be analysed by an empirical case study approach within a socio-technical system. This approach will be further introduced within this chapter. At first, the case at which the empirical research is conducted will be introduced. Sub-questions that are used to address the main research question are introduced and methods to address and analyse these questions are discussed as well in next paragraphs.

6.2 CASE INTRODUCTION

This research will be addressed by empirical research conducted at an intelligence organisation of the Dutch Ministry of Defence called JISTARC (Joint Intelligence, Surveillance, Target Acquisition &

Reconnaissance Commando). Within this organisation, this first five steps of the (rational) decision-making process as discussed in paragraph 4.3.3 are conducted to create intelligence during missions abroad. Within this process, multiple agents operate to create intelligence products and trade-offs between speed and accuracy and made constantly. The intelligence that is created by JISTARC is based on information. Increasing velocity of information coming into this process of JISTARC is likely to affect the speed-accuracy trade-offs that are made within JISTARC. These effects of information velocity on these trade-offs are researched.

6.3 RESEARCH SUB-QUESTIONS

In paragraph 1.6, the main research question is introduced (repeated in paragraph 6.1). To address this main research question, at first the sensitising concepts that are related to the main research question are introduced in chapter 2, 3 and 4. Based on these existing theories and on the context of the case in which this research will be conducted, several sub-questions are formulated to address the main research question by empirical research at the organisation JISTARC. The practical methods to address these sub-questions will be addressed in next paragraph 6.4. The sub-questions are described as follows, marked in figure 6.1 and will be discussed in next paragraphs:

1. What institutional factors influence the trade-off between speed and accuracy?
2. What is the base of the trade-off between speed and accuracy?
3. What is the sensitivity of the trade-off between speed and accuracy?
4. What is the pivot in the trade-off between speed and accuracy?
5. What is the influence of velocity on the factors that influence the trade-off between speed and accuracy?

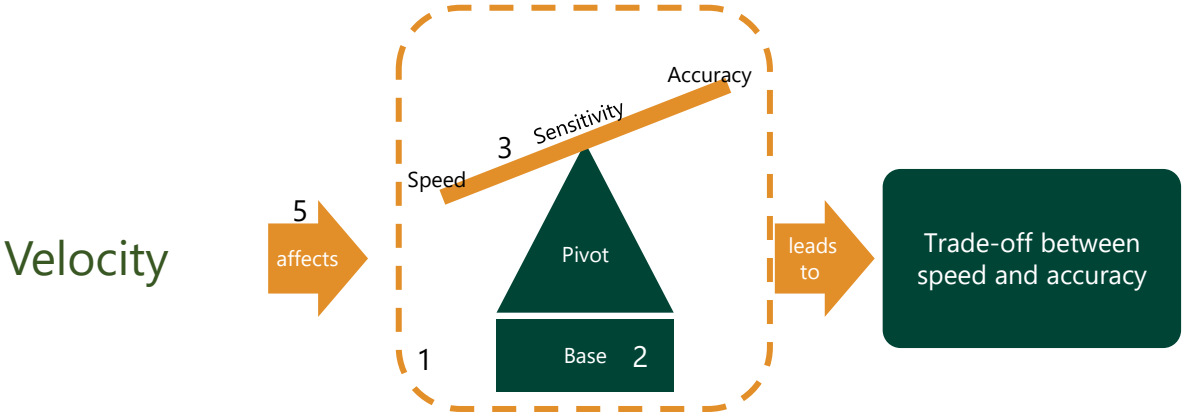


Figure 6.1: Model and research approach

6.3.1 What institutional factors influence the trade-off between speed and accuracy?

To understand the effects of the institutional context on the speed-accuracy trade-off that is made by the agent, the institution in which the agent operates should be analysed. Within this research, the institution that is analysed is the context in which agents of JISTARC operate. The mission, context, values and processes of JISTARC should be addressed to address the institutional context in which the research is conducted and in which the trade-off between speed and accuracy is made.

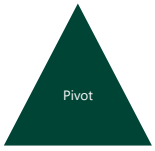
6.3.2 What is the base that influences the trade-off between speed and accuracy?

To understand the factors that lead to a trade-off and to understand the effects of velocity on these factors, the elements that are considered to be part of the base should be identified. Part of the base are the elements that are considered requisites for the process[7]. Within this sub-question, the base and its elements are identified.

6.3.3 What is the sensitivity that influences the trade-off between speed and accuracy?

The sensitivity that influences the trade-off consists of the elements that lead to the elasticity between speed and accuracy. Elements that are part of the sensitivity contribute to the capacity to transform accuracy into speed and vice versa[8]. The elements that are part of the sensitivity are considered to be constant during the process. Within this sub-question, the sensitivity and its elements will be identified.

6.3.4 What is the pivot that influences the trade-off between speed and accuracy?



The last factor that leads to a trade-off, the pivot, should be addressed as well. The pivot consists of the elements that define the efficacy of the capacity and the choices of agents in the process that lead to levels of speed and accuracy. These elements are considered to change during the process[9]. Within this sub-question, the pivot and its elements will be identified.

6.3.5 What are the effects on the factors that lead to a trade-off between speed and accuracy?

An understanding about the factors that lead to a trade-off is gathered within the three previous sub-questions. Within the last sub-question, the effects of information velocity on these factors will be identified.

6.4 METHODS

To understand the effects of velocity on the trade-off between speed and accuracy and to answer the (sub-)research questions, an empirical research study will be conducted within a case study at JISTARC. This approach is suitable, because it is an effective way to analyse certain behaviour and to identify and compare differences within the speed-accuracy trade-offs that are made by agents influenced by information velocity.

Two methods of empirical research are needed to understand the effects of velocity on the trade-off between speed and accuracy that is made by agents. To understand preferences and considerations of agents, interviews with agents are required. To understand the actual trade-offs that are made by agents, these trade-offs should be observed.

6.4.1 Client

To understand the effects of velocity on the trade-off between speed and accuracy, a specific case study will be used to analyse this issue. The case will be carried out within the client's organisation: an intelligence organisation of the Dutch Ministry of Defence. This client conducts decision-making processes: specifically, the information gathering process that precedes the decision. This information process is the main process and focus of this client. Within the organisation, different elements of the

[7] See paragraph 5.2.1.1
[8] See paragraph 5.2.1.2
[9] See paragraph 5.2.1.3

organisation conduct the information process with different levels of information velocity. Therefore, this client is very suitable for analysing the effects of velocity on the decision-making process.

Within next paragraphs, practical methods are addressed to answer the sub-research questions as introduced in previous paragraph 6.3.

6.4.2 Desk research

To understand the specific context in which the speed-accuracy trade-offs are made, it is important to understand the organisation of the client; this can be done by researching (digital) information. Specific decision-making processes are executed by the client; it is relevant to understand these processes and the procedures that are written down as work processes. By understanding determinants of the context of the client, the effects of velocity can be distinguished from the contextual influences on the speed-accuracy trade-off. By doing this, the analysis of the effects of velocity on the trade-off that is made between speed and accuracy can be conducted more accurate. Sub-question 1 and 2 will be addressed by conducting desk research.

6.4.3 Interviews

The experiences of agents within the decision-making processes will be researched by interviewing agents with knowledge and experience in conducting the decision-making processes within the context of the client's organisation. Interviews are effective to address the sub-questions by a qualitative approach. Two types of interviews should be conducted: open and semi-structured interviews. These two types will be further discussed in next paragraphs.

6.4.3.1 *Open interviews*

The open interviews should be conducted to get an understanding of the client's organisation and the context of the case in which this research will be conducted. These interviews should be done with people with expertise about the organisation of the client and with knowledge about processes and velocity of information within (different parts of) the organisation. By doing these interviews, knowledge can be constructed about the way of operation of the (parts of the) organisation and the velocity of information that is present within the (parts of the) organisation. A list of questions that should be addressed in open interviews can be found in appendix E. Sub-questions 1 and 2 will be addressed by this method of research. The findings of the open interviews can be connected to the findings of the semi-structured interviews.

6.4.3.2 *Semi-structured interviews*

To get an understanding of the trade-off that is made by agents between speed and accuracy, semi-structured interviews should be done with agents that have expertise in executing the information process and the process of analysis within the organisation. By doing this, insights can be gathered about how the trade-off between speed and accuracy is made by agents within the process. These semi-structured interviews should be done based on a form, which can be found in appendices F, G, (English), H and I (Dutch). Within next list, the sub-questions will be translated to interview questions as formulated within appendices F, G, H and I.

What institutional factors influence the trade-off between speed and accuracy?

- When did project A start? [10]
- Who gave you the assignment?
- How was the task described?
- With how many people did you work on project A?
- What was your role?

[10] Appendices X.1

- What were your responsibilities?
- What were the roles of the others?
- When was the project finished?
- Did you get a deadline to do the task? If so, who gave you that deadline?
- Except yourself, who were responsible for you completing the task in time?
- Did you get specific quality requirements for the task?

What is the data velocity within the process?

- Did you get the data and information to analyse within batches or continuously?
- If a subject was already analysed, but later more information came into the process about that specific subject, what did you do with this information?

How is the trade-off made between speed and accuracy by the agent?

- How did you make sure the task could be completed before the deadline?
- How did you make sure the task could be done with enough quality (possibly based on specific requirements)?

During the interviews, there should be room to discuss interesting perspectives addressed by the respondent that could lead to insights in one or more of the sub-questions. Why-questions are asked constantly to gather insights in the behaviour and the choices that are made by the respondent. If interesting insights are gathered through an unexpected subject, more will be asked about this subject. Because of the open character of the conversation, the interviews can be characterised as *semi-structured interviews* (Drever & Scottish Council for Research in Education, 1995).

6.4.4 Ethnographic research

To understand the behaviour of agents within the decision-making process, ethnographic research can contribute to an understanding of the practices within the decisions that are made by agents. The behaviour of agents can be observed within their daily context instead of observing these within a context that is created by the researcher. Ethnographic research can create insights that are not coloured by the perceptions of the agent that is subject to this research. Casual conversations are emphasized instead of the formal conversations as would be the case during interviews (Genzuk, 2003). By observing agents in their behaviour in the trade-off between speed and accuracy, first-hand empirical research can be conducted. The data that is gathered is directly observed by the researcher. Ethnographic research creates opportunities to measure the trade-off between speed and accuracy within a process by a quantitative approach, but also by a qualitative approach.

The ethnographic research will be designed based on the fundament of existing theories and academic literature which will create data that can be used as input for the theory to be constructed that addresses the main research question (Wilson & Chaddha, 2009). The form that will be used to conduct the ethnographic part of this research can be found in appendices I, J, K and L. All sub-questions can be addressed by using this type of data-gathering method. Within next list, the sub-question will be related to the observation questions as formulated within appendices I, J, K and L.

What institutional factors influence the trade-off between speed and accuracy?

- Are there specific requirements defined for the quality of the outcomes? [11]
- Who is responsible for the quality of the outcomes? [11]
- Is a concrete deadline defined? [12]
- Who is responsible for meeting the deadline? [12]

[11] Appendices G.1, H.2, I.1, J.2
[12] Appendices G.2, H.3, I.2, J.3

- When is the time constraint/deadline named? [12]

What is the data velocity within the process?

- When is data coming into the process? [13]

How is the trade-off made between speed and accuracy by the agent?

- When is the quality named? [14]
- When do quality and time seem to conflict? [15]
- When are the agents aware of the conflict between time and quality? [15]
- Does this conflict lead to tension between the different agents? [15]
- Are the agents experiencing this tension? [15]
- Who does experience this tension? [15]
- How is dealt with this tension? [15]
- Are agents consciously resolving this tension? If so, who? [15]
- Is the tension dissolved? [15]
- How is the tension resolved? [15]
- Where is the balance between speed and accuracy? [16]
- Why is the balance put there? [16]
- What are the levels of accuracy during the observation day? [16]
- What are the levels of speed during the observation day? [16]

Within each form, there is room during the observation to identify relevant insights within and besides the formulated sub-questions. All questions, except the last two questions about the levels of speed and accuracy during the day are aimed to gather qualitative insights about the trade-offs between speed and accuracy that are made by the agents and why these trade-offs are made in that way. Within the last two questions ('What are the levels of accuracy during the observation day?' and 'What are the levels of speed during the observation day?') quantitative data is collected about the heights of the levels of speed and accuracy. Within figure 6.2, the elements that are measured by quantitative measurement are marked within the model that is introduced in paragraph 3.3 and paragraph 5.2.1, which are the heights of the levels of speed and accuracy within the process.

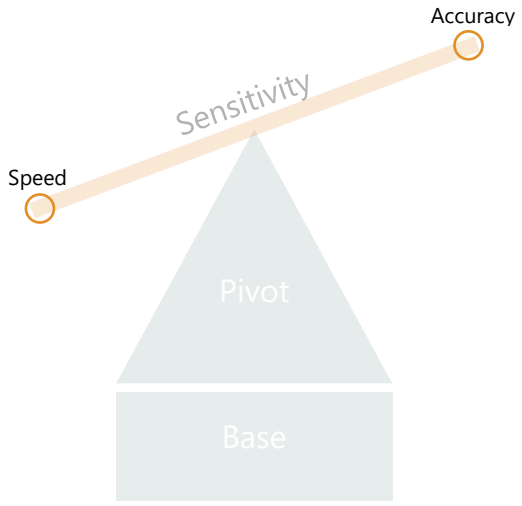


Figure 6.2: The location of quantitative measurement within the model

[13] Appendices H.1, J.1
[14] Appendices G.2, H.3, I.2, J.3
[15] Appendices G.3, H.4, I.3, J.4
[16] Appendices G.4, H.5, I.4, J.5

6.4.5 Overview

An overview of the sub-questions that are stated in paragraph 6.3 and the methods that will be used to address these sub-questions is given in table 6.1.

Sub-question		Desk Research	Open Interviews	Semi-structured Interviews	Ethno-graphic Research
1	What institutional factors influence the trade-off between speed and accuracy?				
2	What is the base of the trade-off between speed and accuracy?				
3	What is the sensitivity of the trade-off between speed and accuracy?				
4	What is the pivot in the trade-off between speed and accuracy?				
5	What is the influence of velocity on the factors trade-off between speed and accuracy?				

Table 6.1: Overview of sub-questions and methods

Within table 6.2, an overview can be found of the type of data that is collected within the different research methods.

Research method	Contextual insights	Qualitative data	Quantitative data
Desk research	Institutional context Relevant issues		
Open interviews	Institutional context Relevant issues		
Semi-structured interviews	Practice of the (small) intelligence process	How the trade-off is made between speed and accuracy (what is the base, sensitivity and pivot)	
Ethnographic research	Practice of the (small) intelligence process	How the trade-off is made between speed and accuracy (what is the base, sensitivity and pivot)	Levels of speed and accuracy

Table 6.2: Overview of research methods and type of data that is gathered

6.5 ANALYSIS OF THE RESULTS

The expected results from the semi-structured interviews and the ethnographic research should create insight in how trade-offs are made between speed and accuracy within the context of this research and what effects velocity has on this trade-off. To describe these effects, the model as discussed in paragraph 3.3 and paragraph 5.2.1 is used to address how the trade-offs are made.

Contextual insights, qualitative and quantitative data is gathered by making use of the three research methods: open interviews, semi-structured interviews and ethnographic research. The contextual insights are not reported, although the created insights are used to construct the research and interview questions as addressed in paragraph 6.4. Both qualitative and quantitative results will be combined to address the sub-questions as discussed in paragraph 6.3 and the main research question. This gathered data will be interpreted to identify the elements that are part of the base, the pivot and the sensitivity that lead to a trade-off.

An overview of the type of data that can be used to create insights in how trade-offs are made by making use of the model as discussed in paragraph 3.3 and 5.2.1 can be found in figure 6.3.

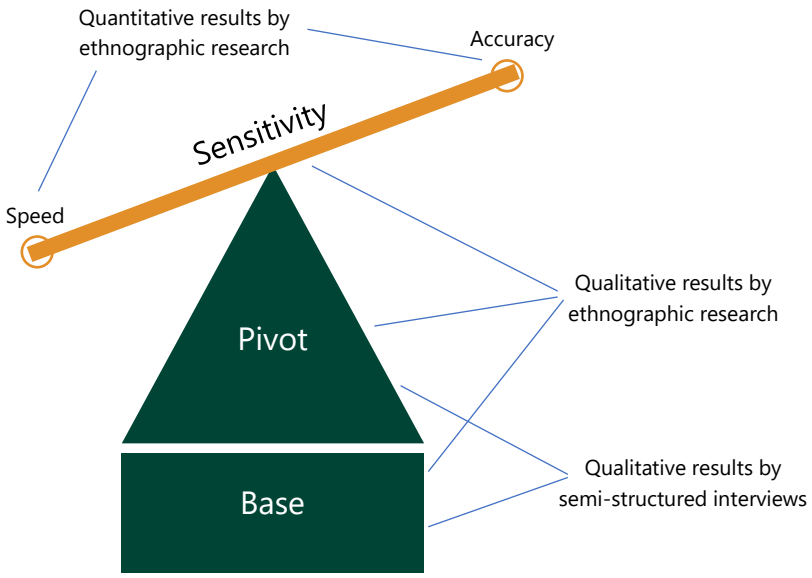


Figure 6.3: Overview of gathered data to identify factors of the model

Within table 6.3 an overview is given which gathered data can be used for which element within the model.

Concept element	Quantitative results by ethnographic research	Qualitative results by ethnographic research	Qualitative results by semi-structured interviews
Sensitivity			
Levels of speed			
Levels of accuracy			
Pivot			
Base			

Table 6.3: Overview of research methods and type of data that is gathered

6.6 CONCLUSION

The grounded theory method as introduced in chapter 1 will be further conducted by gathering data within a specific case at the client's organisation. The main methods of data gathering will be desk research, open interviews, semi-structured interviews and ethnographic research. Sub-questions are stated that will be addressed by these methods to identify factors that lead to a trade-off. Data that is gathered will be used to address the main research question by making use of a model based on a model of Da Silveira and Slack (2001) as described in paragraph 5.2. The sensitivity, the pivot and the base of the trade-off will be identified and described by making use of the gathered data.

7 Introduction to intelligence

On October 7th 2001 the US Army invaded Afghanistan after the attack on 9/11 on the World Trade Centre in New York (NOS, 2019). The US demanded the Afghan leaders to hand over the supposed responsible man for the attack, Osama Bin Laden, but the Taliban refused to do so (BBC, 2012). From 2002 on, the Dutch Army joined the US Army together with other NATO allies (BBC, 2012; Ministerie van Defensie, 2019b) to contribute to the peace enforcement mission in Afghanistan (Ministerie van Defensie, 2019e). In 2011, Osama Bin Laden was found and killed (BBC, 2012). From 2015 on, The Netherlands contributes to the NATO-mission called *Resolute Support* that aims to rebuild the Afghan army and police and the justice system of Afghanistan (Ministerie van Defensie, 2019b).

Many (Dutch) soldiers were killed during the operations in Uruzgan and Kunduz (NOS, 2010); Afghanistan is a dangerous place for soldiers to operate. In 2019, intelligence was found about the location of a Taliban leader. When soldiers were on their way to arrest this leader, the soldiers were ambushed. The enemy had received information about the soldiers being on their way to arrest their leader (Sondermeijer, 2019).

Information is essential for taking action and can create advantages during battle, secure the safety of soldiers and to find enemy leaders. The enemy gathers and possesses information as well. The new Dutch Defence Doctrine defines information as a source of power. Information can be of great value, own information should be secured and outsiders should not be able to gain access to important information (Ministerie van Defensie, 2019c).

During such missions like the mission in Afghanistan, intelligence is required for the commander to make informed decisions. Knowledge about the enemy, such as the location of enemy leaders like Osama Bin Laden and the Taliban leader can be created. Risks to safety can be mitigated by gathering information, for example by the identification of improvised explosive devices (IEDs). Such information is gathered by intelligence operators of JISTARC. Operators collect data and information in the field. By

analysing this data and information, intelligence is created towards an understanding about the situation the unit operates in. This can be done by e.g. describing geographic aspects, the weather, political situation, local economy, local culture and infrastructure (Berkhout, 2019).

8 JISTARC

8.1 INTRODUCTION

To understand the effects of data velocity on the trade-off that is made between speed and accuracy, a case study is conducted at the organisation of JISTARC: an intelligence organisation. This organisation is part of the Dutch Ministry of Defence, which will be discussed first. The Ministry of Defence conducts missions abroad, which will be discussed as well. The command and control process and the military decision-making process will be discussed to understand the context of the organisation of JISTARC. The organisation of JISTARC will be discussed hereafter, along with the context, the element and the mode of operation. Also, the values and objectives of JISTARC will be discussed.

8.2 MINISTRY OF DEFENCE

The Dutch Ministry of Defence is the governmental organization that is responsible to contribute to peace, freedom and safety in the Netherlands. The organization has three main tasks: 1) to protect the territories of the Netherlands and allies, 2) to promote (international) legal order and stability and 3) to aid in the case of disaster and/or crisis (Ministerie van Defensie, 2019f). The aim of the military is described by Gooren (2006) as follows:

"to conduct military operations in the field that will achieve planned strategic objectives and create the desired postconflict situation".

8.3 ORGANISATION OF THE MINISTRY OF DEFENCE

The Ministry of Defence is organized into several bodies. The organization chart can be found in figure 8.1. On the operational level, the organization of Defence is divided into 6 parts: The Royal Netherlands Navy, The Royal Netherlands Army, The Royal Netherlands Air Force, The Royal Netherlands Marechaussee, the Joint Support Command and the Defence Materiel Organisation. The Navy, Army,

Air Force and Marechaussee are part of the Armed Forces and these Armed Forces without the Marechaussee are called the Operational Commands.

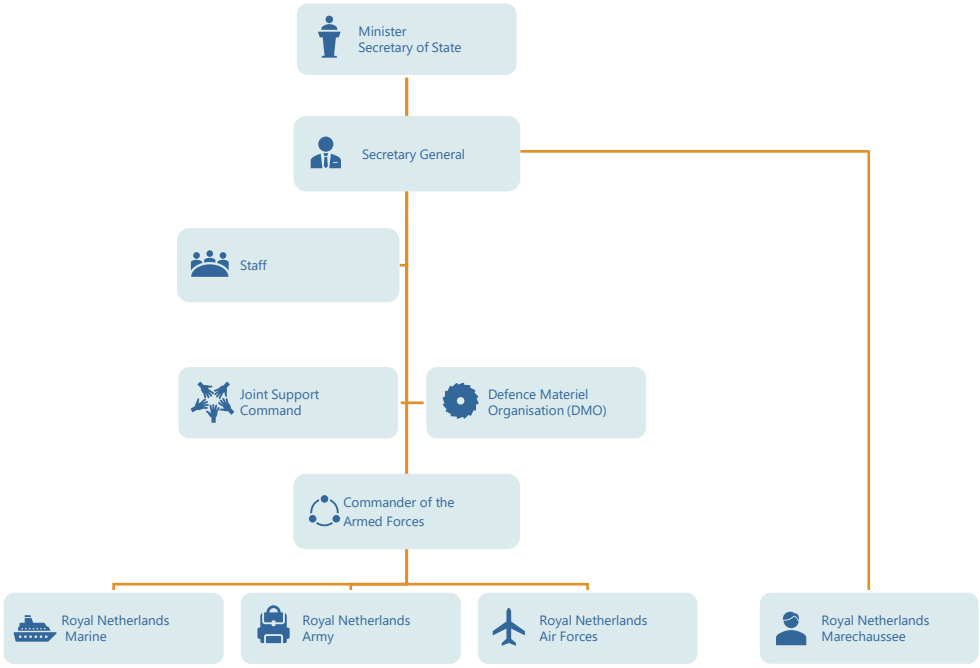


Figure 8.1: Organization Chart Ministry of Defence
From 'Over Defensie', by (Ministerie van Defensie, 2019d) (https://www.defensie.nl/overdefensie/organogram)

8.4 MISSIONS

Within the Dutch Military, the aim of missions abroad is to restore peace or to prevent conflict. Missions are organised by the United Nations, the NATO and the European Union. Dutch military operations can be categorized into three types: observer missions, peacekeeping missions and peace enforcement missions (Ministerie van Defensie, 2019e). Each of these types will be further described in next paragraphs.

8.4.1 Observer missions

During observer missions, unarmed soldiers are positioned in an area that used to be in a crisis. The aim is to control local parties whether they handle conform to peace agreements that were made (Ministerie van Defensie, 2019e).

8.4.2 Peacekeeping missions

During peacekeeping missions, Dutch soldiers are positioned in a current crisis area. The delegation is meant to be a neutral party that has a passive role in between the parties that are at war. The aim is to gain time, so a political or military solution can be found without escalating the situation or having many people to die. During these missions, it is important to have a good rapport with local authorities and to work close with them, even as with local NGO's (Ministerie van Defensie, 2019e).

From 2014 until 2019 the Dutch Ministry of Defence contributed to the mission called *Minusma* in Mali. The goal of this mission was to enforce peace in the area of Mali. Minusma was an organised mission by the United Nations. Around 1300 patrol rounds were made by Dutch soldiers to gather information about the situation for the headquarters of the operation in Bamako.

Example 8.1: Mission in Mali
Based on 'Missie in Mali' by Minsterie van Defensie (2020)

8.4.3 Peace enforcement missions

The peace enforcement missions are meant to force peace into an area in which multiple parties are in conflict. These missions are the only missions in which soldiers are allowed to use violence, even though they are not assaulted. The aim of such missions is short-term oriented (Ministerie van Defensie, 2019e).

8.5 ABOUT JISTARC

The case and client, the Joint Intelligence, Surveillance, Target Acquisition & Reconnaissance Commando (JISTARC) is a unit embedded within the Royal Netherlands Army, although it services all four parts of the Armed Forces (Van Westerhoven, 2011). **Joint** means the means the unit operates with personnel from all Armed Forces together. **Intelligence** is the product that is created by the unit. **Surveillance** is a method that is used by the unit to create intelligence and **Target Acquisition** is one of the goals and also a method. **Reconnaissance** is also a method that JISTARC uses to create intelligence (JISTARC, 2016).

Figure 8.2: Emblem of JISTARC

JISTARC was established in 2011 by merging all intelligence departments of the Operational Commands with the Tactical Air Reconnaissance Centre. By combining these bodies, it is expected to achieve a higher effectiveness and efficiency (Van Westerhoven, 2011).

The emblem of JISTARC can be found in figure 8.2. This emblem symbolizes the earth because the commando operates in the whole world, and a torch, which is an international symbol for intelligence organisations (Koninklijke Landmacht, 2019b).

JISTARC's responsibilities are to support operations instructed by the Commander of the Armed Forces and to support the Military Intelligence and Safety Service (MIVD) and the Operational Commands. They offer modules or components for the purpose of operational deployment by the Commander of the Armed Forces and to support these deployments They offer also their services for the purpose of National Operations (Koninklijke Landmacht, 2019a).

JISTARC contributes to the situational awareness and situational understanding of the Netherlands Armed Forces. JISTARC is responsible for gathering, analysing and communicating intelligence during missions (Ministerie van Defensie, 2019a). This includes human intelligence, mapping and operating different sensing techniques (Army Technology, 2011).

The process of JISTARC is a process that is all about information. Changing velocity of this information is likely to influence the process of JISTARC .

Figure 8.3: Tasks of JISTARC

"The 800 soldiers are stationed at the base in 't Harde, but they are everywhere where Dutch units operate – from Afghanistan to Mali. Before every operation, every commander of every unit consults the present JISTARC-man or -woman and before making a decision. ,,We are the suppliers of insights and supply the information comprehensible. Subcommander Hans adds:,, We decrease the uncertainty of a commander during an operation in a crisis area."

Example 8.2: The role of JISTARC
From 'Hapklare info voor de strijd' by K. Berkhout (2019)

8.6 CONTEXT OF JISTARC

There are several layers to distinguish within decision-making within the Dutch Ministry of Defence. Each layer has its own command and control process with their own intelligence processes. The military layers are the strategic layer, the operational layers, the tactical layer and the technical layer (Ministry of Defence, 2018). Within (non-military) organisational theories, the tactical and operational layer are reversed (Bilgen & Ozkarahan, 2004; McNair & Vangermeersch, 1998). Within military organisation these are arranged different, because tactical decisions should be made within the operational theatre. Within the operational theatre, decision-makers will have more insights in the local situation, so they are able to make a more informed decision.

Each of the military layers will be shortly described.

8.6.1 Strategic layer

Within the military strategic layer, decisions are made on country level. Decisions that are made by politics and the Commander of the Armed Forces are decisions that are made within the strategic layer. Examples of such decisions are which missions are carried out abroad and which type of (large) military materiel should be purchased. The MIVD (Militaire Inlichtingen en Veiligheids Dienst; the military intelligence and safety service) is the intelligence organisation that operates within the layer and supports the decisions that need to be taken on country level (Ministry of Defence, 2018).

Figure 8.4: Layers of decision-making within the Dutch Ministry of Defence

8.6.2 Operational layer

Within the operational layer, operational decisions are made. Which personnel and materiel are deployed, when and where, are decisions that are made within this operational layer. JISTARC intelligence capabilities can be used in this layer to analyse the needs that are needed during a mission (Ministry of Defence, 2018).

8.6.3 Tactical layer

Within the tactical layer, tactical decisions are made during missions. JISTARC support these decisions by their intelligence capabilities. Threat analysis is one of the main goals of intelligence in this layer, which is done by creating situational awareness (Ministry of Defence, 2018).

8.6.4 Technical layer

All personnel operating in the theatre are part of the technical layer. Decisions that are made in these layers, are decisions that are made by military individuals in their exact way of operating (Ministry of Defence, 2018).

8.6.5 JISTARC

JISTARC operates mainly in the operational and the tactical layer. Their main goal is to create situational awareness of the theatre of operation, in order to be able to analyse threats and support mission decisions. They answer Intelligence Requirements that are constructed by the commander of the brigade (operational level), the international operating unit (operational level) or the battalion (tactical level).

8.6.6 Interaction between layers

The most common interaction between the four layers, is that orders derive from the top layer that are divided towards the bottom layer. Data is gathered within the bottom layered and analysed within each layer and the outcomes are communicated to the layer above. In principle, interaction takes places between layers that are connected to the next layer. Sometimes, layers are connected although they are not next to each other. An example of such situations are outcomes that are found within the technical layers that will directly influence the strategic level.

During a mission, layers can interact with each other. On the technical level, an accident can happen in which a person dies. If this person was the ambassador of Iran, the operational practice influences world politics and the technical layers interacts with the strategic layer of decision-making.

Example 8.3: Interaction between layers

8.7 VALUES, OBJECTIVES AND JISTARC

The Ministry of Defence has defined values and objectives that are important for the organisation and for the organisation of JISTARC. Some of these values and objectives will be discussed in next paragraphs.

8.7.1 Safety

The product of JISTARC should be created to contribute to the safety. Safety is a big topic within the Dutch Ministry of Defence. The people that work within this Ministry, especially military personnel, are exposed to high risks. This safety is relevant e.g. for the agents that operate within the mission's areas. Safety is a boundary-setting value for all operations (Koninklijke Landmacht, 2018).

8.7.2 Prospect

JISTARC operates within the Dutch Ministry of Defence and therefore the values of the Ministry are also important as values for JISTARC. Prospect can lead to safety, because prospect about the future gives the possibility to take measures to mitigate the effects of unfortunate events. Such prospect can be created by intelligence; prospect is an essential element of the intelligence that is created by JISTARC (Koninklijke Landmacht, 2018).

8.7.3 Responsiveness

Responsiveness within the context of JISTARC means the module should answer to the commander on its need for situational awareness and understanding in time with intelligence product of high quality. Besides answering the questions of the commander, the JISTARC module should also give input about insights that are relevant but were not asked for (Ministerie van Defensie, 2012). The responsiveness of the intelligence process can be related to the speed at which the process is conducted, but also the accuracy that is used in creating intelligence.

8.7.4 Timeliness and continuous review

Two other objectives defined by the Ministry of Defence for intelligence processes are timeliness and continuous review. Both objectives should contribute to the legitimacy of the intelligence products of JISTARC. If information has a high volatility, the intelligence products just have a short period of validity, since information is changing fast. Therefore, intelligence products should be delivered fast and as soon as possible, so the validity of the intelligence product is high and has a high value for the decision-maker. By continuously reviewing the intelligence products, the validity can be kept up-to-date. (Ministerie van Defensie, 2012).

8.7.5 Objectivity

For intelligence product, it is important that the conclusions are based on facts instead of on assumptions. Especially when agents have many experiences and need to make sense of information that is gathered towards an intelligence product, maintaining the objectivity of the outcomes can be a challenging objective (Ministerie van Defensie, 2012). The objectivity of intelligence can be related to the accuracy of the intelligence process.

8.7.6 Accessibility

The (intermediate) intelligence products should be accessible for the agent that needs to use the information. Therefore, the information and the intelligence products should be accessible (Ministerie van Defensie, 2012). An aspect of accessibility is the comprehensibility of the intelligence products, which should therefore be disseminated in an accessible. The accessibility of intelligence is partially defined by the accuracy and quality of the intelligence products.

8.7.7 Centralised coordination and systematic exploitation

To coordinate intelligence processes efficiently, these processes should be coordinated centralised. Communication and tuning between agents of the intelligence process is important to conduct an efficient and non-redundant intelligence process. JISTARC consists of many different elements with different capabilities and roles within the organisation. These different elements with each their aspects should be exploited efficiently and systematically (Ministerie van Defensie, 2012). The trade-off between speed and accuracy should therefore be made effectively to allocate resources in an efficient way.

8.7.8 Conclusion

The values and objectives that are stated in previous paragraphs lead to a way of operation that is safe and makes use of its resources in an efficient way. The intelligence process should be conducted in an objective way with high speed, so relevant information is delivered in time and update is necessary.

The output of the intelligence process, the intelligence product, should create situational awareness and situational understanding for the commander that is relevant, accurate, in time and disseminated in an understandable way for the commander.

8.8 ELEMENTS OF JISTARC

JISTARC consists of several units (squadrons) which each have their own function. The operational units can be found in figure 8.5. Squadrons 102, 104, 105, 106 and 107 are sensors and are currently operational. In 2019-2020 two new sensors will be initiated: 108 and 109. Squadron 108 will gather and create intelligence from technical exploitation. 109 will have (digital) open sources as their main source of data intelligence. Squadron 108 will be the focus of this research.

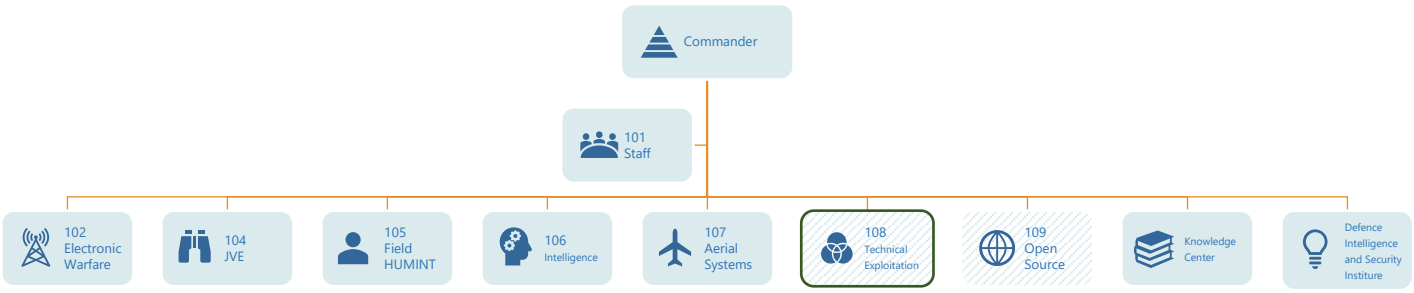


Figure 8.5: Organization Chart JISTARC

Each sensor has its own type of gathering data and information to create intelligence from. More about the data gathering method of squadron 108 will be discussed in next paragraph 8.9.

8.9 SQUADRON 108

Squadron 108 is the focus of this research. The outcomes will be specified towards this squadron. Squadron 108 is a new squadron within JISTARC that will collect and analyse data and information by technical exploitation. Data is collected and created from DMAT: DNA, Material, Artefacts and Traces. Such DMAT is Captured Enemy Materiel (CEM) (Air Land Sea Application Center, 2006). The process of 108 starts with the collection of this materiel from a physic location. This is done by the *Collection Team.* After collection, data and information is extracted from this materiel by the *Exploitation Cell*. This facility makes use of several technical methods, such as media exploitation, document exploitation, electronic exploitation, forensic exploitation and chemical exploitation to create data and information from the collected material. This data and information are communicated to the *Analysis Cell* Within the Analysis Cell, the data and information that is received is analysed towards an analysis.

An example of a DMAT object is a cell phone. A cell phone can be found by a Collection Team and exploited by the Exploitation Cell by multiple methods of exploitation. Fingerprints and DNA can be collected by forensic exploitation, the documents and media that are on the phone can be collected through document and media exploitation and information can be gathered from the circuit board of the phone through electronic exploitation. All information that is gathered from the phone is send to the Analysis Cell that will analyse the multi-type information to single-source intelligence.

Example 8.4: Example of DMAT exploitation

8.10 CONCLUSION

JISTARC is an intelligence organisation within the Dutch Ministry of Defence. Within JISTARC, data is gathered and processed towards intelligence products during missions. The fact that JISTARC usually operates during missions and delivers intelligence for the course of these missions brings a unique context in which safety is an extra important boundary condition, since human lives are at risk within areas in which enemies are operating. Within the responsibilities of JISTARC, this includes that the intelligence products of JISTARC should be delivered in time and with a certain accuracy. Based on these products, the commander will make decisions about the course of the mission.

9 Military intelligence

9.1 INTRODUCTION

The intelligence process is an information process which needs to be organised in a certain way to support decision makers with objective and relevant insights into the issue (Anderton, 1987). The intelligence process is a process of decision-making, except the decision itself is not made within this process.

Within this chapter, the military intelligence process at the client JISTARC will be introduced. At first, the military decision-making process is discussed in paragraph 9.2. In paragraph 9.3, the intelligence process as conducted by JISTARC is introduced. This intelligence process will be further addressed by addressing the process steps and the agents that operate within these processes in paragraph 9.4 and 9.5. The specification of the intelligence process for the client, squadron 108, is discussed in paragraph 9.7. The issue of the speed-accuracy trade-off within the intelligence process is introduced in paragraph 9.8 and the information velocity of JISTARC and squadron 108 is introduced in paragraph 9.9.

9.2 MILITARY DECISION-MAKING PROCESSES

The military decision-making process is defined as the 'command and control' process. In each type of mission, command and control is relevant. The command and control process includes the management of people and resources in military operations. This can also be described as a set of organisational and technical practices to solve problems and to carry out missions by human, information and physical resources (Vassiliou, Alberts, Agre, Alberts, & Agre, 2014).

9.2.1 Dynamic decision-making process

Some decision-making processes can be identified as a *dynamic decision-making process*. Characteristics of such a process are that the decisions that are made interact with each other and that the environment in which the decisions are made is changed by events that occur or by the decisions

that are made (W. Edwards, 1962). Time constraints are often a dominant factor in making decisions during these processes (Brehmer, 2005). In time sensitive operations, it is important to conduct the decision-making process at high speed to maximize the value of information, preferably even process it (near) real time. (Baldassarre, 2016).

Unique within dynamic decision-making processes, are decision-making processes that are executed by the military during abroad missions. The decisions that should be made during military operations are often made under high time pressure, entail high uncertainties and should have a low fault tolerance because often human lives are at risk (Blackmond Laskey, D'Ambrosio, Levitt, & Mahoney, 2000).

Eisenhardt argues fast (strategic) decision making is essential in changing environments (1990a), such as military operations during abroad missions. Increasing the amount of information is important to make successful decisions, which should be given real-time instead of in a delayed way or predictive overview (1989). Relying on experts could also improve decision-making speed and quality. When decisions alternatives are ready, decisions can be made faster and better (1990a). There can be a trade-off identified in this optimum, since good decisions are argued to be made on as much information as possible which is as real-time as possible, but the process of creating information takes time. The more information is created, the more time the information process often takes.

In each type of mission, command & control is relevant. Command & control can be described as the management of people and resources in military operations, especially during missions. This can also be described as a set of organisational and technical practices to solve problems and to carry out missions by human, information and physical resources (Vassiliou et al., 2014). This process is a specific type of a decision-making process during operations. The information process can support the decision-making. The information process that supports the decisions takes place in the intelligence organisations, which will be described later.

9.2.2 Command and control

During the command & control (C2) process, decisions are made about the mission. For making such decisions, situational awareness is needed. Situational awareness (SA) can be described as knowledge about the 'things in the world' and how they interact (Baumgartner & Retschitzegger, 2006). Situational awareness is created by intelligence cells that collect data and generate knowledge about the situation (Biermann, De Chantal, Korsnes, Rohmer, & Ündeger, 2004) and will be further discussed in 9.4.2. Human operators of the command & control process receive such intelligence in different forms, like summaries, briefings or reports that describe the situation by facts or consist of recommendations about the decisions that should be made (Dragos, 2013). The decision-cycle that is defined for military operations is constructed by Boyd (2018). This cycle contains four steps: 1. observation, 2. orientation, 3. decision and 4. action. A commander of a military unit that is operating during a mission executes this cycle continuously. At first, the commander observes and assesses if there is a need for more information to be able to orient in an unknown environment. If the commander has enough knowledge about the situation, a decision is made about the course of the mission. Such decisions often lead to action by the military unit (Boyd, 2018). Decisions that are made during military missions are often made under high time-pressure, are based on imperfect information and require a low fault tolerance, since often human lives are at risk (Blackmond Laskey et al., 2000; Brehmer, 2005)

The command & control cycle can be found in figure 9.1.

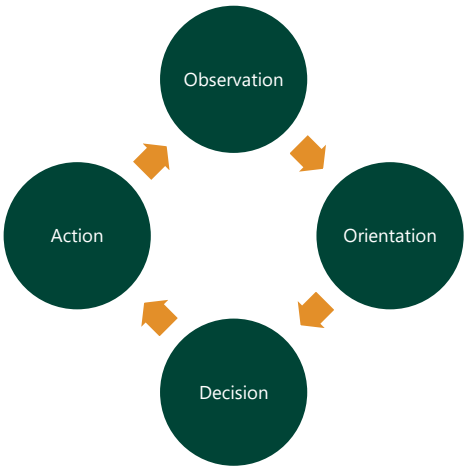


Figure 9.1: OODA Loop for Command & Control (C2)
by Boyd (2018)

Military organisations operate under time pressure during missions abroad. The time it takes to execute the command & control cycle causes a delay from observation until action (Brehmer, 2005). One of the factors that cause a time delay is the information delay that takes place between the 'observation' step and the 'orientation' step in the process as described in 2.6.

Between the observation and the orientation step within the command & control loop, intelligence is created and used to create situational awareness so the commander that makes decisions can conduct an accurate orientation. If intelligence is needed to conduct a thorough orientation in order to make informed decisions, the intelligence cycle is initiated, and the information process starts. The demand that drives the intelligence loop is a result of the observation in the command & control process (Biermann, 2009).

9.3 JISTARC AND THE INTELLIGENCE PROCESS

Within the military decision-making process, a JISTARC module has an important role. JISTARC is responsible for creating intelligence products that support the decision-maker to make an informed decision about the course of the mission. The part of the decision-making process that is conducted by JISTARC is called the (military) intelligence process. This intelligence process can be put in context within the model that is introduced in paragraph 9.4, 9.5 and 9.6.

JISTARC's role takes place within the decision-maker's side of the model within the aspect of situational awareness. JISTARC is responsible for creating intelligence products that contribute to the situational awareness of the decision-maker. If a decision-maker wants to make an informed decision based on such intelligence, the decision-maker is dependent for the accuracy of the intelligence and the speed at which such intelligence is received on how the intelligence process is executed by the agents of JISTARC.

(Military) intelligence is about the creation of knowledge about the past, the present and the future of the situation that the military unit is operating in (Kirkpatrick, 1997). Such knowledge within the Dutch military is mainly defined as *situational awareness*. Situational awareness is needed to be able to operate in unknown areas. By having situational awareness, military agents can have information about objects in complex environments. This knowledge (or intelligence) is used by decision-makers to make informed decisions in the command & control process (Biermann et al., 2004). Situational awareness consists of information about objects, attributes, relations, roles, the geo-spatial situation and events (Baumgartner & Retschitzegger, 2006). To create knowledge about these aspects of situational

awareness, data and information is gathered and analysed. This process is defined as the intelligence process. During missions abroad this is very relevant, because the commander of a military unit will be able the make informed decisions about the course of the mission. Such decisions can have a high impact and might involve high risks, and therefore the fault tolerance is low (Blackmond Laskey et al., 2000). It is often beneficial for the organisation to speed up the process to increase the effectiveness of the operation (Brehmer, 2005).

The process of creating intelligence is a process that is often executed under time pressure while information available is imperfect and accurate results are expected (Biermann et al., 2004). Trade-offs are made constantly to increase the speed of the process and to ensure the accuracy of the outcomes (Brehmer, 2005).

Within next paragraphs, the intelligence process that leads towards situational awareness will be discussed. This intelligence process will be addressed by three different aspect: the process aspect, the multi-actor aspect and the behavioural aspect.

9.4 THE PROCESS OF THE INTELLIGENCE PROCESS

The intelligence process is defined by multiple steps and subprocesses. Within next paragraph, these steps will be described and related to the process steps of the rational decision-making process as described in paragraph 4.3.3.

9.4.1 The major and the small intelligence loop

The intelligence process can be divided into two processes: the major intelligence process and the small intelligence process. The major intelligence cycle is the process that is executed by the JISTARC module. Every agent within the module has a role in executing this process. The small intelligence cycle is the process that is executed within each squadron (which are 102, 104, 105, 106, 107, 108 and 109). The agents within each squadron have a role in conducting the small intelligence process.

The intelligence loop as described in paragraph 9.2.2 is called the major intelligence loop that consists of four major process steps. Besides the major intelligence loop, there is also a small intelligence loop defined, which will be discussed in paragraph 9.4.3. This small intelligence loop takes places within the collection process of the major intelligence loop.

The case of this research takes place within squadron 108. This squadron is responsible for conducting the small intelligence process. In next paragraphs, first the processes of the major intelligence loop will be introduced. After this, the processes of the small intelligence loop will be discussed.

9.4.2 The major intelligence process

9.4.2.1 *Relation to C2*

The intelligence process of JISTARC is in close relation to the command and control process (C2). Intelligence needs are derived from the command and control process. The intelligence process is at the service of the command and control process and demand that drives this process is created in C2. Decisions are made by a decision-making actor (often the commander) within the command and control process. These decisions are based on situational awareness that is created by the JISTARC module. If there is a perceived gap in situational awareness (or situational understanding), the command and control operators communicate intelligence requirements to the JISTARC module. These intelligence requirements enter the major intelligence process.

9.4.2.2 *Overview of the process*

The major intelligence process or intelligence cycle is initiated by the ‘observation’ step in the command & control loop and starts with a needs assessment that follows from the observation. After deciding

which information is needed, data is collected and processed towards a useful analysis. The results of the analysis are communicated and distributed back to the command & control department. The orientation phase of the command & control loop can be conducted successfully, and informed decisions can be made.

The intelligence cycle and the relation of this cycle to the command & control cycle can be found in figure 9.2. Each (sub)process of this major intelligence process will be discussed in next paragraphs.

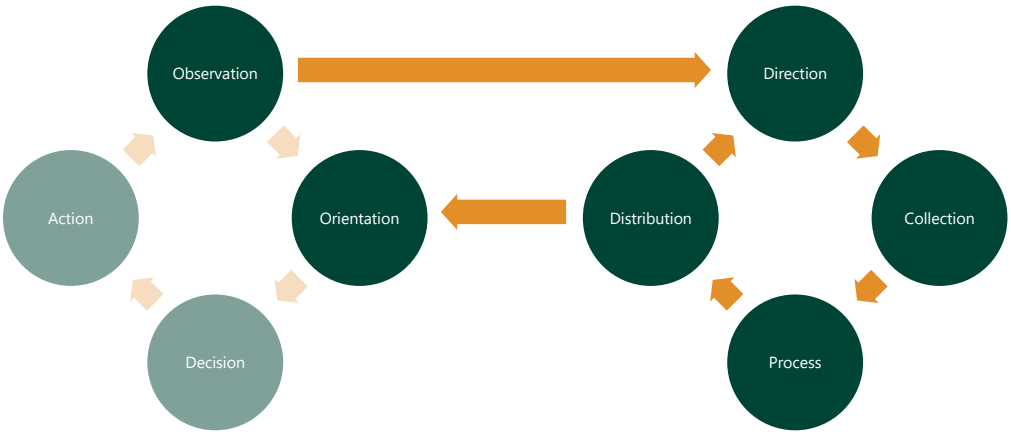


Figure 9.2: Intelligence Loop in relation to the Command & Control Loop
by Biermann et al. (2004)

Doctrines define the processes within military operations at the Ministry of Defence. These processes are often based on NATO doctrines. The processes that will be described as the processes of JISTARC are based on the Standard Operating Procedure of the ISTAR Module and conversations with experts within the organisation of JISTARC.

To create intelligence, several steps must be executed. The process from the stage of observation towards the stage of orientation is defined by another cycle: the intelligence cycle. This cycle is based on the intelligence cycle that is used by NATO and described by multiple scientists (Baartz, 2005; Hulnick, 2006; Johnson, 1986; Omand, 2013). This cycle contains four stages: 1. Direction, 2. Collection, 3. Process and 4. Distribution. These processes are managed by a fifth process: The Intelligence Requirement Management and Collection Management (IRMCM). The main processes of a JISTARC module (which is the major intelligence process) can be seen in figure 9.3.

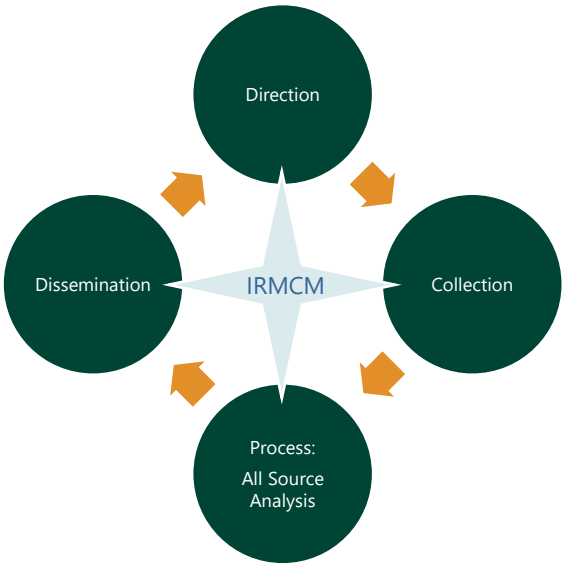


Figure 9.3: Main processes of JISTARC's major intelligence process

In further paragraphs these processes will be further discussed. The process of 'observation' and 'orientation' will be discussed as well in next paragraphs, although these are not part of the major intelligence process but are closely related, since these are directly connected to the (major) intelligence cycle of JISTARC.

9.4.2.3 *Observation*

In the observation step, which is part of the command and control process, the need for intelligence is originated. The decision-maker in this process defines a gap in knowledge by observation. In this step, intelligence requirements are defined. The demand for intelligence is originated in this process step. The commander must deal with the trade-off between an increase in the decision-making speed and an increase in the knowledge available by which decisions can be made (Brehmer, 2005).

This observation step is similar to the first step of the decision-making process step: 'Definition of research goal' as described in 4.4.1. A knowledge gap is identified; the commander needs extra situational awareness or understanding to make an informed decision in a situation. The need for SA and SU is communicated to the intelligence process owners of the mission: the JISTARC module.

A difference in the intelligence process compared to the information process, is that the need for intelligence is defined in the command & control loop (as described in 9.2.2), but the more elaborated information requirements are defined in the step 'direction' in the intelligence loop, which is discussed in next paragraph.

9.4.2.4 *Direction*

In the direction step the intelligence requirements are received from the command and control operators and translated into an intelligence collection plan (ICP). Intelligence requirements are divided into smaller tasks and specific tasks are defined, and suitable agencies are tasked to collect information and create intelligence. The direction step is executed by the commander of the JISTARC module, but also by operators of other processes of the major intelligence process. Within this step, the general strategy of the module is defined.

The focus of the direction process is mainly externally: the responsibility of the operators within the direction is the communication with the operators of the command & control process. The direction

element receives intelligence requirements and based on that, defines the priorities and areas of interest and communicates these towards the intelligence process. The focus of the direction is on the command & control process.

What is not part of this step in the intelligence process, is the initial identification for the need of intelligence which is defined within the command & control process. Although, often intelligence products create intelligence requirements as well besides answering them. Therefore, the major intelligence cycle is defined as a loop (figure 9.1).

Within the decision-making process that is defined in 4.4, this step is similar to the 'Definition of research goal' as described in 4.4.1. In this step, the need for knowledge is translated to the identification of an information-gap and a data-gap.

9.4.2.5 *Collection*

During the collection of intelligence, sensing techniques and other methods of data gathering are used to collect the information that is needed to create intelligence. This process is executed by the squadrons 102, 104, 105, 107, 108 and 109. Sources are exploited and the data is communicated to the processing agency (Biermann, 2003). As in all process steps, time pressure is very relevant during this collection step.

The Intelligence Collection Plan (ICP) is the input for the collection process. Within the collection process, a plan is made for collection effort. Single sensor squadrons (102, 104, 105, 107, 108, 109) are tasked, data is collected and a single-sensor analysis on the data is conducted by the squadrons that have collected the data. These outcomes are exploited and disseminated to the All Source Analysis Cell (ASIC; 106). This collection process is be split into five steps: 1. Tasking, 2. Collection, 3. Processing, 4. Exploitation and 5. Dissemination which is the *small intelligence process* which will be further discussed in paragraph 9.4.3.

This step in the intelligence cycle can be related to the 'Data collection' as described in 4.4.2.

9.4.2.6 *Process*

In the process step, from data and information intelligence is created. This can be done in several ways, like evaluating trends, analysing datasets, integrating information or collating datapoints (Huang et al., 2015). Many different steps can be performed and different methods can be used for processing this data towards useful insights in the situation (Bannon, 2013) and an intelligence product that answers an intelligence requirement as defined in the command & control process. Biermann et al. (2004) define five activities within the process step of the intelligence loop: collation, evaluation, analysis, integration and interpretation.

Within JISTARC, the process step is mainly executed by the All Source Intelligence Cell (ASIC; 106). The process starts with registering and evaluating the outcomes of the single sensor collection results. These results are evaluated and analysed. The results are also combined and integrated, so a multi-source analysis can be conducted.

This process step can be related to step 4: Data analysis in the decision-making process as described in 4.4.4. In this step, knowledge is created from the information that was created in previous step.

9.4.2.7 *Dissemination*

Within the dissemination process, the outcomes of the All Source Analysis process are reviewed. After verification, the results are released and disseminated. When intelligence is created, it should be communicated in the right way, so the message will be clear for the decision-makers in command & control. This could be done in various ways, like textual or visual messages or conversations.

The distribution step within the intelligence process can be related to step 5: Data visualization and communication as described in 4.4.5. The results of the intelligence process are communicated to the decision-maker.

9.4.2.8 *Orientation*

The results of the intelligence cycle are communicated to military commanders or other decision-makers and contribute to situational awareness and enable situational understanding. In the last step of the intelligence process, the *orientation* step, outcomes are received. These outcomes are added to the knowledge or situational awareness of the decision-maker. This step is part of the command & control process (paragraph 9.2.2).

9.4.2.9 *Intelligence Requirement Management and Collection Management*

In the IRMCM process, the other processes of the major intelligence cycle are managed. In this process, there is kept track of what information is collected and processed and which requirements still need to be fulfilled. When intelligence requirements (IR) enter the JISTARC module through the direction, at first the IR's are validated. The IR's are also prioritised, so the most essential intelligence is created first. The IR's are refined and split into 'Essential Elements of Information' (EEIs). Within the IRMCM (in close communication with operators of the other processes) an intelligence collection plan (ICP) is created. This document consists of a list of specific intelligence requirements (SIRs) with the EEIs that are needed to answer the SIRs. Each EEI is given a priority and a deadline: the latest time information of value (LTIOV). The ICP is the guideline for the squadrons to collect, process and disseminate. The IRMCM process is focussed on managing the intelligence process. Aspects that are important for this process are documentation, information management, stability, control and continuity (Quinn, 1984). The focus of IRMCM is mainly internal, while the direction has a more external focus (Denison, Hooijberg, & Quinn, 1995).

In figure 9.3, the IRMCM process is placed in between the other elements of the intelligence cycle, because IRMCM interacts with all elements.

9.4.2.10 *Overview*

An overview of the described steps of the decision-making process as described in 4.4 and the steps of the intelligence process (in relation to the command & control process) can be found in table 9.1.

Steps	Decision-making process as defined in 2.3	Further discussion	Intelligence process as described in 2.6	Paragraph	C2 Cycle	Intel Cycle
1	Definition of research goal	Appendix D.1	Observation	9.4.2.3		
			Direction	9.4.2.4		
2	Data collection	Appendix D.2	Collection	9.4.2.5		
3	Data preparation and storage	Appendix D.3	Collection & Process	9.4.2.5 & 9.4.2.6		
4	Data analysis	Appendix D.4	Process	9.4.2.6		

5	Data visualization and communication	Appendix D.5	Report and visualization	9.4.2.7		
			Orientation	9.4.2.8		
6	Decision-making	Appendix D.6	Decision	9.4.2.1		
	Management of the other process steps		Intelligence Requirement Management and Collection Management	9.4.2.9		

Table 9.1: Comparison generic decision-making process and the intelligence process

9.4.3 The small intelligence process

9.4.3.1 *Relation to the major intelligence process*

Within the major intelligence process, the small intelligence process is executed. This small intelligence process is conducted during the 'collection' sub-step or subprocess within the major intelligence process as is displayed in figure 9.4. The executers of the small intelligence process are called *sensors*. A JISTARC module can consist of multiple sensors constructed from the different squadrons. A part of the sensor is part of the direction process of the major intelligence loop. Within the direction process tasks are divided among the sensors.

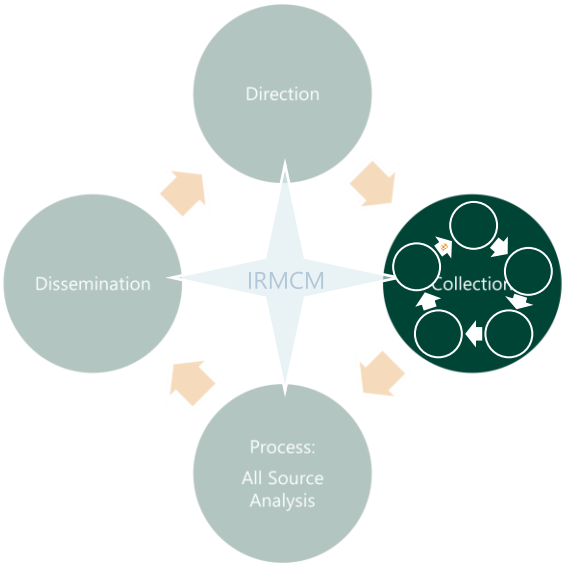


Figure 9.4: The small intelligence process within the major intelligence process

Sequential, the process of the major and the small intelligence process can be found within figure 9.5. This flow shows the flow of the information through the whole process. Within this visualisation, the incremental steps are not displayed.

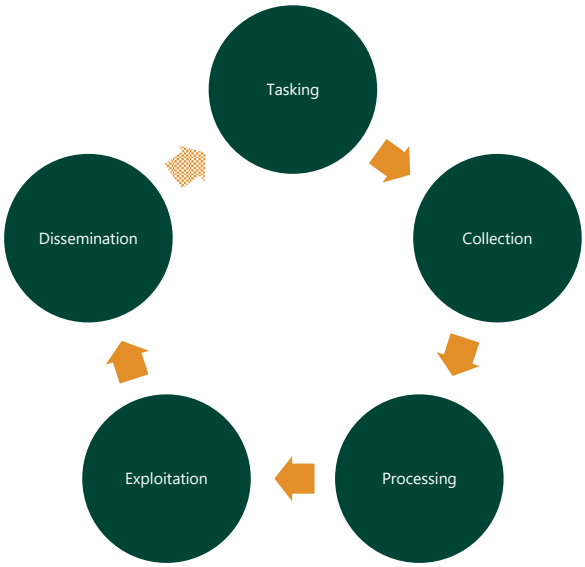


Figure 9.5 Process from Intelligence Request to answer

9.4.4 Processes

Within the small intelligence process, five activities can be distinguished that process-wise would be executed sequential. These steps are: 1. Tasking, 2. Collection, 3. Processing, 4. Exploitation and 5. Dissemination. The small intelligence process is, just as the major intelligence process, a circular process. The small intelligence process can be found in figure 9.6.

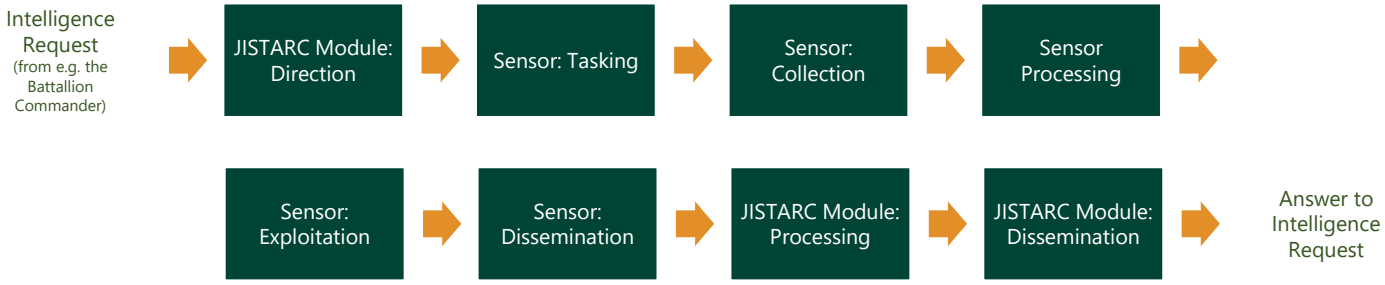


Figure 9.6: Small intelligence process

9.4.4.1 *Tasking*

Within a squadron, tasks are collected and given to the other agents within the process. Essential Elements of Information (EEIs) that should be gathered are translated to tasks for the operators within the squadron. Often these tasks include collecting, processing, exploiting (or analysing) and disseminating. The tasking activities within the small intelligence process are executed by the chief operations, the mission manager and the (deputy) platoon commander (paragraph 9.5.2.1; 9.5.2.2; 9.5.2.3)

9.4.4.2 *Collection*

Within the collection subprocess, the operator is tasked to collect information. This can be done in several ways; each squadron has its own method of gathering data. Often people are sent into the field with sensors such as cameras and radiofrequency sensors. E.g. within 108, in the collection process, DNA, materials, attributes and traces (DMAT) are collected and brought to the lab where the items are

processed. The collection process within the small intelligence process is mainly executed by *operators* (paragraph 9.5.2.4).

9.4.4.3 *Processing*

During the processing step of the small intelligence cycle, the collected data is processed. Relevant datapoints are identified and put in a database. E.g. within 108, the collected items are processed in the laboratory where digital data is created from the DMAT. The processing step of the small intelligence process is mainly executed by *collators* (paragraph 9.5.2.5).

9.4.4.4 *Exploitation*

During exploitation, the processed data is exploited and analysed in order to create an EEI. The data is analysed, and insights are created from the data; this process is mainly executed by *(single source) analysts* (paragraph 9.5.2.6). This exploitation is done by using the data from the *collection* step (paragraph 8.8.4.3? 9.4.4.2) that is processed within the *processing* step (paragraph 9.4.4.3). Often, several (digital) applications are used to assist the analyst within the exploitation process.

9.4.4.5 *Dissemination*

Within the last step of the small intelligence cycle, the outcomes of the analysis are disseminated by the mission manager (paragraph 9.5.2.2) to the IRMCM operator (of the major intelligence process) which disseminates the output to the All Source Intelligence Cell (paragraph 9.5.1.5) which conducts the *process* step of the major intelligence cycle (paragraph 9.4.2.6).

9.4.4.6 *Overview*

The process steps within the small intelligence loop can again be related to steps within the process approach of the decision-making process. These steps can be found within table 9.2.

Steps	Decision-making process as defined in 2.3	Further discussion	Intelligence process as described in 2.6	Paragraph
1	Definition of research goal	Appendix D.1		
	Translating step 1 to step 2		Tasking	9.4.4.1
2	Data collection	Appendix D.2	Collection	9.4.4.2
3	Data preparation and storage	Appendix D.3	Processing	9.4.4.3
4	Data analysis	Appendix D.4	Exploitation	9.4.4.4
5	Data visualization and communication	Appendix D.5	Dissemination	9.4.4.5

Table 9.2: Small intelligence processes related to information process steps

9.5 AGENTS OF THE INTELLIGENCE PROCESS

9.5.1 The major intelligence process

The major intelligence process is executed by multiple agents. Each agent has own tasks and responsibilities. Some agents operate in one process as discussed, other agents operate in more than one of these processes. The most relevant actors will be discussed in next paragraphs.

9.5.1.1 *Commander of the JISTARC module*

The commander of the JISTARC module is responsible for the activities and output of the activities. The commander has a leading role within the *direction* step as described in paragraph 9.4.2.4. The commander can be considered the *top management* within the context of the JISTARC module, since this person is responsible for leading the module (Mintzberg, 2006).

9.5.1.2 *IRMCM operators*

The IRMCM operators are responsible for the management of the intelligence requirements and the collection operations. This entails the management of all other major intelligence loop processes. IRMCM is part of the *direction* step (paragraph 9.4.2.4) as well.

Within larger operations, the IRMCM process is not executed by only one person but by multiple. The tasks can be divided in Intelligence Requirement Management, Collection Coordination and Information Management. Each task can be executed by one or multiple agents. The intelligence requirement management is responsible for answering the Intelligence Requests (IRs) or Requests for Information (RFIs) from C2, the Collection Coordination (CC) is responsible for coordinating all collection activities and the information management (IM) is responsible for managing the information streams of the JISTARC module.

The IRMCM operators are responsible for verifying and monitoring the answers to the intelligence requirements and communicating these to the command & control operators within the *dissemination* process (paragraph 9.4.2.7).

The IRMCM operators can be described as the management of a module. The role these operators have in the *direction* process (paragraph 9.4.2.4) defines their role as *top management* of the module since in this process the general strategy of the module is defined; their role as managers of the others processes of the JISTARC module defines their role as *middle management* since in this process the execution of the general strategy is kept on track (Mintzberg, 2006).

9.5.1.3 *Chief Operations*

The chief operations (CHOPS) is responsible for the operations that are conducted by the JISTARC module. The CHOPS also has a role in the *direction* process (9.4.2.4) and coordinates all operations that are executed by the JISTARC module. The CHOPS is responsible for all collection activities of the *small intelligence process* operators. The role the CHOPS has within the *direction* process (paragraph 9.4.2.4) can be defined as top management, since the CHOPS thinks along in this process with the strategy of the module.

9.5.1.4 *Single Sensor unit*

The single sensor is responsible for executing all five steps within the small intelligence process, which entails the collection of information and conducting a first (single source) analysis on this information. Within the context of the major intelligence cycle, the single sensor conducts the *collection* process, which is discussed in paragraph 9.4.2.5 and called the small intelligence process. The actors within this small intelligence process will be discussed in paragraph 9.5.2. The Chief Operations (discussed in previous paragraph 9.5.1.3) is the link between the major intelligence process and the single sensor unit.

9.5.1.5 *All Source Intelligence Cell*

The All Source Intelligence Cell (ASIC) is responsible for analysing all analyses that are done by the single sensors towards a multi-source analysis, which is the combination of the results of the small intelligence processes that are conducted by all sensors. The ASIC is responsible for answering the intelligence requirements that were received by the module by the input from the collection processes. The ASIC is responsible for conducting the *processing* step (paragraph 9.4.2.6) within the major intelligence loop. The output of the ASIC is disseminated to the IRMCM operator which will disseminate the outcomes to the command & control process, the ASIC has therefore a major role within the *dissemination* process as described in paragraph 9.4.2.7.

The chief of the All Source Intelligence Cell is also involved in the *direction* process (paragraph 9.4.2.4) of the JISTARC module. The ASIC chief can be considered *top management* for its role within the *direction* process and working on the strategy of the module. For its role as leader of the ASIC, the ASIC chief can be considered *middle management,* since within this task the ASIC chief translates the vision of the top management to a part of the working base: the ASIC.

9.5.1.6 *Overview*

All actors within the major intelligence process are listed in table 9.3 and the processes in which the actors are mainly involved is indicated.

Actor	Paragraph	Direction	Collection	Processing	Dissemination
Commander of the JISTARC module	9.5.1.1				
IRMCM operators	9.5.1.2				
Chief Operations	9.5.1.3				
Single Sensor Unit	9.5.1.4				
All Source Intelligence Cell	9.5.1.5				

Table 9.3: Overview of the major intelligence process actors and the major intelligence process steps in which they are mainly involved

9.5.2 The small intelligence process

The small intelligence process takes place within the collection process, within the single sensor as discussed in paragraph 9.5.1.4. This small intelligence process is executed by multiple agents which will be discussed in next paragraphs.

9.5.2.1 *Chief Operations*

The Chief Operations (CHOPS) has a role in both the major intelligence process (9.4.1.3) and in the small intelligence process. The CHOPS is responsible for all data collection activities and its goal is to allocate resources of all sensors, like human resources and vehicles, in an effective way, considering the need of situational awareness and understanding of the decision-making actor. The role of the CHOPS within the small intelligence process can be considered as *top management*, since the CHOPS is responsible

for all operations within the small intelligence process and responsible for creating a general vision for all operations and agents within the small intelligence process (Mintzberg, 2006).

9.5.2.2 *Mission Manager*

For each single sensor, a mission manager is responsible for the tasking process within the small intelligence process. The mission manager of a sensor is appointed to communicate between the single sensor and the IRMCM operator(s). The mission manager has insights in the capabilities of a sensor and can deliver input for creating an Intelligence Collection Plan (ICP), often through the CHOPS. Within the ICP, collection tasks are defined that should be followed by the operators of the sensors. The mission manager is mainly in contact with the CHOPS and with the platoon commander and its deputy. The mission manager is (partially) responsible for the input of the small intelligence process (which is the definition of the research goal as described in paragraph 4.4.1 and disseminating the results from the single sensor unit to the IRMCM operator, back into the major intelligence cycle. This is the subprocess of *dissemination* within the small intelligence cycle, as described in paragraph 9.4.4.5.

9.5.2.3 *Platoon Commander (and deputy)*

The platoon commander (PC) (and its deputy, the OPC) can be described as the leader of a sensor. For each single sensor, a platoon commander is appointed that tasks the operators, collators and analysts with assignments that lead to answering Essential Elements of Information (EEIs) that are stated within the ICP. The platoon commander can be considered *middle management* according Mintzberg's theory (2006) since these actors are responsible for assigning the tasks that are stated in the ICP to the operating agents of the unit. The process that is executed by the PC and OPC is the process of *tasking*, as described in 9.4.4.1. The PC and OPC are also responsible for the products that are delivered by the single sensor unit.

9.5.2.4 *Operator (collector)*

The operators of the single sources are the agents that collect the data itself, which is often done in the field. The operators conduct the *collection* process of the small intelligence process. The method of data gathering differs from squadron to squadron. Within the model of Mintzberg (2006), the operators can be placed within the working base. They create input for the small intelligence process. This input is processed towards output, which is done by the collators and the (single source) analysts. The process that is executed by the operators is the process of *collection*, as described in 9.4.4.2.

9.5.2.5 *Collator*

The collators of a single sensor process the data that is created by the operators. Data is cleaned and put into a database in a standardised format. The collators conduct the *processing* step of the small intelligence cycle. Within Mintzberg's model the collators can be defined as the working base that processes the input towards an output (2006). The output of the collator is the input for the (single source) analysts. The process that is executed by the collators is the process of *processing*, as described in 9.4.4.3.

9.5.2.6 *(Single Sensor) Analyst (SSA)*

Within a single sensor, analysts can be appointed to analyse the data from the sensor. Not within all JISTARC modules analysts are appointed. The output from the collators is the input for the analyst. Insights in the data are created before the outcomes are disseminated to the All Source Intelligence Cell. Also the analysts are part of the working base within Mintzberg's theory (2006): the analysts create output from the processed data. The analysts conduct the *exploitation* process of the small intelligence cycle. The outcomes are communicated to the platoon commander or the mission manager. The process that is executed by the analysts is the process of *exploitation*, as described in 9.4.4.4.

9.5.2.7 *Overview*

An overview of all actors within the small intelligence process is given in table 9.4 and the processes in which the actors are mainly involved is indicated.

Actor	Paragraph	Tasking	Collection	Processing	Exploitation	Dissemination
Chief Operations	9.5.2.1					
Mission Manager	9.5.2.2					
Platoon Commander	9.5.2.3					
Operator	9.5.2.4					
Collator	9.5.2.5					
Single Source Analyst	9.5.2.6					

Table 9.4: Overview of the small intelligence process actors and the small intelligence process steps in which they are mainly involved

9.6 NON-RATIONAL ASPECT OF THE INTELLIGENCE PROCESS

The intelligence process is defined as a circle, which implicates a sequential process. In practice, this process does often not occur in sequence, but iterative and even continuous. Sometimes even steps are skipped.

Doctrines and standard operating procedures (SOPs) define the working processes that should be executed by the agents within the major intelligence process. An organisation with a high level of standardisation, such as the Dutch Army and all its units, is defined by Mintzberg as a *machine bureaucracy.* The technostructure of the organisation has a large influence and the working base operates based on pre-defined processes (Mintzberg, 2006).

During missions, these SOPs are followed but exceptions can be made because of the daily practices that turn out to be different than prescribed by the SOP. Although doctrines exist, most processes are executed based on current situations and adjustments. Good communication between actors is essential for such organisations. Agents need to depend on each other's expertise to conduct the processes in the most appropriate way (Mintzberg, 2006). Within the Dutch Army doctrine, the application of an adhocracy is called 'mission command'. Mission command implies that orders are given centralized but are executed decentralized by own insights of the executer. This method gives freedom to the local executers that have the most knowledge of the local situation and which actions might be most suitable. This tactic is used because it stimulates robust decision-making under situations with high uncertainties (Vogelaar & Kramer, 2004).

Although operations are planned by many details in the Dutch Armed Forces, the way of operation is often different from the doctrine. During operations, agents choose often the way of operation that is

considered most practical and would have the best results at that moment. Doctrines and procedures are often followed until the daily practices turn out to be different than prescribed within the doctrine or SOP. Within the major and within the small intelligence process, such exceptions are made often. Especially when insights are found about immediate *threats to the mission, threats to the force* or about other triggers that ask for immediate action. Such findings are often found by the single sensor units or the All Source Intelligence Cell. Such findings are communicated to the CHOPS or the Commander of the module immediately.

9.7 THE INTELLIGENCE PROCESS OF SQUADRON 108

Within a JISTARC module, the squadron 108 can deliver intelligence by technical exploitation. The 108 element conducts the small intelligence cycle to create intelligence. This process is divided into three elements: the materiel collection element Collection Team, the data and information extraction element (Exploitation Cell) and the analysis element (Analysis Cell). In figure 9.7 the Collection Team, the Exploitation Cell and the Analysis Cell are related to the steps within the small intelligence cycle as described in paragraph 9.5.2.

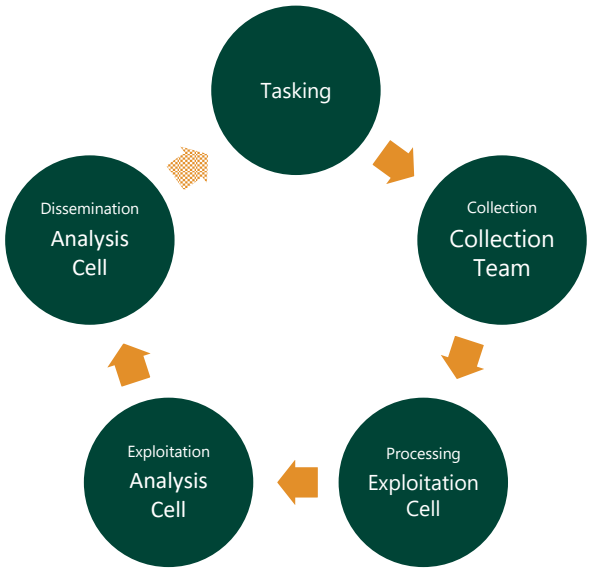


Figure 9.7: The elements of squadron 108 within the small intelligence cycle

Within table 9.5 these elements of the Analysis Cell in relation to the steps of the small intelligence process are presented within a table.

108 subprocess	Small Intelligence Process step	Paragraph
Collection Team	Collection	9.4.4.2
Exploitation Cell	Processing	9.4.4.3
Analysis Cell	Exploitation, Dissemination	9.4.4.4 & 9.4.4.5

Table 9.5: 108 elements and process steps

Within the Exploitation Cell, multiple types of exploitations are defined that create information from physical objects. These different methods are defined to gather multiple types of data from DMAT.

These exploitation methods are document exploitation, electronic exploitation, chemical exploitation, forensic exploitation and media exploitation. DMAT objects can be exploited through one to multiple or even all types of exploitation. If more types of exploitation are required for an object, these different exploitations should be conducted in sequence in most cases. This process is displayed in figure 9.8. Each type of exploitation is a subprocess that requires agents with a specific type of expertise.

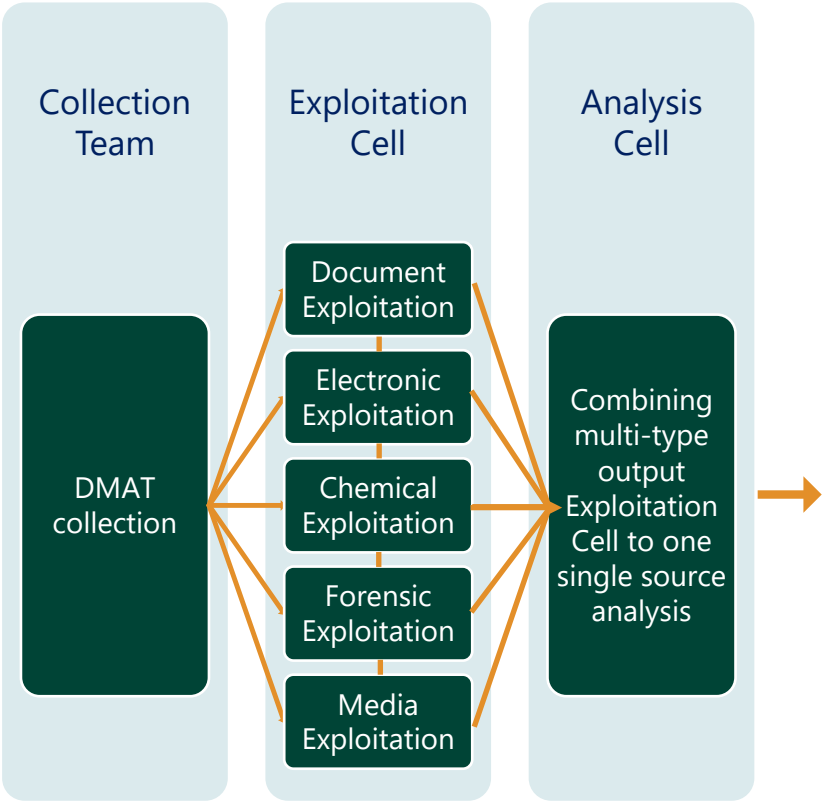


Figure 9.8: The subprocesses of the Analysis Cell

9.8 THE SPEED-ACCURACY TRADE-OFF WITHIN THE INTELLIGENCE PROCESS

Within the intelligence process, constantly trade-offs are made between speed and accuracy. Intelligence has to be delivered in time, but the accuracy of the outcomes should be high enough, because decisions are based on these outcomes. Such decisions often involve the risk of human lives, so the fault tolerance is very low. Especially when intelligence is required fast and information is time sensitive, the trade-off between speed and accuracy is a challenging issue and a thought-out balance should be chosen between speed and accuracy.

9.9 INFORMATION FLOWS WITHIN THE INTELLIGENCE PROCESS

Within JISTARC and its squadrons, like squadron 108, information flows can be identified to address the velocity within the small and major intelligence process. The identification of these flows and the velocity of these flows are useful to understand the institutional context of JISTARC and its squadrons, which will be further addressed within the context of the empirical research in paragraph 10.3.1.

9.9.1 Information flows within the major and small intelligence process

The velocity of information is part of the information that flows between processes. Within figure 9.9 and 9.10 the information flows can be identified in between the subprocesses as the orange arrows.

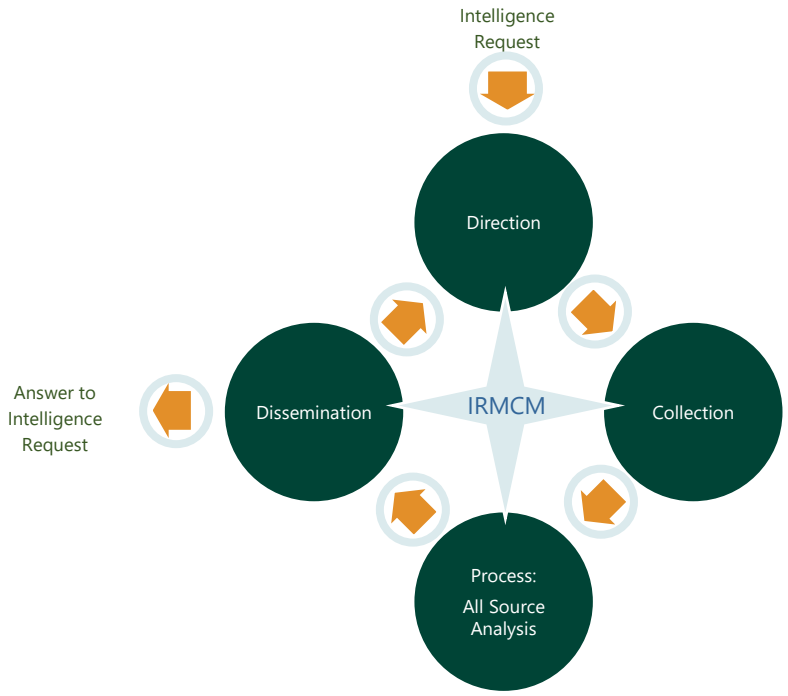


Figure 9.9: Information flows within the major intelligence process

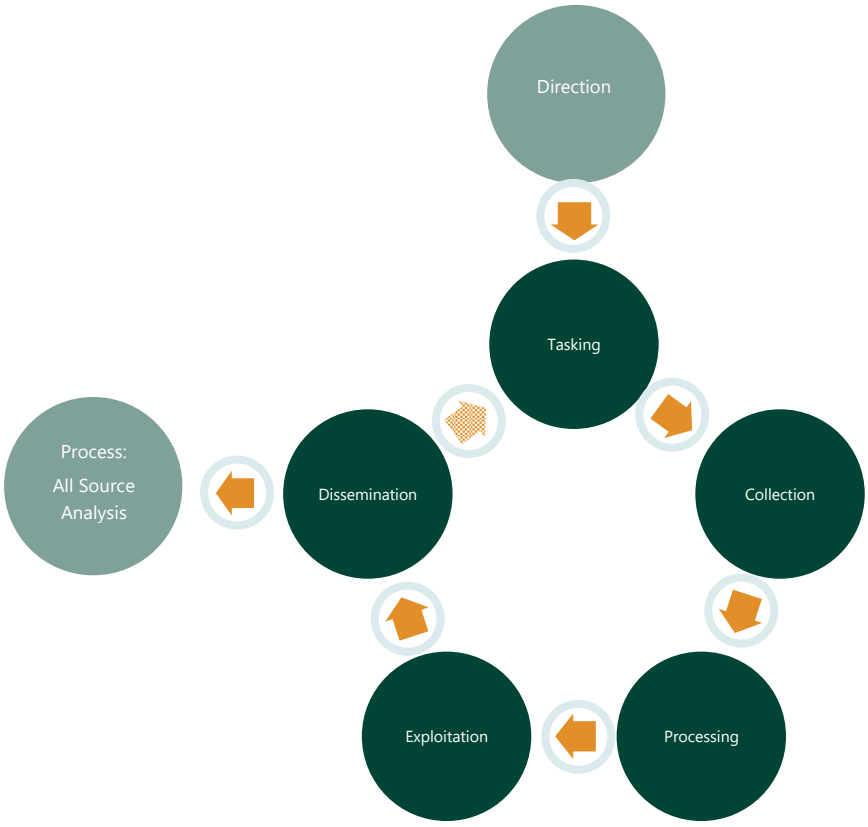


Figure 9.10: Information flows within the small intelligence process

One of the characteristics of these information (or data) flows is the information velocity, which is further discussed in paragraph 9.9.3.

9.9.2 Information flows within the process of 108

The elements the process of 108 consists of can be found in figure 9.11. To address the effects of information velocity on the process of squadron 108 and the trade-offs that are made within this process, an understanding about the information flows within the process is required. The information flows within squadron 108's processes are encircled. Te information flows in between the different types of exploitation methods can vary between zero (just one type of exploitation is used on an object) to four connections (all five types of exploitation are used on an object).

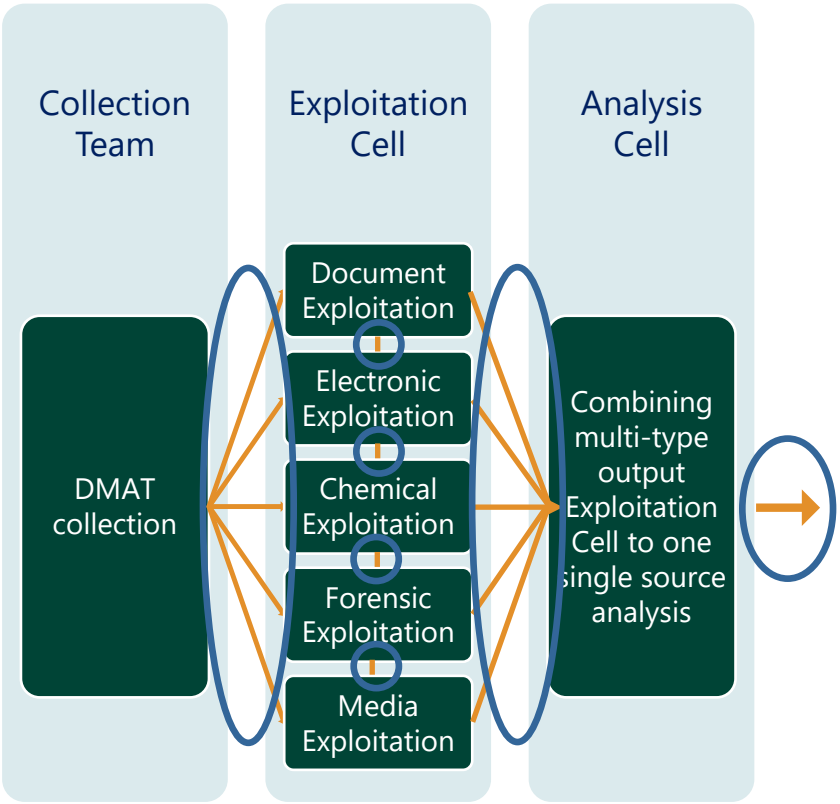


Figure 9.11: Process of squadron 108

9.9.3 The velocity of information flows

As discussed in chapter 2, velocity of information has multiple aspects: 1. The speed of information, 2. The mode at which information flows and 3. Information volatility.

9.9.3.1 *Speed of information*

The speed of information within JISTARC is the speed at which information is shared between different process steps within the major and within the small intelligence cycle. Most different process steps are executed by different agents, so the speed of information sharing between process steps is similar to the speed at which information is shared between different agents.

9.9.3.2 *Information continuity*

Information between agents can be shared in multiple ways. If information is shared through reports, this mode of information flow is batch-wise. If information is shared through batches, the (sub-)process of one operator is often finished before the other agent can use the information from the previous subprocess.

9.9.3.3 *Information volatility*

Information that is gathered for analysis can have a temporal validity, which means information is only of value for a short period of time. If such information is gathered by collectors and this information

enters the intelligence process, the lead time of the process is limited before the validity of the information is expired. If the intelligence process takes longer than the validity of information, created intelligence must be discarded or decisions will be based on information that is not valid anymore.

9.10 CONCLUSION

Military intelligence is created within multiple steps. Different agents execute the steps that are defined within this process. The intelligence process can be related to the decision-making process. Like the execution of the decision-making process, the intelligence process is not always executed within the steps that are defined, but agents within the process make different choices based on their perceptions. Within the intelligence process, trade-offs are made constantly between speed and accuracy. The achieved levels of speed and accuracy of the intelligence products contribute to the decision quality.

RESULTS

10 Empirical Research

10.1 INTRODUCTION

The several ways in which data is collected were already discussed in chapter 6. This chapter shows how the methods *semi-structured interviews* and *ethnographic research* are used to address the main research question. The process of data collection will be addressed first. After this, the observations that are made within the structured interviews and the ethnographic research are shared. Hereafter, these observations are interpreted and analysed by using the model as discussed in paragraph 5.2.1.

10.2 THE DATA COLLECTION PROCESS

The open interviews, the semi-structured interviews and the ethnographic research are conducted with people that operate in the small intelligence cycle[17].

[17] See paragraph 9.4

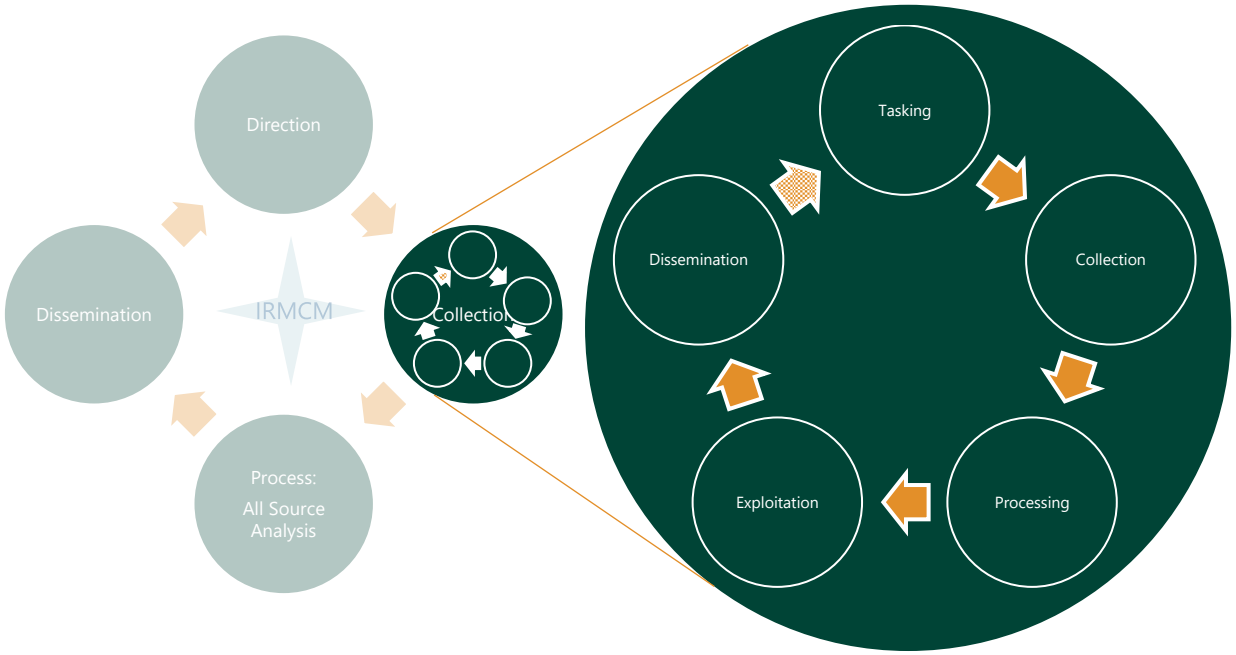


Figure 10.1: The small intelligence process within the major intelligence process

10.2.1 Two methods of empirical research

Within this research, two methods of empirical research are used to answer the main research question. Both methods, semi-structured interviews and ethnographic research, have qualities and disadvantages. By using both methods, these disadvantages can be mitigated.

The disadvantage of (semi-structured) interviews can be described as the subjectivity of the data that is gathered during interviews (Barriball, 1994). Data gathered is coloured through the perception of the respondent. Especially within the speed-accuracy trade-off of an agent, the respondent can have different perceptions about the trade-off he or she makes than the trade-off that is made. The interviews give insights in the perception of agents and a perspective of the factors that influence the trade-off that is made. The ethnographic research gives insights in the actual balance that is chosen between speed and accuracy during the process, although it provides less insights in (intermediate) factors that influence the trade-off.

Chronically, some semi-structured interviews are held first. After conducting some of these interviews, the ethnographic research is conducted with questions based on the findings of the first part of the interviews and the findings of the answers of sub-question 1, 2 and 3 (paragraph 6.3.1; 6.3.2; 6.3.3). After conducting ethnographic research, more semi-structured interviews are conducted to create more insights about the observations, to confirm or verify the findings of the ethnographic research and to identify factors that lead to the outcomes as observed during the ethnographic research.

10.2.2 Open interviews

The open interviews are held with multiple squadrons: 102, 104, 105, 106 and 108. These were done before conducting the other methods of empirical research. During these interviews, an introduction is given by operators and experts from squadrons. The mode of operation of each squadron is one of the main subjects discussed during these open interviews. The results of the open interviews are used to understand the different squadrons and their mode of operation, but these results cannot be used to answer the main research question itself. By using open interviews, the gathered data from the semi-

structured interviews and the ethnographic research can be put into context. The questions that are used as guidelines during the open interviews can be found in appendix E.

10.2.3 Semi-structured interviews

Semi-structured interviews are done with agents of the small intelligence process that are experienced as single source analyst (SSA) or mission manager within a JISTARC squadron. The interviews took place in a private environment. These interviewed agents were part of squadron 102, 104 and 105. Each squadron has a different method of data gathering and therefore a different level of velocity. Especially the squadron 102, Electronic Warfare, has experienced a major change in information velocity over the last 10 years which offers useful insights in changes in velocity over the years. Six agents within this squadron are interviewed to create insights in the differences in the speed-accuracy trade-off that are caused by these differences in velocity. Most of these agents operated the 'processing' step (paragraph 9.4.4.3), 'exploitation' step (paragraph 945.4.4) and 'dissemination' step (paragraph 9.4.4.5) within the small intelligence process as 'mission manager' (paragraph 9.5.2.2) or 'single source analysist' (paragraph 9.5.2.6). These steps are marked within the small intelligence process in figure 10.2.

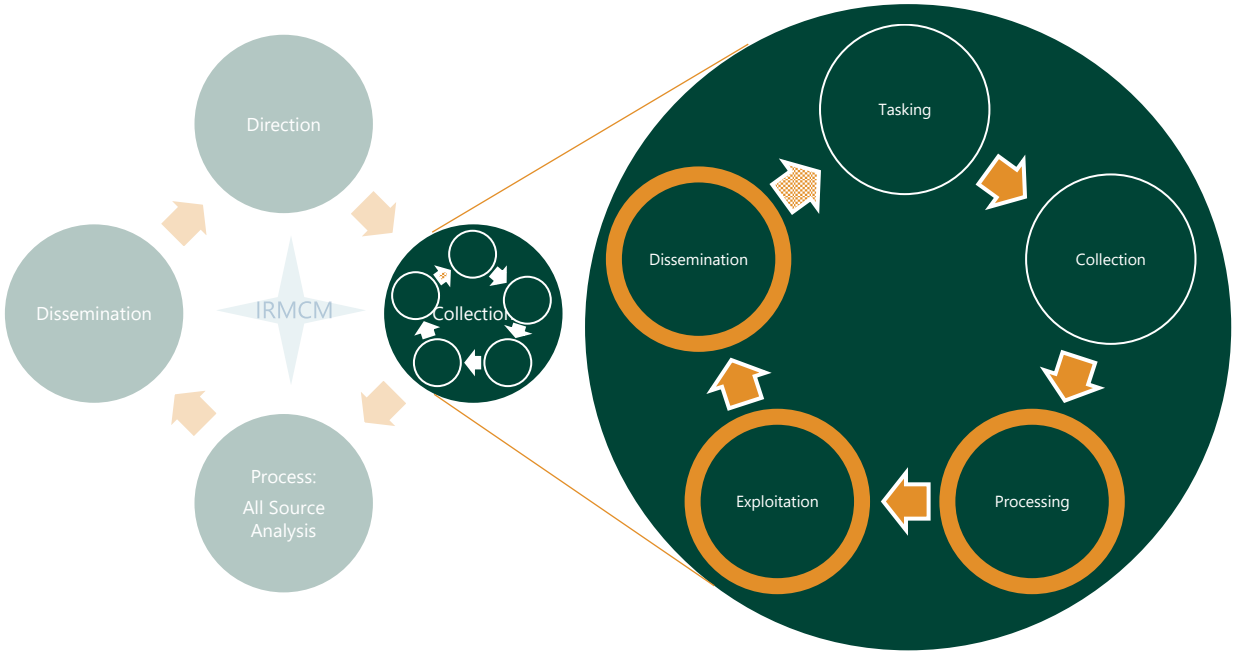


Figure 10.2: Small intelligence process steps in which respondents operated

The form that is used for these interviews can be found in appendices F (English) and H (Dutch). After the ethnographic research the interview form is adjusted to the form than can be found in appendices G (English) and I (Dutch). This second version of the interview form has a higher emphasis on verifying the observations of the ethnographic research and on creating more insights in these findings. Results of the semi-structured interviews can be found in appendix N.

10.2.4 Ethnographic research

After conducting several semi-structured interviews, ethnographic research is conducted at an international exercise. During this exercise, the process of squadron 108 was practiced. Squadron 108 conducts the small intelligence process. This exercise created the opportunity to observe the execution of the small intelligence process.

During the exercise the small intelligence process was conducted within the context of the major intelligence cycle. Several operators that operate within the major intelligence cycle also had a role

within the exercise. The total duration of the exercise was two weeks. Military personnel from allied nations were hosted and the exercise is executed, analysed and wrapped up within these weeks. Ethnographic research was conducted in four days of observation (31 October, 2 November, 4 November and 5 November). The research is conducted within this exercise at the single source analysts of 108 within the Analysis Cell process. The steps of the small intelligence process that are executed by the Analysis Cell are marked within figure 10.3.

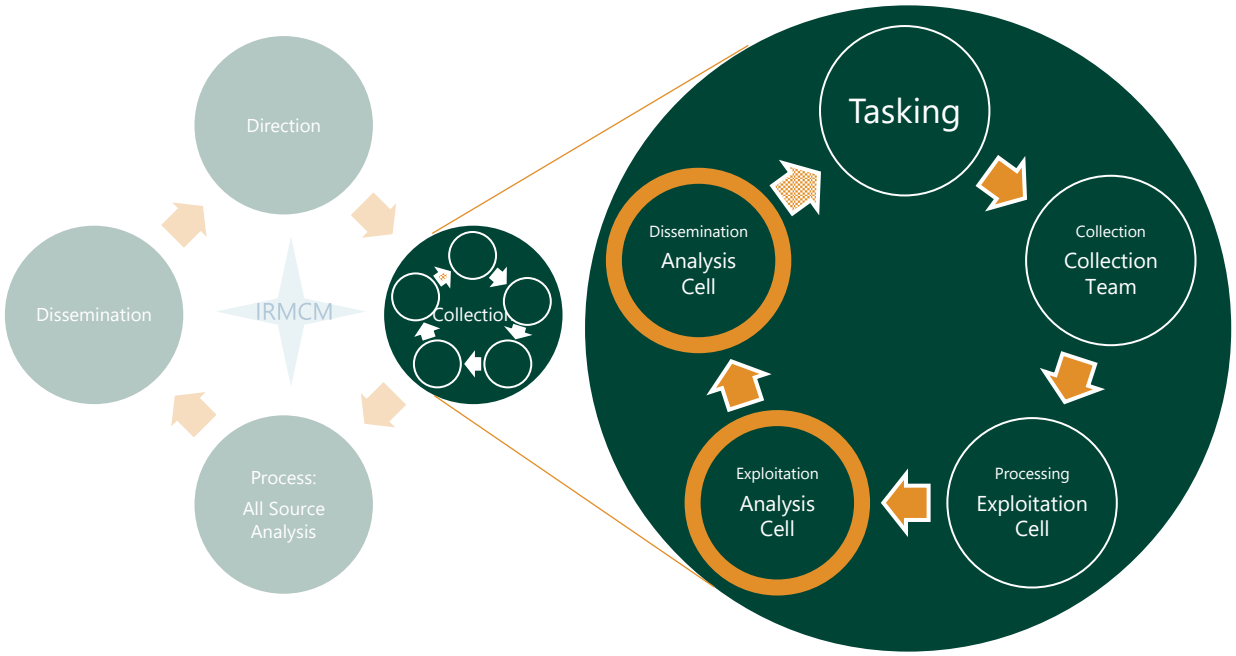


Figure 10.3: Small intelligence process steps (Analysis Cell) that are observed during ethnographic research

Within this Analysis Cell, multiple agents of different nationalities conducted the process of an SSA[18]. Information entered the process that was delivered by the collators of the process[19]. The analysts were very dependent on the input that was created by these agents, and the velocity of the information that entered the Analysis Cell subprocess was defined by the speed at which information was disseminated by the collators. The observant during this ethnographic research had insights in the information that entered the process, so the behaviour of the agents within the Analysis Cell can be compared to the identified velocity of information that came into the process of the Analysis Cell.

The forms that are used for the ethnographic research can be found in appendices J, K (English), L and M (Dutch). Results can be found in appendices O, P and Q.

10.2.5 Accuracy and quality

Within the data collection process of semi-structured interviews, a bridging approach is required to gather insights and findings about the trade-off between speed and accuracy[20]. The term *quality* is considered more understandable and neutral for the interviewed agents than the term *accuracy* and therefore it is easier to talk within these interviews about quality instead of accuracy. Quality does not exactly have the same definition as accuracy, although accuracy is a form of quality. The assumption is

[18] see also paragraph 8.8.2.6
[19] see also paragraph 8.8.2.5
[20] see also chapter 3

made that a high accuracy during the intelligence process will lead to intelligence products of higher quality.

10.2.6 Accuracy of the process and accuracy of the outcomes

The accuracy of the outcomes is an objective of this research. Accuracy of outcomes and accuracy of the process leading to them can be distinguished. This research focuses on accuracy of the outcomes. This concept will be measured by the semi-structured interviews and by the ethnographic research. Within the interviews, this accuracy of the outcomes can be measured through the perception of the respondent. During the ethnographic research, the agents will be observed during the process and the results will not be assessed. To measure the accuracy of the outcomes, it is assumed that the accuracy of the outcomes is defined by the level of accuracy that is used during the process. In some studies the quality of the process and the quality of the outcomes seem to correlate (Herek, Janis, & Huth, 1987). Within the interviews, this accuracy of the outcomes can be measured through the perception of the respondent. Within the ethnographic research, the accuracy of the outcomes is measured by measuring the accuracy of the process. Within this research the assumption is made the accuracy of the process is equal to the accuracy of the outcomes. No further distinction will be made between the accuracy of the outcomes and the accuracy of the process.

10.2.7 Information and data

The interviewed and observed operators analyse data and information that is given to them by the collectors within their specific unit. The type of input that is received depends on the squadrons the operators belong to. Parts of the received input can be classified as data, since no meaning was already given to the collected data, while other data that is received can be classified as information, since data was already interpreted by the collectors within the collection process. (Ackoff, 1989; Rowley, 2007). An overview of both types of data processes can be found in figure 10.4a and figure 10.4b.

Figure 10.4a: Data flow in case of the transmission of data from collectors to single source analysts

Figure 10.4b: Data flow in case of the transmission of information from collectors to single source analysts

Both data and information are analysed by the single source analysts who conduct the 'processing', 'exploitation', and the dissemination step of the small intelligence process. Data or information is communicated from the operators of the 'collection' step towards the operators of the 'processing' step as can be seen in figure 10.5.

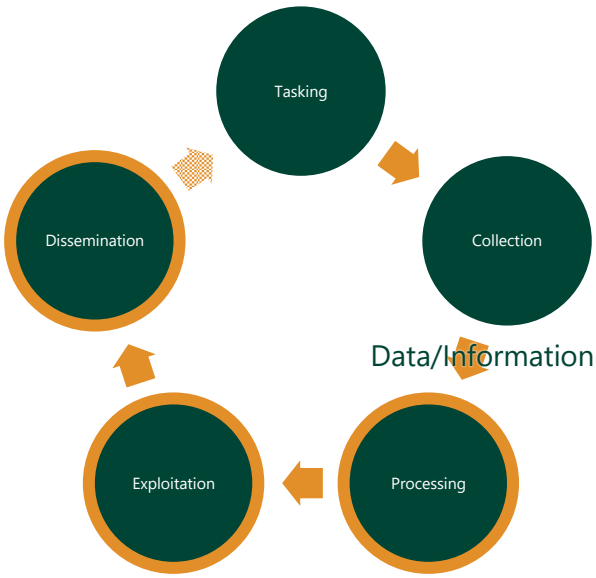


Figure 10.5: Small intelligence process steps in which respondents operated

Within the empirical research, the velocity of information is identified as the speed and mode of both data and information that is received by the analysts. No distinction will be made between data and information during the empirical research.

10.3 RESULTS

Observations are done during the semi-structured interviews and during the ethnographic research. The results of these methods of empirical research can be found in appendices N, O, P and Q. Categorised observations are discussed in appendices R and S. Results within the research framework are created based on the observations described in these appendices.

This paragraph addresses the results of both methods of empirical research by using the combined research framework as introduced in paragraph 5.2.

At first, the institutional context is described in paragraph 10.3.1. In next paragraph 10.3.2 a diagram is introduced that contributes to the identification of the factors that lead to a trade-off and to identify effects of velocity. After this, the factors that lead to a trade-off between speed and accuracy will be addressed in paragraph 10.3.3. In paragraph 10.3.4 the effects of velocity on these factors are addressed. At last in paragraph 10.3.5 the main research question will be addressed by describing the effects of velocity on the trade-off between speed and accuracy.

10.3.1 Institutional context

The analysis process is executed within a certain context. This context is defined by institutions: procedures, rules, legacy and values of JISTARC and its squadrons. These institutions define the context in which the trade-off between speed and accuracy is made.

10.3.1.1 *Safety*

Safety is a highly emphasised value during all JISTARC's operations according all respondents. Especially the data gathering process can be a dangerous process in which human lives are put at risk. Many data is gathered within the field, close to the enemy.

Within the sensor that creates intelligence by gathering electronic signals, operators drive around in vehicles close to the enemy to gather enemy-radio signals. If these operators are discovered by the enemy while they are too close, this can cause high risks for these operators.

Example 10.1: Safety of operators

Another aspect of the impact of safety is the low fault tolerance that is required in making decisions, decisions that are made by the intelligence that is created in the process of JISTARC. Since decisions are based on the intelligence process outcomes, the fault tolerance of the intelligence process outcomes is low as well.

The value of safety has an overarching influence within the institutional context. Other aspects of the institutional context are influenced by the value safety.

10.3.1.2 *Process context*

The analysis process of a sensor is part of a larger process: it is defined as the 'dissemination' and the 'exploitation' steps within the small intelligence process. The small intelligence process is part of the major intelligence process. Each process step is executed by agents. The steps that are (mainly) subject to this research within their context can be found in figure 10.6.

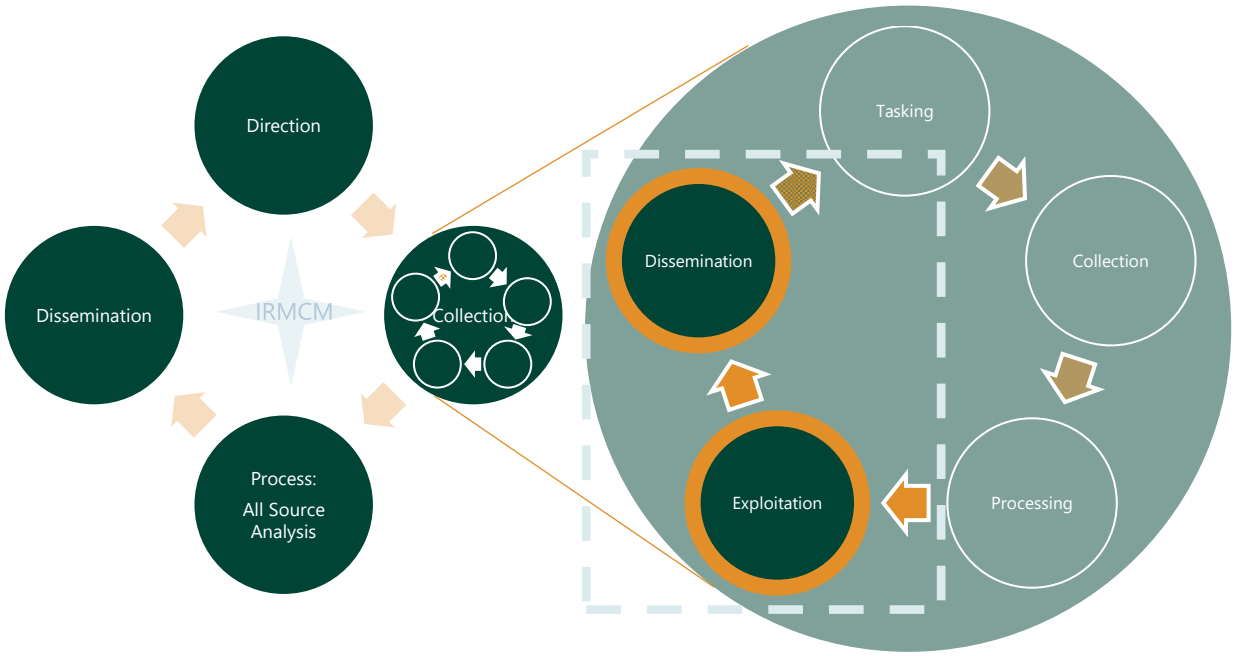


Figure 10.6: The analysis process within the small and major intelligence cycle.

All agents and processes contribute towards the same goal: finding answers to intelligence requests. The answers to the intelligence request contribute to the situational awareness of the decision-making commander. By use of this situational awareness, decisions can be made that should contribute to the goal of the mission and the safety of the agents of the mission. All decisions and activities are executed with the safety of agents as the most important constraint.

Collaboration with the agents that operate the other steps of the small and major intelligence process is important, since all agents contribute to a shared goal: to deliver answers to the intelligence requirements. Information is collected and needs to be analysed. All information that is collected needs to be analysed; all information that enters the intelligence process during collection should be

processed and analysed by the agents that operate within the intelligence process. The small intelligence process is executed by multiple sensors: delegates of the squadrons that are part of the JISTARC module during a missions or exercise. These multiple sensors execute the collection process (or the small intelligence process) in parallel as can be found in figure 10.7.

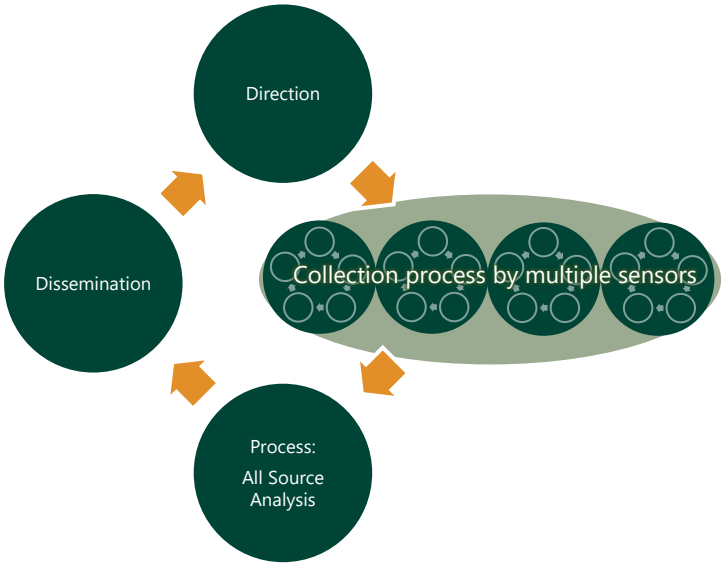


Figure 10.7: Execution of multiple small intelligence processes

All the sensors that execute the 'collection' step of the major intelligence cycle operate according a Standard Operating Procedure (SOP).

10.3.1.3 *Standard Operating Procedures*

The processes that are executed by the respondents are defined by the Standard Operating Procedures (SOP's) of JISTARC. Such SOP's define the process step-wise that should be executed within the data gathering and analysis process. Within the SOP the detailed execution of the small cycle, specific steps that should be executed and the specific agent that should execute these steps are all defined. Following these procedures should lead to a certain level of quality, because within this SOP data collection and analysis procedures are defined that include necessary quality control steps, like checking assumptions and defining certainty. These steps should lead to a certain level of quality. This quality control approached different by operators. Amongst the different squadrons, different quality control requirements are defined, mostly unwritten. Some requirements are defined as requirements to asses quality of the report itself, other requirements emphasise the quality of the assumptions and reasoning. The process of quality control within the small intelligence can be identified as an additional step within the small intelligence process steps as can be seen in figure 10.8. This quality control is usually done by agents that are responsible for the outcomes that are disseminated by the sensor, like the mission managers[21] or the platoon commander[22]. There will always be deviated from the SOP in case the safety of operators is at risk. There will always be deviated from the SOP in case the safety of operators is at risk.

[21] See also paragraph 9.6.2.2
[22] See also paragraph 9.6.2.3

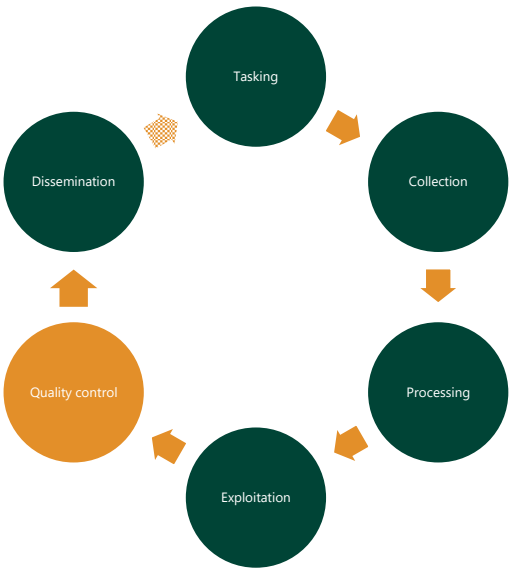


Figure 10.8: Small intelligence process including quality control

The SOP also defines how information is received, shared and disseminated with operators of other process steps.

10.3.1.4 *Information sharing*

Between operators of the steps of the major and small intelligence information needs to be shared. Most information within a JISTARC module is shared batch-wise. This mode of information sharing is caused by the operation method that are defined within the SOP. At the end of each subprocess within the major intelligence cycle, a report is constructed and disseminated to the operators of the next step. This method implies a filtering function for agents, since information is translated to a report, often in a compressed and filtered way. Information that is considered relevant is disseminated, information that is not considered relevant is not disseminated.

Figure 10.9: Batch-wise information flows through reports from between operators of major intelligence process steps

Within the small intelligence cycle, the mode of information sharing within the squadrons can be organised as a batch-wise process or as a (near) real-time process. This method depends on the method of information gathering and the possibilities to share information from the field with the analysts. Within some squadrons, collectors are constantly connected to the analysts and are able to share the gathered data and information instantly as can be seen in figure 10.10a. Within other squadrons, collectors collect information for a period in the field, come back to the SSAs and report the information that is collected during that time as can be seen in figure 10.10b. When information is shared in batches, a delay can be identified with the length of the duration of the process of making a report from information

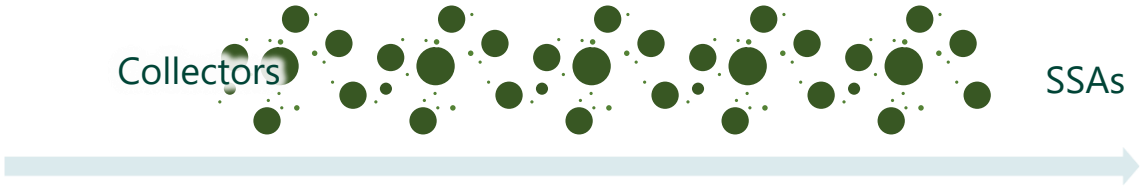


Figure 10.10a: Real-time information flow from collectors to SSAs

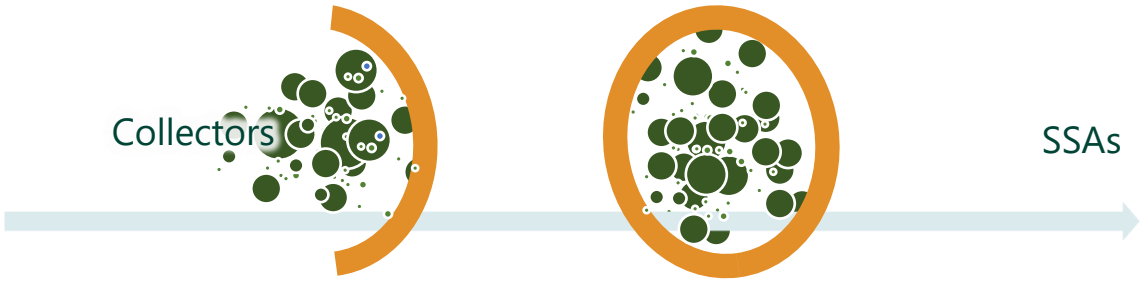


Figure 10.10b: Batch-wise information flow from collectors to SSAs

The SSAs analyse the received data and information towards an outcome that contribute to answering the intelligence requirements. All data and information that is received should be analysed. These results are disseminated to the operators of the next major intelligence process step: The All Source Intelligence Cell (ASIC) that conduct the 'processing' step of the major intelligence cycle. The ASIC combines the results of all sensors towards one answer to the intelligence requirement. The ASIC needs time to combine the results of all sensors, so the outcomes of the small intelligence process should be received in time, so enough time is left for the ASIC to conduct the analysis. To be able to collaborate effectively with operators of the different process steps of the small and the major intelligence cycle, a *battle rhythm* is defined during missions and exercises to structure cooperation between all operators of the mission, e.g. the ASIC and the sensors, and to set deadlines for the different operators to share information.

10.3.1.5 *Battle rhythm*

During missions and exercises, a battle rhythm is defined that structures the cooperation between different military units. This battle rhythm is often defined as a daily schedule in which meetings and briefings are defined. Based on this schedule, deadlines for information sharing are created. These deadlines are especially relevant within the context of the major intelligence cycle. The main deadlines that are identified is the deadline from the small intelligence cycle operators towards the ASIC and the dissemination of results towards answering the intelligence requirements that are received by the JISTARC module. Within figure 10.11 a graphical representation of deadlines within the battle rhythm of the major intelligence cycle is given.

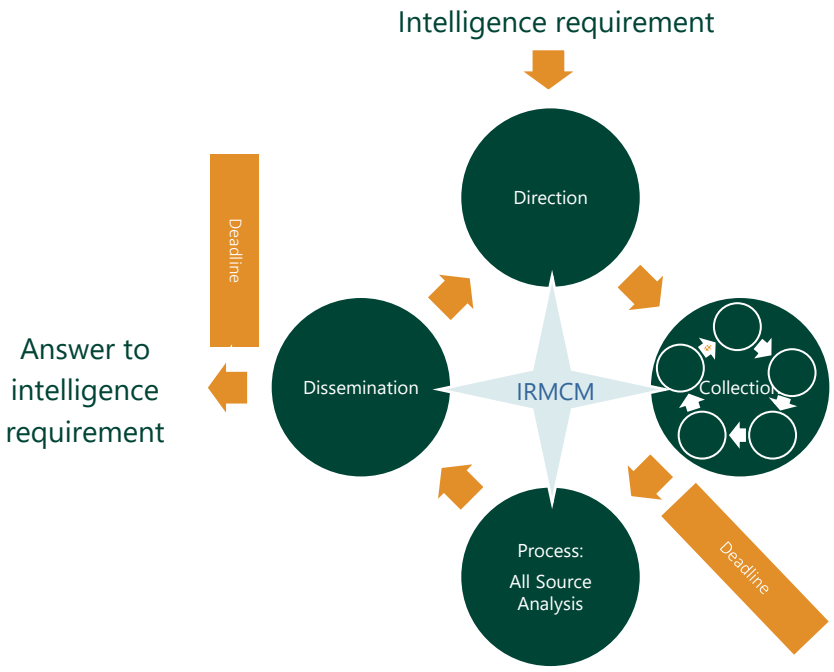


Figure 10.11: Deadlines within the major intelligence process

The deadline can be placed in the context of the small intelligence cycle in between the 'collection' and the 'processing' step, which is given in figure 10.12.

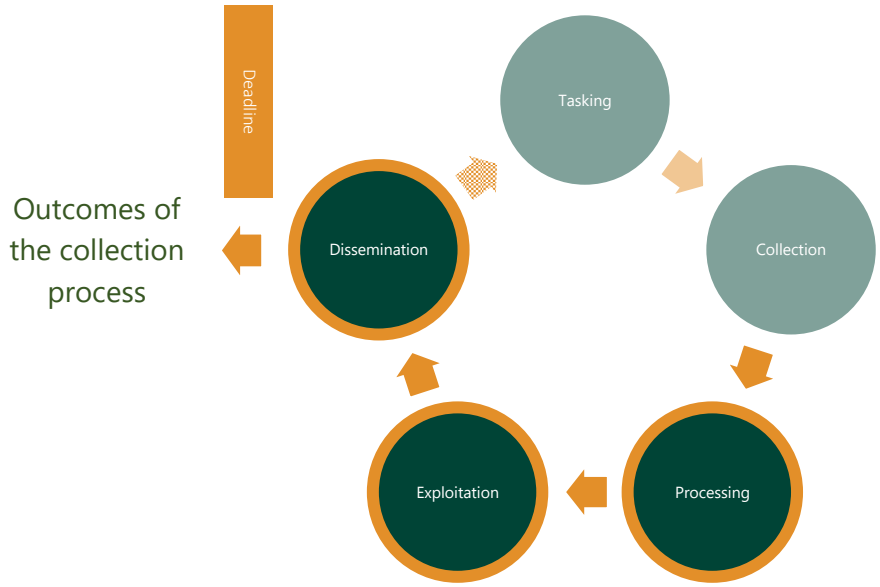


Figure 10.12: Deadline of the Analysis Cell within the small intelligence cycle

The deadlines defined by the battle rhythm lead to time constraints. The limited lead time requires a certain level of speed within the intelligence process. Sometimes these time constraints are pressing. Within the intelligence process, time constraints are often defined by *latest time information of value*

(LTIOV) of an intelligence request, which is a deadline after which the information is no longer of value. The answer to the intelligence request should be disseminated before the LTIOV, otherwise the intelligence is no longer of value.

10.3.1.6 *Supporting Systems*

Within the analysed situation, systems that support the analysis process are part of the institutional context. Examples of such systems are e.g. software packages that enable agents to understand and comprehend the content of the information that is received and needs to be analysed. Other supporting systems enable information sharing between agents that operate different subprocesses of the intelligence cycle, like a local network.

The institutional context as described above influences the trade-off between speed and accuracy that is made by operators. The next paragraphs discusses the found results about the trade-off that is made between speed and accuracy within the institutional context.

10.3.2 Diagram of research results

Within appendix T, the found relations between elements are presented within a causal diagram. By use of this diagram, the factors of the model as discussed in paragraph 5.2.1 are identified, which are the base, the sensitivity and the pivot. These factors are discussed within next paragraph 10.3.3. Within paragraph 10.3.4, the impact of velocity on the factors is identified using the same diagram. A simplified diagram of the diagram is presented in figure 10.13.

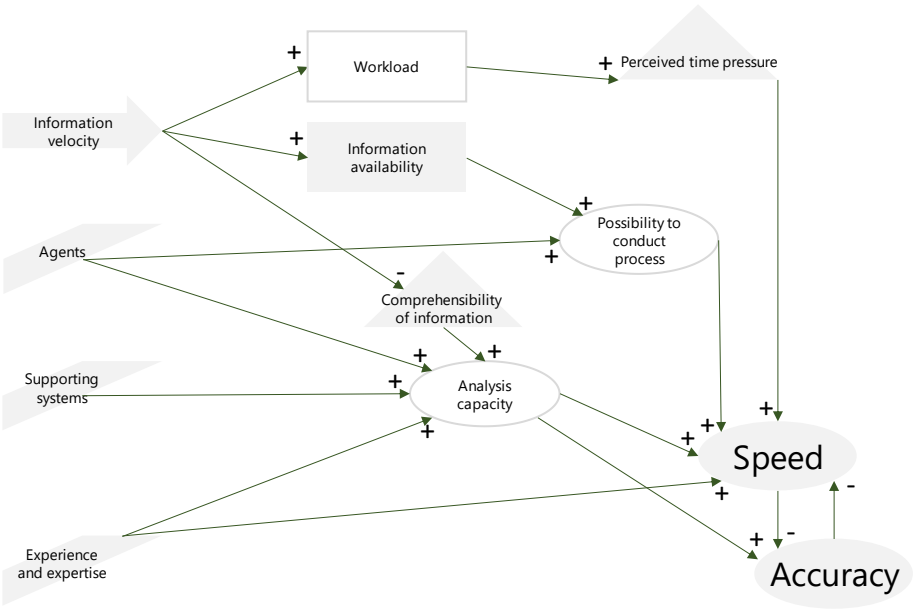


Figure 10.13: Simplified model of results diagram

10.3.3 The trade-off between speed and accuracy

A trade-off between speed and accuracy is made by agents that operate within the small intelligence cycle within the institutional context as described in paragraph 10.3.1. This trade-off between speed and accuracy is recognised during the ethnographic research, as can be seen in figure 10.14. A correlation coefficient of -0,9 is found between the levels of speed and accuracy. The datapoints on (1,1) are not taken into account within this coefficient, since the process was not executed at those moments and no trade-offs between speed and accuracy were made during those moments.

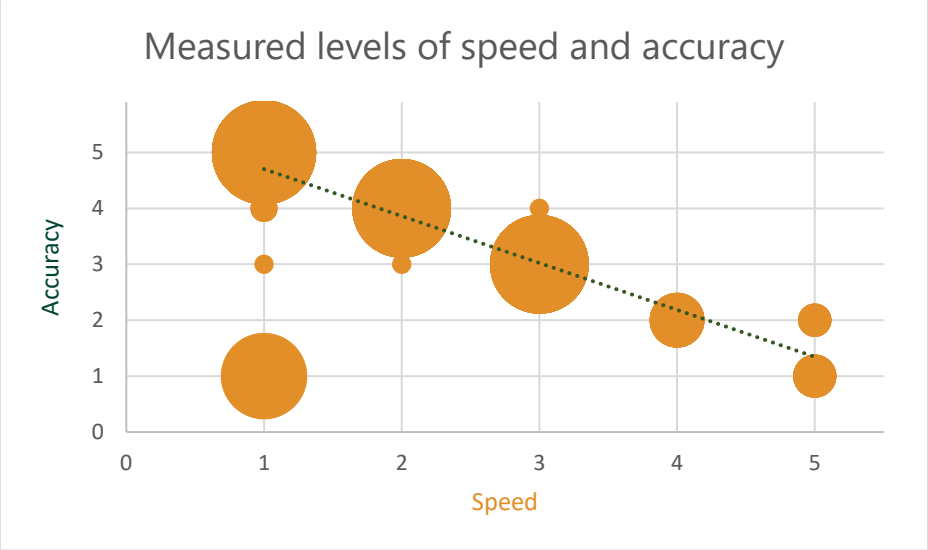


Figure 10.14: Correlation between speed and accuracy
Size of bubble shows the number of datapoints that are gathered during the research
Trendline through datapoints, the datapoints on (1,1) are not taken into account

The trade-off can be addressed by the identification of three factors: the base, the sensitivity and the pivot[23]. These factors influence the trade-off that is made between speed and accuracy. By addressing these factors, an understanding is created to address the main research question.

10.3.3.1 *Base*

The base is a factor that influences the trade-off that is made. This factor defines the required enablers that are necessary to conduct the process and to be able to achieve some speed and accuracy that lead. The identified aspects that are part of the base are *information availability, start-up time*, and *agent availability* and will be discussed within next paragraphs.

Information is needed to enable speed and accuracy

The analysis process cannot be started unless there is data or information available to analyse. If this is missing, the process cannot be started. No speed and no accuracy can be achieved if the information availability is zero. Within the institutional context, information is received by the predecessors in the process. Since information is usually shared batch-wise, a subprocess of the predecessors in the intelligence process should be finished before information is received by the analysts. The information within the analysis (sub) process in this context is a resource that can deplete. When all information is analysed and the results are transferred to the successors within the process, the analysis cannot be improved further, and the accuracy cannot be further increased.

"We still don't have any reports received, so there is nothing to analyse."

Quote 10.1

Start-up time is needed to enable speed and accuracy

Before some accuracy can be achieved within the analysis process, time is needed. During this start-up time, no accuracy can be achieved although the lead time of the process decreases. The start-up time

[23] See also paragraph 3.3 and paragraph 5.2

of a process is needed to understand the information that is received and to achieve some level of accuracy of the outcomes.

Agents are needed to enable speed and accuracy
Within the institutional context, the analysis process is conducted by agents; the analysis cannot be done without human resources. The last elements of the base that is considered a requisite of the analysis process is the agent that analyses information towards outcomes. Without human agents, no analysis process can be conducted, and no speed and no accuracy can be achieved within the process. The availability of agents in the analysis process is influenced by the institutional context. If agents are also assigned to other responsibilities, the availability of agents for the analysis process is lower (and at some moments even zero) than when agents are assigned full-time to the analysis process. If at a moment no agent is available to conduct the analysis process, this will lead to little or no process execution and to zero achievement in speed and accuracy.

The capabilities of the agent to create intelligence from information is not a part of the base, but part of the sensitivity as described in paragraph 10.3.2.2. The extent to which these capabilities are used are caused by other behavioural aspect that are part of the pivot and will be discussed in paragraph 10.3.2.3.

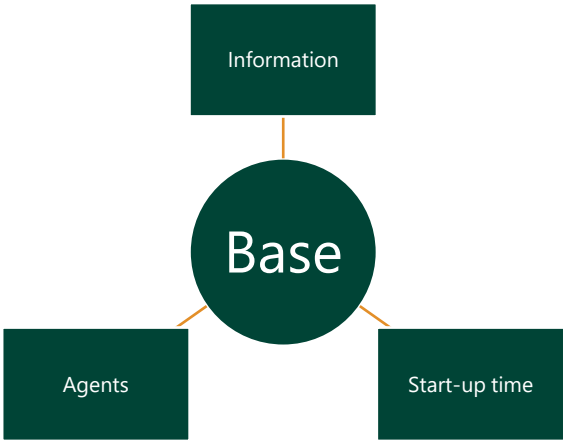


Figure 10.15: The elements of the base

10.3.3.2 *Sensitivity*
The sensitivity is the decrease of accuracy that is caused by the increase of speed and vice versa. A higher sensitivity means a higher capability to create fast and accurate results from information. Within the context as described in paragraph 10.3.1, three elements are identified to contribute: *the expertise of agents*, *the experience of agents* and *supporting systems.*

Expertise of agents contributes to the analysis capacity
The expertise of agents can contribute to a higher sensitivity between speed and accuracy. The processing time of a more skilled agent is shorter than the processing time of less skilled agents. These skills can concern the ability to use supporting systems such as software packages or the understanding of the content of the information that needs to be analysed. An agent with a lot of expertise can create the same outcomes within less time than an agent that has little expertise in the analysis process.

"Each agent within the squadron gets education to be able to conduct the analysis process and to understand the received input to create intelligence. If you do not understand battle practices, you cannot understand what the enemy is doing."

Experience of agents contributes to the analysis capacity
Experience affects the height of the levels of speed and accuracy that are achieved during a process. Agents with a lot of experience can put gathered data into the context of other experiences from their past. This experience gives agents the capacity to give meaning to incoming data and information and gives the agent the opportunity to conduct the analysing process with a higher speed. The total lead time of the process can be decreased by the experience of agents. A higher total of both accuracy and speed can be achieved by the positive effects of experience.

"I know where these photos are made. We just have to check whether I am correct."

Quote 10.3

More agents contribute to the analysis capacity
When more agents are part of the team of analysts, the analysis of information can be conducted at a higher speed since more analysing capacity is available. The lead time of the process can be reduced or more time can be spent to increase the accuracy of the outcomes of the analysis.

"Agent x and agent y are not present, they should stay longer this evening to finish the analysis."

Quote 10.4

Supporting systems contribute to the analysis capacity
Within the analysis process, other elements are identified that contribute to the capacity of agents to create a level of accuracy within a time frame. Such elements within the research are software packages that support analysts within their analysis by enabling the agent to conduct the process at a higher pace. Supporting elements can also contribute to the process by making information more comprehensible for the agent. If incoming information is understood better, a more accurate analysis can be done of the information.

"The software package helps us, analysts, to relate pieces of information to each other, so we can understand better how the situation can be explained."

Quote 10.5

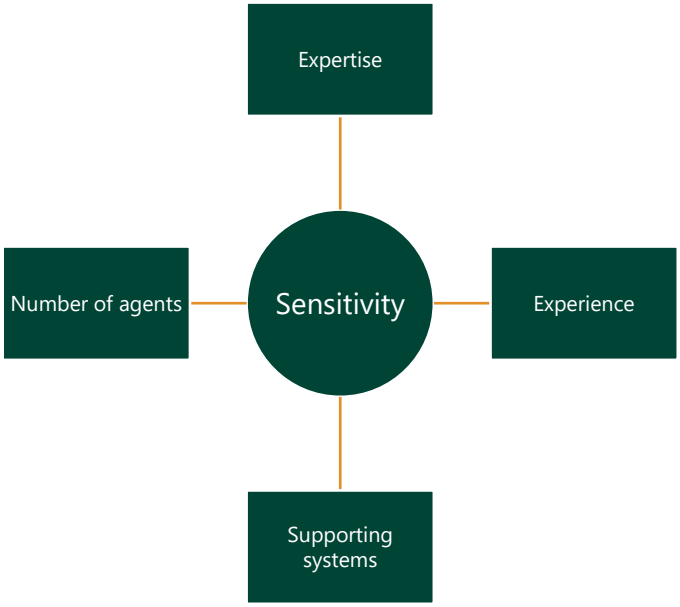


Figure 10.16: The elements of sensitivity

10.3.3.1 *Pivot*

The pivot of a trade-off is the factor of the trade-off that can differ through the process and influences the actual levels of the objectives that are achieved during the process. The pivot factor is twofold: the pivot influences the sum of the total of the levels through the efficacy of the analysis capacity, but also how the two objectives of speed and accuracy are balanced by agents. Elements that are found to be part of the pivot are *time pressure, considered importance of speed, considered importance of accuracy, transparency, perceived expectations, personal preferences, motivation, transparency* and *comprehensibility.*

Higher time pressure leads to a higher sum of the levels of speed and accuracy

The institutional context defines deadlines that are fixed. This type of time pressure is influenced by the time that is left before the deadline combined with the work that is left. Another moment when time pressure increases is when agents experience a high urgency of the analysis. When agents perceive higher time pressure, more accuracy and speed can be achieved by the agents because agents are motivated to finish the analysis in time. Also, a shift in the balance between speed and accuracy is found.

When deadlines came closer and still much work had to be done, agents were working more accurate and with higher speed than at other moments.

Example 10.1

Higher time pressure leads to more emphasis on speed
The institutional context defines that deadlines that must be met and all incoming information should be analysed, so the time available to analyse the information is limited. When a deadline comes closer or the perceived workload is higher, the emphasis within the speed-accuracy trade-off is put on speed. Because all work should be done before the deadline as described within paragraph 10.3.1.4.

Urgent information leads to more emphasis on speed and a higher sum of the levels of speed and accuracy
Another moment when time pressure is experienced is in case information has a high urgency to analyse. Such information changes fast and action should be taken fast as well, information with high volatility that is considered important leads to time pressure within the analysis process. Agents are motivated to deliver intelligence in time; safety is often involved during such situations. Because action should be taken fast within such situations, the speed of the process is considered more important than following the SOP. Quality control steps are skipped: a decrease in the accuracy of the outcomes is identified because action should be taken fast by the found insights: the lead time should be decreased as much as possible. The importance of speed is considered high in case of important volatile information.

"We know it [the outcome], action should be taken now. I am certain enough about this outcome and therefore I will communicate it immediately to the Chief Operations, so we can go there now."

Quote 10.6

Expertise of agents leads to more emphasis on speed
How the trade-off is made between speed and accuracy is affected by the expertise of an agent within the institutional context as described in 10.3.1. Agents with a lot of expertise are aware of the importance of the deadlines that are caused by the institutional context of the intelligence process. If these deadlines are not met, other agents within other parts of the process are delayed within their processes or within the decisions that should be made. Such delays should be avoided. When agents have expertise, they are often aware of the importance of these deadlines. The importance of these deadlines is defined by the institutional context in which the agent operates. Within the institutional context of research this importance is very high, therefore speed is given a higher emphasis by more experienced agents than by less experienced agents.

"Especially inexperienced colleagues tend to dive into the analysis and forget to write the report. When the deadline is almost there, they don't have enough time left to write the report and sometimes they even ask for an extension of the deadline. An extension of the deadline is no option, reports should be communicated in time. You learn such things in time. "

Quote 10.7

Low considered importance of the quality of outcomes leads to less emphasis on accuracy

When outcomes of the process are considered less important, for example because the outcomes are just a small part of the information that is used to enable the decision-maker to make an informed decision, less emphasis is put on the accuracy of the outcomes. The relevance of the outcomes of the process is defined by the institutional context which defines the role of the outcomes of the process within the decision-making process.

"Our report is just a part of the total intelligence product "

Quote 10.8

Long lead times of the leads to more emphasis on accuracy

When the agents perceive high expectations from agents outside of the process about the results of the process, this leads to high considered importance of the quality of the outcomes of the process because agents want to comply to expectations. This considered importance of quality leads to an emphasise the accuracy of the outcomes. High perceived expectations within the institutional context are caused by long lead times; when a process takes longer, the expectations about the outcomes are (considered) higher.

"Because it takes a lot of time before we can deliver intelligence, other people expect us to deliver high results. To justify our long process, we must deliver high quality intelligence. We'd rather deliver our results later than being unsatisfied about the quality of the report. "

Quote 10.9

Higher transparency about the accuracy of outcomes leads to less emphasis on accuracy

When the agents of a previous subprocess can be transparent about the accuracy of the outcomes towards the agents of the next subprocess, less emphasis is put on the accuracy compared to speed. Because the decision-maker is aware of the accuracy of the information on which a decision is based, this accuracy can be considered while deciding

"If we are not 100% sure about the analysis, we communicate our uncertainties about these results. Other analysts or the commander can take these uncertainties into account within their analyses or decision."

Quote 10.10

Motivation leads to a higher sum of the levels of speed and accuracy

Differences between agents and differences in time of the same agent lead to insights of the impact of the motivation of an agent. Motivation can lead to concentration, which leads to a higher sum of the levels of speed and accuracy.

"Come on guys, the exercise only last for 2 more days. I expect you to work your best for the time that is left, just like we do."

Quote 10.11

More comprehensible incoming information leads to a higher sum of the levels of speed and accuracy

The speed at which information is processed and analysed increases when information is less comprehensible. Therefore, more comprehensible information can lead to a decrease in lead time and less accurate outcomes can be created within the same time (deadlines).

"Through the system the received input is made comprehensible, so it is understandable to analyse. Therefore, we can deliver better results within the same time. Otherwise, the overload of information paralyses us."

Quote 10.12

Personal preferences can lead to more emphasis on speed or accuracy

The trade-off that is made by different agents is influenced by the personal values and preferences of agents. The behaviour of different agents is different during the analysis process. Personal values and behaviour can be influenced by the specific context of the agent, e.g. in which squadron the agent operates. Within some squadrons the accuracy of the outcomes is considered more important than the speed of the process, while in other squadrons the speed of the process is considered more important. Agents are influenced by their specific context and their behaviour is influenced by this specific context. Personal preferences can be influenced by many other factors as well, which are difficult to define within the context of the analysis process of JISTARC.

"Quality is always considered more important than speed."

Quote 10.13

"Meeting deadlines is always more important than being 100% certain about the outcomes."

Quote 10.14

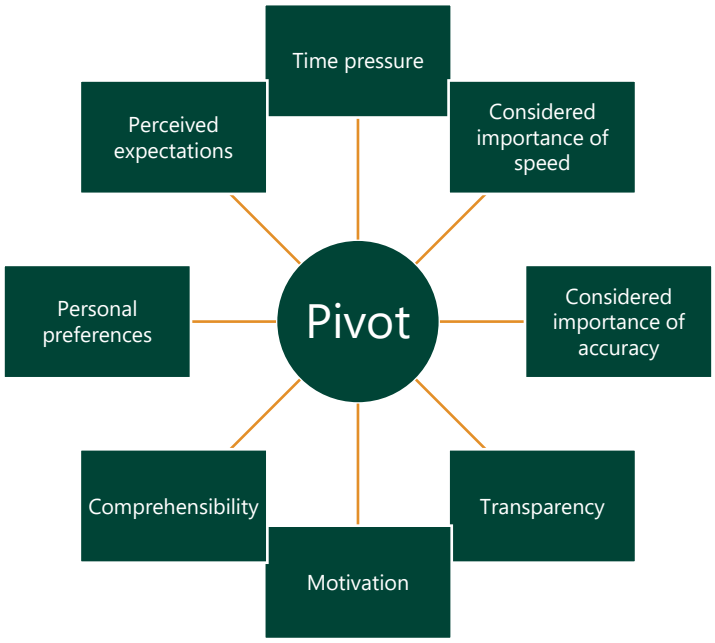


Figure 10.17: Elements of the pivot

10.3.4 The impact of velocity on the factors of the speed-accuracy trade-off

Velocity influences the trade-off that is made between speed and accuracy within the analysis process of the small intelligence cycle within a military organisation like JISTARC. These effects can be identified by the three elements that lead to a trade-off: the base, the sensitivity and the pivot. The influence of velocity on the identified aspects of the elements of the model, as discussed in previous paragraph 10.3.2, will be described in next paragraphs.

10.3.4.1 *Base*

The identified base consists of *information availability, start-up time*, and *agent availability*.

Velocity can influence the base through the information availability, but velocity is not proofed to have impact on the agent availability and the start-up time within a process.

Higher velocity leads to higher information availability
When the speed of information is higher, more information enters the process within the same timeframe, so more information is available to analyse. Available information is a resource for the analysis process. When there is more information available to analyse, this resource is less likely to deplete. Therefore, more time is available for the analysis itself, which creates more time to increase accuracy and a higher sum of the levels of speed and accuracy can be achieved.

Another aspect of velocity, the mode of the information flow, will affect the information availability. Within the current context, information is shared batch-wise which causes a delay of a subprocess length for the information to enter the next subprocess. If information flows instantly through the process, the information flow would not (or less) be delayed. When data or information is shared in a (near) real time method, data and information is available earlier to the analysts earlier in the process, which decreases the waiting period for the analysts. This mode of information sharing leads to less unavailability of information to analyse. If no time is lost because of the unavailability of information, more time is available to conduct the analysis which enables a higher sum of the levels of speed and accuracy.

These two aspects of velocity impact the speed-accuracy trade-off only if the information is the only missing requisite that is needed to conduct the analysis process.

10.3.4.2 *Sensitivity*
The identified sensitivity consists of *the expertise of agents*, *the experience of agents, supporting systems and the number of agents.*

Velocity does not affect the elements of sensitivity that influences the trade-off
Supporting systems and the expertise and experience of agents lead to more analysis capacity. When more information enters the process, it is not proofed the speed of the incoming information will increase the analysis speed, nor influence the effect of systems, expertise or experience on the sensitivity.

10.3.4.3 *Pivot*
The identified pivot consists of *time pressure, considered importance of speed, considered importance of accuracy, transparency, perceived expectations, personal preferences, motivation, transparency* and *comprehensibility.* Velocity influences (direct and indirect) all these elements.

Velocity increases time pressure

The workload of analysing agents is determined by the volume of the information that should be analysed. The institutional context defines all incoming information should be analysed and deadlines are fixed that limit the time available to conduct the analysis. Within this context, a higher volume of information that should be analysed leads to a higher workload. Information that is received at a higher speed lead to a higher volume of information that needs to be analysed, which increases the workload. Since the time available for the analysis is fixed, a higher speed of analysis is required to analyse all incoming information. When more analysis had to be done within the same time, the time pressure increases. This increased time pressure increases the sum of the levels of speed and accuracy and emphasises the speed within the speed-accuracy trade-off.

After multiple reports were received within a short time frame, agents had the idea information kept coming and the work load was higher compared to the time available than earlier in the process.

Example 10.2

Time pressure is a factor that is influenced by the time available and the workload of an agent but is a factor that is influenced by the perception of the agent too. High speed information can cause a higher perceived workload as well.

Low velocity increases the considered importance of quality

When the information speed is the missing requisite of the process and the absence of information causes delays in the process, the speed at which intelligence can be created is very low as well. When intelligence can only be delivered after a usually long process, the expected quality of the delivered intelligence is high. These perceptions lead to an emphasis on accuracy instead of speed when agents want to comply to these (perceived) expectations. Compliance to the expectations leads to a high considered importance of quality which leads to an emphasis on accuracy. Therefore, low velocity leads to an emphasis on accuracy.

"Because we cannot gather data in a fast way, our process takes longer than the process of other sensors. Therefore, the quality of the outcomes must be high."

Quote 10.15

Volatility of information increases motivation

When information volatility goes along with urgency, the time pressure and motivation of agents increases. Information should be analysed quickly, and higher levels of speed and accuracy are achieved. This increased sum is caused by time pressure and an increased motivation, which leads to higher concentration of the agent. The capabilities to transform the resources (information) into outcomes is temporarily increased. The time pressure an increase in the

"If a situation is urgent and we know that, we want to deliver intelligence to take action as soon as possible."

Quote 10.16

Higher speed of information leads to a less comprehensibility of information

When information is received at higher speed, more information should be processed by the analysts within a time frame. Less time is available to comprehend each piece

"An information overload paralyzes us because the information is not understandable anymore."

Quote 10.17

of information, which leads to less comprehensibility of the incoming information.

10.3.5 Effects of information velocity on the trade-off between speed and accuracy

The results as discussed in paragraph 10.3.2 and paragraph 10.3.3 are combined into insights in how information velocity will affect the trade-off between speed and accuracy. These insights are discussed in the next paragraphs.

Velocity leads to an emphasis on speed when deadlines are fixed

If information velocity is higher and more information is received within a timespan of a process, the total volume of information increases. Since all incoming information must be analysed by the analysts and the timespan is fixed because of the deadlines defined by the battle rhythm, a higher information velocity will lead to a higher workload. Information that enters the process at a high speed can lead to a higher (perceived) information volume and therefore a higher workload. If the (perceived) workload of agents is higher, the (perceived) importance of the speed increase, and therefore the emphasis on speed within the speed-accuracy trade-off increases as well. Therefore, a higher velocity leads to more emphasis on speed compared to accuracy within the trade-off.

Low information velocity leads to an emphasis on accuracy

Very low information velocity can lead to a slow intelligence process. The (perceived) expected quality of the outcomes is considered high when an agent operates within a relatively slow intelligence process. This perceived expected quality leads to an emphasis on accuracy within the speed-accuracy trade-off.

High speed information can lead to a lower sum of the levels of speed and accuracy

If information enters the analysis process at a higher speed than is comprehensible by the analysing agents, the start-up time increases and the analysis speed decreases. It takes longer for the analyst to understand the pieces of information and to understand the situation about which intelligence is created. A high information speed that is considered an overload by the agent can lead to a lower sum of speed and accuracy.

Batch-wise information sharing leads to a lower sum of the levels of speed and accuracy

Because the batch-wise information sharing causes delays in the information stream through the process, less time is available for the analysis. This leads to lower available lead time, which lead to a decrease in the sum of speed and accuracy.

Higher information volatility leads to an emphasis on speed

If information is relevant for just a short time, higher levels of speed and accuracy can be achieved. This increase in the sum of these levels is considered to be caused by time pressure and the motivation of agents, that perceive a sense of urgency.

10.4 CONCLUSION

Information velocity consists of three elements: speed of information, information continuity and information volatility[24]. Increased speed of information can increase information availability. When the information availability is not the only missing requisite of the process, higher speed of information does not increase the sum of the levels of speed and accuracy but leads to an emphasis on speed within a context in which deadlines are fixed. High speed information can also lead to an overload of information. An overload of information decreases the comprehensibility and decreases the analysis capacity, which leads to lower speed and accuracy.

[24] See also paragraph 2.2

11 Policy advice

11.1 INTRODUCTION

The effects of velocity on the trade-off that is made between speed and accuracy are described in chapter 10. By combining these outcomes with the context of squadron 108 and JISTARC, a policy advice is composed to advise squadron 108 of JISTARC about the effects of velocity on the trade-off between speed and accuracy.

The speed within the speed-accuracy trade-off defines the speed by which intelligence can be created and given to the decision-making commander. The accuracy is part of the quality of the intelligence that is used to make informed decisions. The trade-off between speed and accuracy should be made in a way within the intelligence process that is suitable for the required intelligence. This trade-off is influenced by velocity, which is likely to increase in the next years. This increasing velocity brings challenges to the intelligence processes, because the speed-accuracy trade-off is made differently when velocity changes. Increases information velocity can also bring opportunities to JISTARC and specifically squadron 108.

11.2 ANALYSIS OF STRENGTHS AND WEAKNESSES

The current strengths and weaknesses of the small intelligence process of 108 concerning the speed-accuracy trade-off can be discussed, which is useful to identify opportunities and threats. These opportunities and threats will be described in case of increasing velocity. The opportunities and threats create understanding about the robustness and resilience of the process of 108. The four quadrants are displayed in figure 11.1.

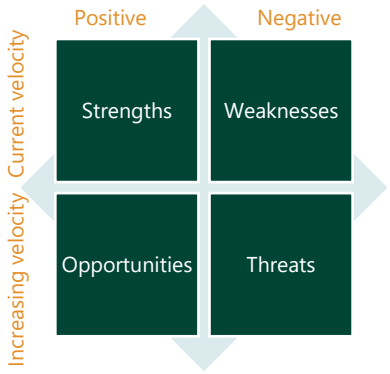


Figure 11.1: Analysis matrix

11.2.1 Strengths of the current process

In the search for and the identification of factors that lead to a trade-off between speed and accuracy within an intelligence process such as the process of squadron 108, strengths about the process are found which will be discussed in next paragraphs.

11.2.1.1 *Threats to the force and threats to the mission*

A strength of the current analysis process of the squadrons of JISTARC is the way in which information which is considered a threat to the force or a threat to the mission is treated. Such information has often a high veracity and urgency: the information has only a temporal validity and action should be taken fast. The agents within the process understand the urgency of intelligence and speed up the process when this is needed. Agents are motivated to contribute to fast and accurate action within such cases, which requires a short lead time and a high accuracy of the outcomes of the process. Steps within the intelligence process can be skipped by these agents to achieve a higher decision-making speed when this is needed as can be seen in figure 11.2. The autonomy of the agent can contribute to the decision speed when this is needed.

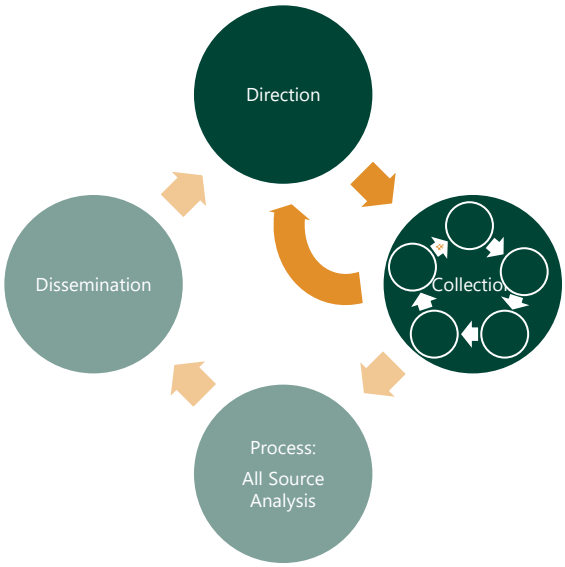


Figure 11.2: A shortcut in case of a threat to the force/mission

11.2.1.2 *Cooperation through battle rhythm*

Battle rhythm defines deadlines that facilitate the cooperation between agents that operate different processes. Because of the deadlines that are defined within this battle rhythm, agents know when to finish their analysis and to deliver the results to the operators of the subsequent process. Agreements

lead to clarity and operators often know by when they will receive new input for their process. If results are delivered by the squadron in time, the analysists of the All Source Intelligence Cell have time to conduct their follow up process (which is the combination of the intelligence of all sensors) and to create answers to the intelligence requests that are received by the JISTARC module.

Squadron 108 consists of more subprocesses than other squadrons that are each exploited by different agents, which increases the relevance of agreements and deadlines within the process.

11.2.1.3 *Flexibility of adjusting speed to be ready before the deadline*

If more information is received, the workload is higher, and agents often work faster to be able to analyse all information. The importance of being ready before the deadline to collaborate with other operators in both the small and major intelligence cycle is considered high. Therefore, time pressure increases in case of a higher workload. The speed of the process can be adjusted so all information can be analysed before the deadline. A comprehensive overview of this effect can be found in figure 11.3.

Figure 11.3: Adjusting speed by higher workload

11.2.1.4 *Transparency about accuracy*

Agents within squadrons emphasise the importance of transparency if the accuracy of the outcomes is not high enough to base decisions on. Because the accuracy of results can be shared, the considered importance of the accuracy of the outcomes is lower than when this aspect could not be shared. Because the ASIC or the decision-maker is aware of the accuracy of the outcomes, decisions that are based on the outcomes are not based on information that is unconsciously less accurate than expected. When a decision that is made by a commander entails high risks for soldiers, the accuracy of the information that is used for such is known and can be considered in making the decision.

11.2.2 Weaknesses of the current process

The intelligence process of squadron 108 has weaknesses which are found in the identification of factors that lead to a trade-off between speed and accuracy. These weaknesses of 108's process are discussed in next paragraphs.

11.2.2.1 *Batch-wise information sharing causes delays*

The current intelligence process is based on information that is transferred in reports, which are batches of information. After each subprocess is finished, a report is constructed which is communicated towards the operators of the next subprocess. Each subprocess causes a delay, which means that after each subprocess information is shared with a delay of the duration of that subprocess.

Different agents conduct different subprocesses of the (major and small) intelligence cycle. This separation of responsibilities and the division of tasks lead to a fragmentation of the intelligence process. Information flows through the process from subprocess to subprocess and delays are caused by the duration of these subprocesses.

Squadron 108 conducts the small intelligence cycle for information that can be gathered from DMAT (DNA, Materiel, Attributes and Traces). After DMAT is collected by the Collection Team the DMAT is passed to the Exploitation Cell which exploits the DMAT and transform it into information. The Exploitation Cell which consists of multiple subprocesses. After each subprocess, information is shared with the Analysis Cell. These multiple subprocesses cause delays in the information flow, because information is shared batch-wise after each subprocess. Because more subprocesses are defined within squadron 108 compared to other squadrons, the delay of the information flow is higher. The delays

that can occur by the different subprocesses in 108 are marked in figure 11.4. The delays of information impact the Exploitation Cell, the Analysis Cell and the ASIC.

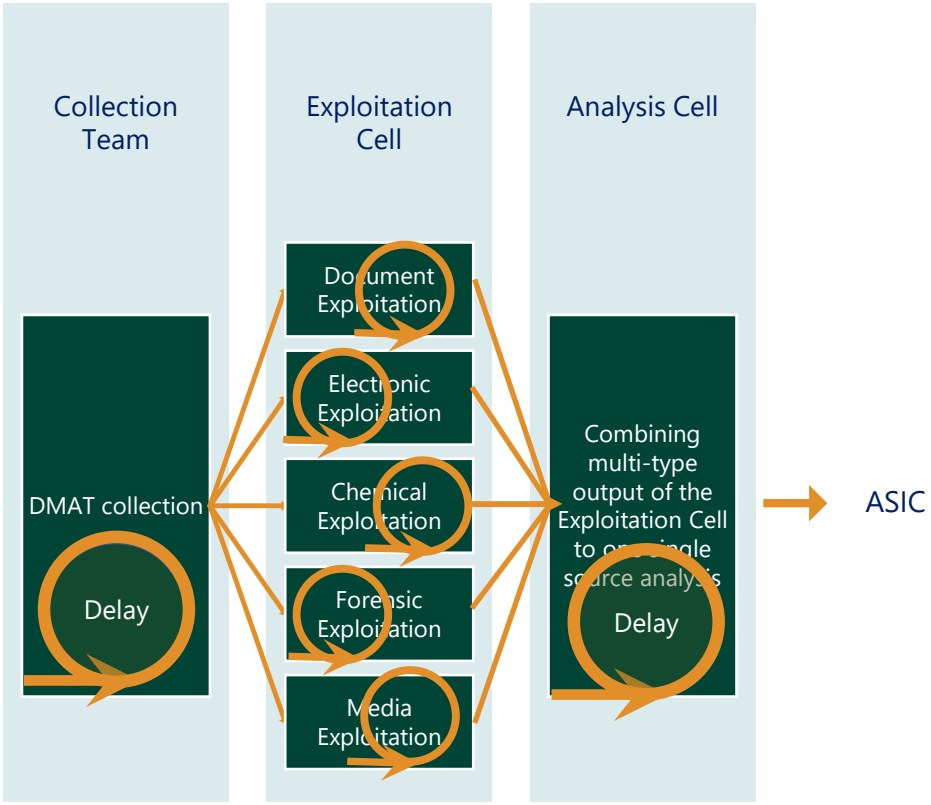


Figure 11.4: Information delays within the process of squadron 108

11.2.2.2 *Deadlines decrease accuracy*

The deadlines that are defined by the battle rhythm affect the considered importance of speed. The deadlines increase the time pressure, which leads to a higher work speed. When more speed is used in the process, this goes usually along with a decrease in accuracy. The decrease in accuracy is not always a conscious choice but implied by the increase of speed. If intelligence requires high accuracy, this requirement can be neglected by the deadlines that are set. This effect can be found in figure 11.5.

Figure 11.5: Deadlines decrease accuracy

11.2.2.3 *Sharing reports instead of all information can lead to the loss of important intelligence*

Usually only reports are shared by analysts with operators of the subsequent process step. If relevant information is not recognised by the Analysis Cell, the information is not shared with the ASIC as is illustrated in figure 11.6. Since each sensor also possess information about some elements of the mission's situation, some relevant insights can only be found when combining the outcomes of different sensors. If the relevance of such information is not found within the sensor itself, the information is probably not shared, and the relevant outcomes cannot be found.

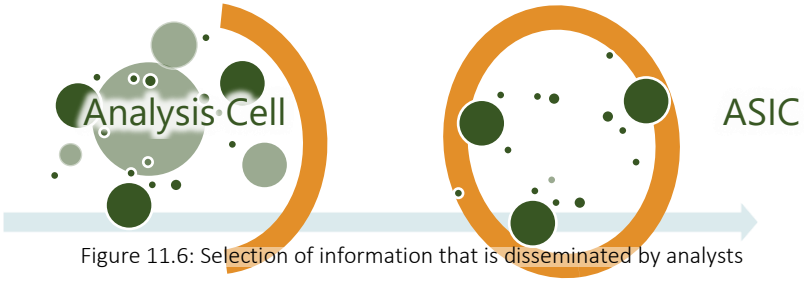


Figure 11.6: Selection of information that is disseminated by analysts

11.2.2.4 *Lack of transparency between sub-processes causes unclarity about workload*

The workload of the operators in de process is defined by the information that is collected by the Collection Team. The perceived total workload of the operators of the Analysis Cell is influenced by what is received from the Exploitation Cell. The perceived workload is dependent on what is received by the analysts, and not by the actual workload. When the perceived workload and the actual workload are very different, the trade-offs that are made between speed and accuracy might not entail the trade-off that is made if the agent is aware of the actual workload.

11.2.3 Opportunities when velocity increases

Increasing velocity can bring opportunities for the intelligence process of squadron 108. These opportunities are discussed in next paragraphs.

11.2.3.1 *Information sharing in flows decreases delay time*

Within JISTARC, information is shared in reports, which are batches of information. Information that is shared in flows instead of batches, which is an increase in information continuity, can increase the information availability to analysing agents in the decision-making process: the operators of the Analysis Cell within squadron 108. If outcomes are shared immediately instead of waiting for the report to be ready, information is received faster by the operators of the subsequent process. This is beneficial when information is unavailable in the subsequent process and more information enables the agents to conduct the analysis process. When information is made available faster by the previous process, the time available for the analysis process of the Analysis Cell can be extended and more time will be available to conduct the analysis. A higher accuracy of intelligence can be delivered to the ASIC while making the same deadline.

When missions entail high risks for the safety of the force, decisions should be based on accurate information. When more time is available to conduct the intelligence process, more accurate intelligence can be delivered and/or faster results can be delivered to base decisions on. Therefore, within high-risk situations decreases in delay time are considered relevant and these delay times within the process should be minimised by enabling a continuous flow of information through the (sub-)processes of squadron 108.

11.2.3.2 *High speed information increases information availability*

Within the current process of squadron 108 deadlines by battle rhythm are defined that limit the time available to conduct the process. If the speed at which information is gathered increases, more information can be gathered within the same period. This is most relevant within the Exploitation Cell, in which information is created from objects. If this information can be created faster, the subprocesses of the Exploitation Cell can be executed faster. These subprocesses can consist of one to five subprocesses, which depends on which types of exploitation are applicable and required to collected information from the collected objects. If the process of the Exploitation Cell is conducted faster, information can be made available to the Analysis Cell earlier in the process; it increases the information availability. The methods that are used within the Exploitation Cell should be optimised to create

information from the objects at high speed, so the information can be shared earlier in the process with the sub-sequent process operators: the operators of the Analysis Cell.

Information speed can contribute to the availability of resources. Although, the availability of information is just a requisite within the analysis process and does not contribute to the speed of the analysis itself.

11.2.4 Threats when velocity increases

When velocity increases, threats to the process of squadron 108 can occur. These threats are identified by analysing the effects of velocity on the trade-off that is made between speed and accuracy by agents in the small intelligence cycle.

11.2.4.1 *High information speed can lead to lower analysis capacity*

When the information speed increases, the comprehensibility of information decreases because of the high volume of information that is received. This reduced comprehensibility can result in a lower analysis capacity because the overload of information slows down the analysis process of the agents by an information overload. Too high information speed that leads to less comprehensibility is considered a threat to squadron 108, since it reduces the analysis capacity which lead to a decrease in speed and accuracy of the process.

When information speed increases, the decreased comprehensibility will lead to a decrease in speed and accuracy. Created intelligence with less speed and accuracy will lead to less decision quality as is presented in figure 11.7. Especially when high-quality decisions are required, for example during missions that entail high safety risks, these effects should be mitigated by lowering the speed of information, by increasing the comprehensibility of information or by increasing the analysis capacity.

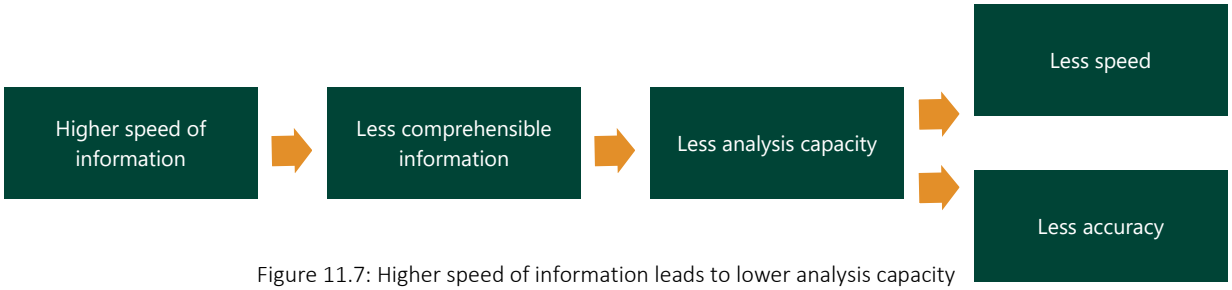


Figure 11.7: Higher speed of information leads to lower analysis capacity

11.2.4.2 *Less relevant information is identified*

Higher speed of information leads to a higher volume of information. Within JISTARC, mainly information is shared through reports are shared between operators of the different (sub-)processes. When only reports are shared and the amount of information that is shared within such reports stays the same[25], the rate of information that is shared through reports decreases. The chance that information, which is relevant but not found to be relevant by analysts within 108, is not shared to the ASIC becomes larger when the relative amount of information that is not shared increases. The sharing rate of (relevant) information decreases by higher information speed.

A higher information volume because of higher information velocity leads to a lower sharing rate of relevant information. When elements that are relevant are not notified by operators of the process, this gathered information cannot contribute to the decision that is made by the decision-maker during a mission. A less informed decision can be made, which decreases the decision quality. To ensure decision quality concerning this threat, the information share rate should be maintained or increased,

[25] See also paragraph 11.2.2.3

even though the speed of information increases. More information should flow through the system and less information should be filtered through the reports that are written by operators.

11.2.4.3 *High information speed can lead to lower accuracy*

Within the current process of JISTARC and 108, sharp deadlines are defined within the battle rhythm. These deadlines define time frames in which the analysis should be conducted by operators of the Analysis Cell.

High speed of information leads to a higher volume of information that should to be analysed. If the analysis capacity is not changing, more information must be analysed within the same timeframe which leads to more time pressure for agents. If agents experience a higher time pressure, the speed of the process will be increased. An increase in speed of the process usually goes along with a decrease in accuracy as can be seen in figure 11.8.

Within many missions, decisions that are made can lead to dangers for soldiers or local people. Such decisions require high quality and need accurate information to inform the decision. Therefore, the negative effects of an increase in the speed of information on the accuracy of the outcomes should be mitigated. The total volume of information or the (perceived) time pressure of agents can be decreased to mitigate these effects.

Figure 11.8: higher information speed decreases accuracy

11.3 UTILISE AND MITIGATE

Within previous paragraph 11.2 the opportunities and threats of increasing information velocity on the decision quality are discussed. This decision quality is approached by the trade-off that is made between speed and accuracy. During missions, sometimes fast intelligence is needed to enable the decision-maker to make an informed decision. On other moments, the accuracy of the information by which decisions are made is considered more important than the speed at which the intelligence used for the decision is delivered. Within next paragraphs, methods to mitigate the negative effects of increasing information velocity are discussed, even as methods to utilise the opportunities of velocity.

11.3.1 Utilise opportunities

The opportunities of information velocity discussed in paragraph 11.2.3 concern the availability of information. If information is the missing requisite within the decision-making process to conduct the process, an increase in information availability can enable the execution of the process and therefore contributes to higher levels of speed and accuracy. This opportunity of information velocity should be utilised to improve decision-making by enabling more time for the execution of the process.

11.3.1.1 *Increase information availability*

Currently, information is shared in batches from sub-processes to sub-process. This method of working entails delays, especially when multiple sub-processes are part of the process as in 108. The delays lead to a decreased information availability for subsequent sub-processes, especially at the start of an intelligence process. As formulated in paragraph 11.2.3.1, the continuity of information sharing can increase this information availability. A solution should be found to share information in the small intelligence process of 108 in flows instead of batches, so the continuity of information will be increased, and the information availability will be increased. Instead of sharing reports, an information platform that consists of all information that is available within the process and can be accessed by all

agents within the process of 108 can contribute to the continuity of information and a higher speed of information that flows through the system.

11.3.2 Mitigate threats

Threats that increased information velocity brings to the decision-making process are formulated in paragraph 11.2.4. The mitigation of these three threats are discussed in next paragraphs.

11.3.2.1 *Increase comprehensibility of information*

Currently, all information that is collected enters the decision-making process of JISTARC. Threats of information velocity include the decrease in comprehensibility of information. If information is shared with agents at a speed that is too high to be comprehensible, the analysis capacity of the agent the process decreases. This comprehensibility of information should be increased. A solution should be found to increase the comprehensibility of information. In paragraph 11.2.4.1 three methods for mitigation are listed: lowering the speed of information, increasing the comprehensibility of information and increasing the analysis capacity. The first two methods will be further discussed. The last method will be discussed in paragraph 11.3.2.3.

Decreasing speed

Lowering the speed of information can be done by filtering incoming information so less information enters the process. When information is filtered, only the least relevant information should be filtered, but to filter the right elements of information the information should be understandable and comprehensible.

Improve comprehensibility

A method that could be applied to make high velocity information comprehensible is by utilising supporting systems within the process to increase the comprehensibility of information to the agent. Such systems can be used to create an overview of the content of the information, for example by visualising or summarising the available information. Also, techniques that can interpret pieces of information can contribute to the comprehensibility of information, like weapon recognition software.

Within squadron 108, the analysts within the Analysis Cell need to be comprehend the information about the objects that are gathered by the Collection Team and from which (digital) information is created by the Exploitation Cell. When the speed at which the Analysis Cell receives information increases and the comprehensibility of this information for the Analysis Cell decreases, methods by which information can be presented in a comprehensible way can contribute to the comprehensibility of the information and therefore to the analysis speed by which higher levels of speed and accuracy can be achieved. Systems can contribute to the understanding of agents on the received input of information. Such systems should be capable of handling information with a high volume that is received with high speed. It should offer a comprehensible overview of the gathered information so intelligence requests can be answered effectively at a high speed.

11.3.2.2 *Increase sharing rate of relevant information*

Within the process of 108, multiple sub-processes are defined. Operators within these sub-processes collaborate through sharing information reports. Within each moment of information sharing, information is filtered towards the subsequent sub-process. Only information that is considered relevant is captured within the report that is shared; when more information is coming into the process because of the increased information speed and a similar amount of information is shared in reports, the sharing rate decreases. The lower sharing rate that could lead to the loss of relevant information is another threat to the decision-making quality that should be mitigated. Two methods can be used to mitigate this risk: To increase the sharing rate or to ensure no relevant information is lost within the process. A solution should be found to increase the sharing rate of relevant information.

Within the current process, information is filtered by analysts by sharing outcomes in reports that are considered relevant by the analysts. By making all information that has entered the decision-making process at the Collection Team available for all agents, no information is lost because it is not disseminated but kept within a sensor. To maintain the sharing rate of information, more information should be shared between operators of the sub-processes of 108 when the speed, and therefore the volume, of information increases.

11.3.2.3 *Increase analysis capacity*

The third threat of velocity to the decision-making process that should be mitigated is the lower accuracy of intelligence that is caused by a higher information volume. Because deadlines are fixed, the same amount of time is available to conduct the sub-process. When the workload is defined by the information that enters the process and the speed of information increases, agents need to conduct a faster process that will lead to less accuracy of the outcomes. Within the current context, the analysis capacity should be increased to maintain accuracy within the same time frame. When the information volume increases, the analysis capacity should be increased to mitigate the decrease in accuracy caused by higher information speed.

Increase expertise of agents

By training agents (further) in the analysis process, the analysis can be conducted faster by increased capabilities of agents. When agents have more expertise, the analysis capacity increases and more speed and accuracy can be achieved in the process. When information velocity increases, it is important that agents are capable to handle high velocity information velocity. Besides more expertise, also different expertise can be useful to contribute to the analysis capacity of agents. When agents are trained to comprehend large amounts of data into a comprehensible overview, for example by educating agents in data analytics or advanced searching methods, specifically large amounts of information can be made comprehensible.

Increase number of analysts

The increase the analysis capacity, more agents can be added to the Analysis Cell process to be able to handle more information within the same time frame. Adding agents to the process is only a temporary solution when velocity keeps increasing and often not scalable when a limited number of agents are available during a mission. Also, an increased number of agents can lead to a decreased efficiency per agent

11.3.3 Conscious trade-offs

During the process of 108, trade-offs between speed and accuracy are made constantly by the operators of the process. All decisions that are made in the balance between speed and accuracy are based on perceptions. These perceptions should correlate with reality, otherwise the trade-offs that are made by the agent might not be based on the actual workload and the actual time pressure. When agents perceive more time pressure than necessary, high speed can be used to execute the process, which leads to a lower accuracy of the outcomes of the process. When the agents perceive less workload than the actual workload, the speed of the process might be too low which leads to an unfinished analysis at the deadline.

Currently the process of 108 is organised in sub-processes that communicate through reports. This method of collaboration has a low transparency, since information is shared through reports and information enters the process at the Collection Team and flows through the process step by step. When the Analysis Cell receives information, the information was already in the process for some time although the Analysis Cell did not have access to this information.

When operators of subsequent processes are informed of the information that is handled by operators of previous processes, this higher transparency will increase the overview of the (amount of) information that Is available and should be analysed. E.g., when agents know from the start how much DMAT is gathered by the Collection Team, an estimation can be made about the workload and time pressure that will be needed during the process.

When information speed increases, the emphasis is likely to shift towards speed instead of accuracy. It is important for the operators within or outside the sensor, for example the platoon commander, the mission manager and the IRMCM operator, to be aware of this shift that can happen unconsciously. When agents are aware of this shift, attention can be paid to the trade-off when e.g. high accuracy is acquired for a specific intelligence request. Within missions in which decisions are made that entail high risks (for example for human lives), accurate information is required to base decisions on.

11.4 INTEGRATED SOLUTION

11.4.1 An integrated information sharing platform

For the intelligence process of squadron 108 an integrated solution is suggested to combine methods of utilisation and mitigation, as formulated in paragraph 11.3, into one solution. This solution is described as an *integrated information sharing platform (IISP)* as presented in figure 11.9. This platform should enable the information sharing speed between agents that conduct different sub-processes within 108 and the sensor and the All Source Intelligence Cell. This IISP should increase the comprehensibility of information and should create an overview for agents that operate within the process about the workload.

11.4.2 Sharing information

The IISP can be used as a method to share information between agents. Instead of a direct share of information from agent to agent as currently done in reports, information can be shared through a system in which all information of the intelligence process is gathered and can be accessed by all agents from the different sub-processes. When information is e.g. shared by the Collection Team in the system, the ASIC can directly access this information, just like the Exploitation Cell and the Analysis Cell.

11.4.2.1 *All data and information*

Not only final reports should be shared, but also data that is collected and which is not analysed yet. Operators of the sub-processes should continue to write analyses (reports) to increase the comprehensibility of information, since these operators have expertise in the analysis that should be executed within their sub-process. By sharing all information in the IISP no information is lost and the sharing rate remains high, even though the speed of information is increasing.

11.4.2.2 *Increase sharing moments*

Experienced agents already conduct an iterative/incremental process.[26] Sub-analyses could be shared in sub-reports before the set deadline. Within 108, more sub-processes are defined because of the different exploitation methods. Sub-results could be disseminated through the IISP to the next sub-processes which leads to higher information availability for next sub-processes and more time to analyse the information.

[26] See appendix R.6

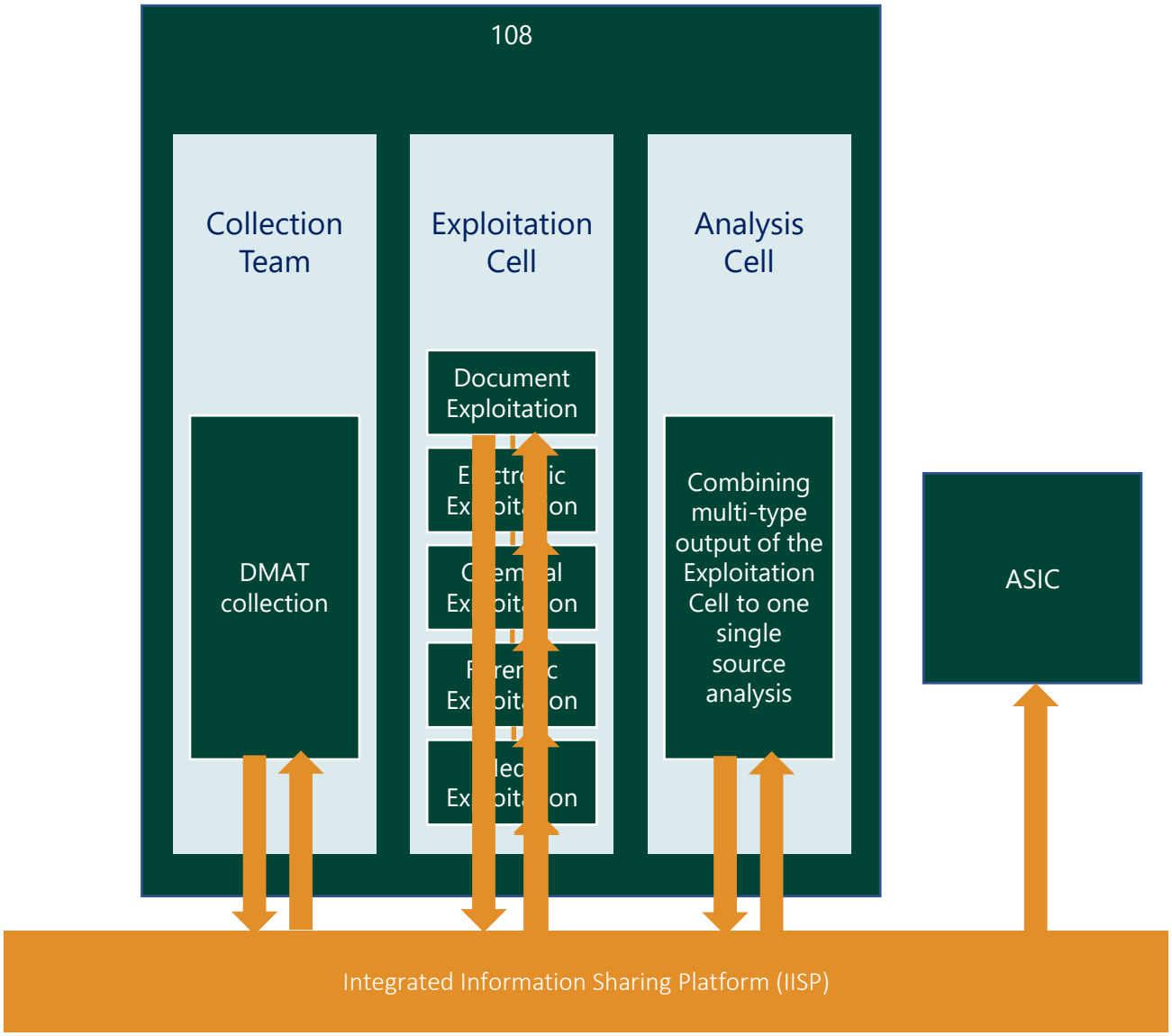


Figure 11.9: An Integrated Information Sharing Platform (IISP)

11.4.2.3 *Access control*

Some information cannot be shared between sub-processes, for example because this information contains information about persons that cannot be shared with other people that the collectors of the information. The IISP should enable role-based access control in which different operators have different rights in accessing information.

11.4.3 New analysis methods

By collecting all available information into one platform, some types of analysis can be conducted that were not feasible before. E.g. machine learning can be used to identify relations between all gathered pieces of information that could not have been found by human analysis. Such methods can be operated when large amount of information and data is available on the same platform.

11.4.4 Insight in total workload

Faster information sharing leads t omore insights in the workload. Although the processes of the Exploitation Cell, the Analysis Cell and ASIC remain subsequent, the operators of each sub-process are

aware when information is gathered by the Collection Team so the transparency of information entering the analysis process is high. An estimation can be made by operators of the subsequent processes about the workload that will be received later in the process.

11.4.5 Increase comprehensibility

Another functionality of the IISP that could be implemented is a presentation of the information that is gathered in the sharing platform in a comprehensible way. It should enable agents to comprehend the information that is shared within the system, so the high volume of information will not paralyse the agents but supports the comprehensibility of information and increases the understandability of information.

Information that is shared within the information system should be presented in a comprehensible way, which can be done by e.g. visualising or summarising the available information. Analysis reports should be shared just like is done within the current process, since these reports usually contain comprehensible information. The information that is shared besides the reports is less comprehensible than the reports, although the availability of this less comprehensible information to operators of subsequent processes increases the information availability of information, which is especially relevant when the information availability is too low to conduct the subsequent process.

11.4.6 Maintenance of the IISP

To make the information that is shared within the process comprehensible, agents should be assigned within the intelligence process to manage the information and to contribute to the comprehensibility of information. These agents should work continuously on the analysis of data and information to maintain the quality and comprehensibility of information within the platform. The role of these agents within the intelligence process will be similar to the role of the IRMCM operators, because these agents operate in between all subprocesses of the intelligence process and are responsible for the information sharing process.

11.5 CONCLUSION

Increased information velocity creates an opportunity for squadron 108 to improve the information availability within the process. By improving this availability, higher levels of speed and accuracy can be achieved to lead to a higher quality of the decision-making process.

Information velocity will also impact the perceptions and behaviour of the agents that operate within the process. The perception of agent can lead to other choices within the trade-off and lower the height of the sum of speed and accuracy by an increased (perception of) workload. Most of these effects of velocity on the sum of the trade-off are negative. To mitigate these measures, measures can be taken to increase the analysis capacity, improve the comprehensibility of information and increase the transparency within the process.

Also, a shift within the trade-off is identified because of increased velocity. Platoon commanders should be aware of the changing emphasis in the trade-off when velocity increases, so measures can be taken when high accuracy is required within missions that entail high risks.

An integrated information sharing platform is proposed to improve the transparency and speed of information that is available within the process, so an overview of the available information (and workload) is available for agents.

12 Validation

12.1 INTRODUCTION

The effects of velocity on the speed-accuracy trade-off are researched by several data gathering methods. Inference of the results, combined with literature research, leads to a conclusion. Validation of the results is necessary to test whether these hold in practice. This study is a single case study, in which many observations are made for just a single situation. The nature of this research type makes it difficult to validate replicability in other cases and situations. Internal validation, however, is useful to determine if the data gathering results, observations and conclusions are reflecting the actual situation in the studied case.

12.2 SINGLE CASE STUDY

This research that describes the effects of velocity on the trade-off that is made between speed and accuracy is conducted at the organisation of the client: JISTARC of the Royal Netherlands Army. This research can be characterised as a single case study. This research is conducted within a specific context and outcomes are applicable for the case in which the research is conducted. This specific context has influenced the outcomes that are found to address the research question. If this research is conducted at another organisation, the outcomes are likely to be different (Flyvbjerg, 2006). Further research is required to validate the results of this research for other cases and organisations as well. To validate the results within the single case, a method for internal validation can be applied.

12.3 TRIANGULATION

Multiple methods of data gathering are used within this research. Data is gathered through desk research, through interviews and through empirical research. Within each method of research, the results that were gathered through the other types of research could be validated. In this paragraph, each data collection method is mentioned, listing its main assumptions that need validation. The other sources are used for this validation. The interviews, empirical research and desk research have all been

performed with different sources, different trade-off situations and different people. This decreases the correlation between the research methods, therefore making them suitable for validation through triangulation (Denzin, 1970).

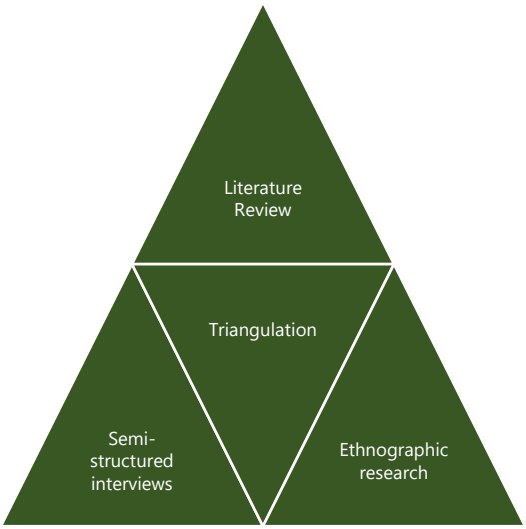


Figure 12.1: Triangulation with the three types of research

12.4 DESK RESEARCH

The theoretical background regarding the main research question was researched during desk research. This not only provides a starting point for other parts of the research, but also embeds the findings of this case in a larger academic background. The main results of this type of research is information about the intelligence process, how the intelligence process is executed at the case organisation, what information velocity entails, how velocity can challenge organisations, that a trade-off exists between speed and accuracy and that information velocity influences this trade-off. The gathered information about the intelligence process could be validated within the client's organisation through empirical research. Results regarding (information) velocity and organisational contexts are often based on research results in other contexts. Still, the other research methods can validate whether these effects are similar in the case.

12.5 SEMI-STRUCTURED INTERVIEWS

A trade-off between speed and accuracy during processes is a complex behavioural phenomenon. It relates to many perceptions about e.g. workload and importance of quality. Interviews were conducted to explore the conscious part of these trade-off related questions. Semi-structured interviews were conducted, these were partially based on the desk research mentioned before, but with a different viewing angle: their actual work rather than theories. This work entails the execution of the analysis within the intelligence process during military missions and exercises. The semi-structured interviews lead to a validation of the other methods of research. The focus was on the perception of the agent in how trade-offs between speed and accuracy are made and which factors influence these decisions. By this method, the factors that influence this trade-off are identified. Consequently, the most interesting determinant is the respondents' view on information velocity. The respondent's past experience with data and information is also relevant in this scope. These personal perspectives are hard to validate one by one, but an overall fit within conceptual research from desk research and the empirical research is visible, thereby validating the applicability of these interviews.

12.6 ETHNOGRAPHIC RESEARCH

The trade-off between speed and accuracy is often made implicitly. Conscious reflection on why a certain trade-off was made is helpful to understand the perceptions, but to validate whether this perceived behaviour was also shown in practice ethnographic research is conducted. Agents that operate within the intelligence cycle (who had to make speed-accuracy trade-offs often) were observed without interaction for a couple of days. These observations gave insight in specific situations in which information velocity and other factors influenced how trade-offs are made. Sometimes, while discussing, these trade-offs were mentioned out loud “we know [the answer], we must go now”. This third research method provides a good measurement to observe how agents operate instead of analysing their behaviour through their own perceptions. The outcomes show correspondence of these observations with the theories (desk research) and their own perceptions (interviews). These outcomes further strengthen the conclusions that information velocity does influence the trade-off through the identified factors.

12.7 CONCLUSION

Three different methods have been used to measure roughly the same: what are the effects of information velocity on the trade-off between speed and accuracy? Each of the research methods provides its own perspective, often leading to unique insights, and diverse opportunities to explore the interaction between these factors. However, the methods also shared a large common base: the conceptual foundation was well visible in the respondents’ own perception and became visible during ethnographic research. The currently resulting conclusions on how information velocity affects the trade-off became more apparent by combining multiple different research methods.

CONCLUSIONS

13 Conclusions

13.1 RESEARCH QUESTION

Within this research, the effects of the velocity of information on the trade-off between speed and accuracy are analysed. The research question that is addressed is stated as follows:

What are the effects of information velocity on the trade-off between speed and accuracy in the decision-making process?

13.2 CONTEXT

This research question is addressed within a specific context. Characteristics of this context that are found to influence the speed-accuracy trade-off are the importance of deadlines, the (unwritten) rule that all information that is received by analysts should be analysed, that information is shared mainly through reports, that agents within the process have specific tasks. These contextual factors influence how trade-offs between speed and accuracy are made and the effects of information velocity on these trade-offs.

13.3 FACTORS THAT LEAD TO A TRADE-OFF

Within this research, factors are identified that lead to a trade-off between speed and accuracy. These factors are distinguished into three elements: the base that consists of the requisites of the process, the sensitivity that consists of the element that increase the speed at which accuracy can be achieved and the pivot, which is the behavioural component of the trade-off which consists of the factors that can change during the process as well as the choice of the agent in balance between speed and accuracy. The base, pivot and sensitivity will be discussed.

13.3.1 Base

The requisites of the process that is analysed within the case are agents, information and start-up time. These elements should be available before the process can be executed. When one of these elements is missing, no speed and accuracy can be achieved. The base has a discrete impact on the trade-off between speed and accuracy.

13.3.2 Sensitivity

The speed at which accuracy can be created and vice versa is found to be influenced by the number of available agents, their expertise, experience and supporting systems. When these elements are available more within the process, more speed and accuracy can be achieved in the process.

13.3.3 Pivot

The pivot consists of multiple elements. These elements influence the use of the capacities of the system and the choice that is made by agent between the objectives. Elements of the pivot are time pressure, perceived expectations, considered importance of speed, considered importance of accuracy, transparency, motivation, comprehensibility and personal preferences. These elements can fluctuate through the process and are influenced by the context of the process, like the pressure that is put on the agents of the process by agents outside of the process.

13.4 EFFECTS OF VELOCITY

The velocity of information can be distinguished into three aspects: information speed, information continuity and information volatility. These three aspects of information velocity have several effects on the trade-off between speed and accuracy that is made by agents within the decision-making process. (A summary of) these effects will be described.

One of the effects that is identified of information speed and continuity on the trade-off between speed and accuracy is an increase in information availability which leads to an increase in the sum of the levels of speed and accuracy that can be achieved. Although, this effect is only apparent when no information is available to conduct the analysis process and increasing this information availability is the enabling factor for (a sub-process of) the decision-making process.

Another effect entails the effects of information velocity on the motivation of agents that conduct the decision-making process. When information that is received by agents is volatile and urgent as well, agents are usually motivated to deliver accurate results within a short period of time. Higher levels of speed and accuracy can be achieved.

Also, effects of information velocity include the effects this velocity has on the perceptions and behaviour of agents that operate within the process. One of these effects that is recognised is the negative effect information speed brings to the comprehensibility of information. High information speed lead to a lower analysis capacity and therefore to lower levels of speed and accuracy.

High information speed also leads to a higher workload in a context in which all information that enters the decision-making process should be handled by the agents through the process. When deadlines of (subprocesses of) the decision-making process are defined, the higher workload requires a higher speed at which the process(es) are conducted. When speed used by agents increases, the accuracy of the outcomes will decrease.

13.5 CONCLUSIONS

High information speed can increase information availability which can lead to higher levels of speed and accuracy. When the information is not the missing requisite for conducting the process, other effects of information velocity are apparent in the decision-making process. Information velocity affects

the behaviour of agents in the process and their analysis capacity, which affects the levels of speed and accuracy that can be achieved. This change in behaviour is (mainly) affected by the (perceived) workload and the comprehensibility of information.

A model of the effects of information velocity can be found in figure 13.1. An integral model can be found in appendix T.

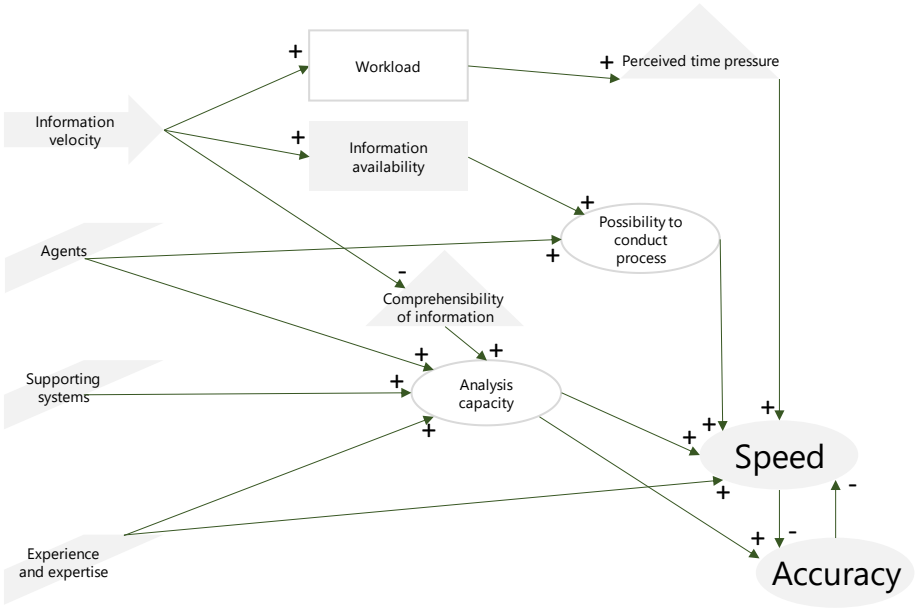


Figure 13.1: Model of the effects of information velocity on the speed-accuracy trade-off

Although information flows faster in the decision-making process when velocity increases, the decision-making process lead time is not likely to decrease when no adjustments are done to the decision-making process. Also, the accuracy of information that is used to base decisions on is likely to decrease when information speed increases within the given context. Velocity can bring opportunities to the decision-making process by increasing information availability, but to cope with the negative impact of velocity, changes should be made within to current decision-making process of the client: JISTARC's squadron 108.

13.6 COPE WITH INFORMATION VELOCITY

Velocity of information affects the decision-making process, mainly through the behaviour of agents that make trade-offs between speed and accuracy in the process. Organisations should cope with velocity to mitigate the negative effects and by amplifying the positive effects.

The organisation of the client at which this research is conducted is organised within multiple sub-processes that share information through reports before set deadlines. When information speed and continuity is high at entering the decision-making process, information is delayed by the current method of information sharing which is done in batches and delayed by the lead time of the sub-processes. Each sub-process decreases the information speed and continuity towards the subsequent process-operators. When the decision-making process of JISTARC is organised in sub-processes, the challenge arises to maintain speed and continuity of the information flow through the process to increase the information availability to operators of the sub-processes of the decision-making process. The legacy within the organisation that defines all information should be analysed and sub-processes should be ready before the deadline leads to an increase in the workload when information speed is

increasing, which leads to an increase in speed and decrease in accuracy. When these rules are maintained and accuracy levels should be kept high, the analysis capacity should be increased. The overload of information can also lead to less comprehensibility of information which leads to a lower analysis capacity. Supporting systems that make information comprehensible for example through visualisation can contribute to the comprehensibility of incoming information and therefore to the analysis capacity of the decision-making process. An integrated information sharing platform is proposed to improve information transparency and speed within the process, which can lead to an overview of the information and the workload for agents.

14 Discussion

Results are given to provide an answer to the main research question. This answer addresses the effects of velocity on the trade-off between speed and accuracy within the decision-making process. This research is conducted at an organisation called JISTARC, which is an intelligence organisation of the Dutch Ministry of Defence.

14.1 CASE STUDY

14.1.1 Differences mission and exercise

Most respondents of the semi-structured interviews had some experience in conducting the analysis process in the field during a mission. The ethnographic research was conducted during an exercise. The risks during an exercise are lower and the events are less unpredictable than can be expected of the risks and the events during a mission. Because the impact on real world events is considered lower during the exercise, the agents within the analysis process during the exercise might behave different than agents would do during a mission in which the intelligence that is created contributes to decisions that can involve the risk of human lives.

14.1.2 Types of data and information

Interviews are conducted at different squadrons. The velocity of the data the different squadrons handle is different, but also the characteristics of this data. The effects of these different characteristics on the effects the velocity has on the speed-accuracy trade-off are not considered during this research.

14.2 USE OF MODEL OF DA SILVEIRA AND SLACK

Within the research, the model of Da Silveira and Slack (2001) is adapted to be applicable to identify aspects that lead to a trade-off, including agent behaviour. Within the original model the role of (individual) behaviour of agents that influences the trade-off that is made was not apparent. Adjustments to the model of Da Silveira and Slack are done to enable the impact of agent-behaviour

within the model, so the agent-behaviour can be addressed within the model on the trade-off that is made between speed and accuracy.

The model of Da Silveira and Slack is considered useful for addressing how trade-offs are made. Although, some factors within the model are intertwined, which complicates the identification of elements that are part of the three factors of the model: the base, the sensitivity and the pivot. Further research of the use of this model for processes and human behaviour is needed to develop the model further for understanding trade-offs.

14.3 MULTI-DISCIPLINARITY

This research touches upon multiple research areas, which are e.g. data science, organisational science, communication science, military science and psychology. Stated conclusions should be validated by experts within the specific research areas. Further research within these fields is required.

14.4 SUBGROUP

The analysis is based on interviews and ethnographic research of a limited number of agents within the organisation of JISTARC. This group was mainly selected by job title and responsiveness of agents. Because the research is based on a subset of JISTARC, differences in outcomes could have occurred when all agents of JISTARC would have been part of this research (Makin & De Xivry, 2019).

14.5 PERCEPTION OF RESEARCHER

The (empirical) research is conducted through the eyes of the researcher and subjective to the researcher's perspectives. Especially during the empirical research agents are observed, and behaviour of these agents is identified and interpreted by the observer. These observations and interpretations are subjective and subject to the perceptions of the researcher. To mitigate these effects, a similar research should be conducted by multiple observers, so more objective results are found during the ethnographic research.

14.6 INTERMEDIATE VARIABLES

Especially during the observations, intermediate variables are interpreted that cannot be measured in a quantified way, like the perception of agents about time pressure, work pressure, sense of urgency and motivation. These intermediate variables are identified by observed behaviour, verbal communication between agents and facial expressions. To validate the results, the effects of velocity on the intermediate variables should be investigated and the effects of these intermediate variables on the speed-accuracy trade-off.

14.7 THE SPEED-ACCURACY TRADE-OFF AND DECISION QUALITY

The speed-accuracy trade-off is described to affect the decision quality. This relation is researched to exist, but the specific effects of the speed-accuracy trade-off on the decision quality requires further research, especially in relation to the impact of velocity on the decision quality.

14.8 CONTRIBUTION TO ACADEMIC LITERATURE

Within current literature, no specific effects of velocity on decision quality and decision-making processes are described. This study contributes to the understanding of the effects of big data, specifically the effects of information velocity, on decision-making addressed by the speed-accuracy trade-off. The concept of information velocity is analysed and the effects of the aspects of velocity on the speed-accuracy trade-off are analysed.

14.9 NEXT STEPS

The results of this research are found within a specific context of JISTARC. To generalise results, further research is required.

14.9.1 Further development of the model of Da Silveira and Slack

The model that was created by Da Silveira and Slack is used within this research to identify factors that lead to a trade-off. The model is translated to be applicable to be useful for trade-offs that involve human behaviour. Within this research, the behaviour of agents was considered to be part of the pivot. Within further research, the model as presented within this research should be further developed and tested to be applicable to address factors that influence trade-offs. Whether behaviour should be addressed within the pivot or should be addressed by a new element should be researched specifically. Also, the distinction and characteristics of elements that are part of the factors should be further addressed.

14.9.2 Generalisation of results

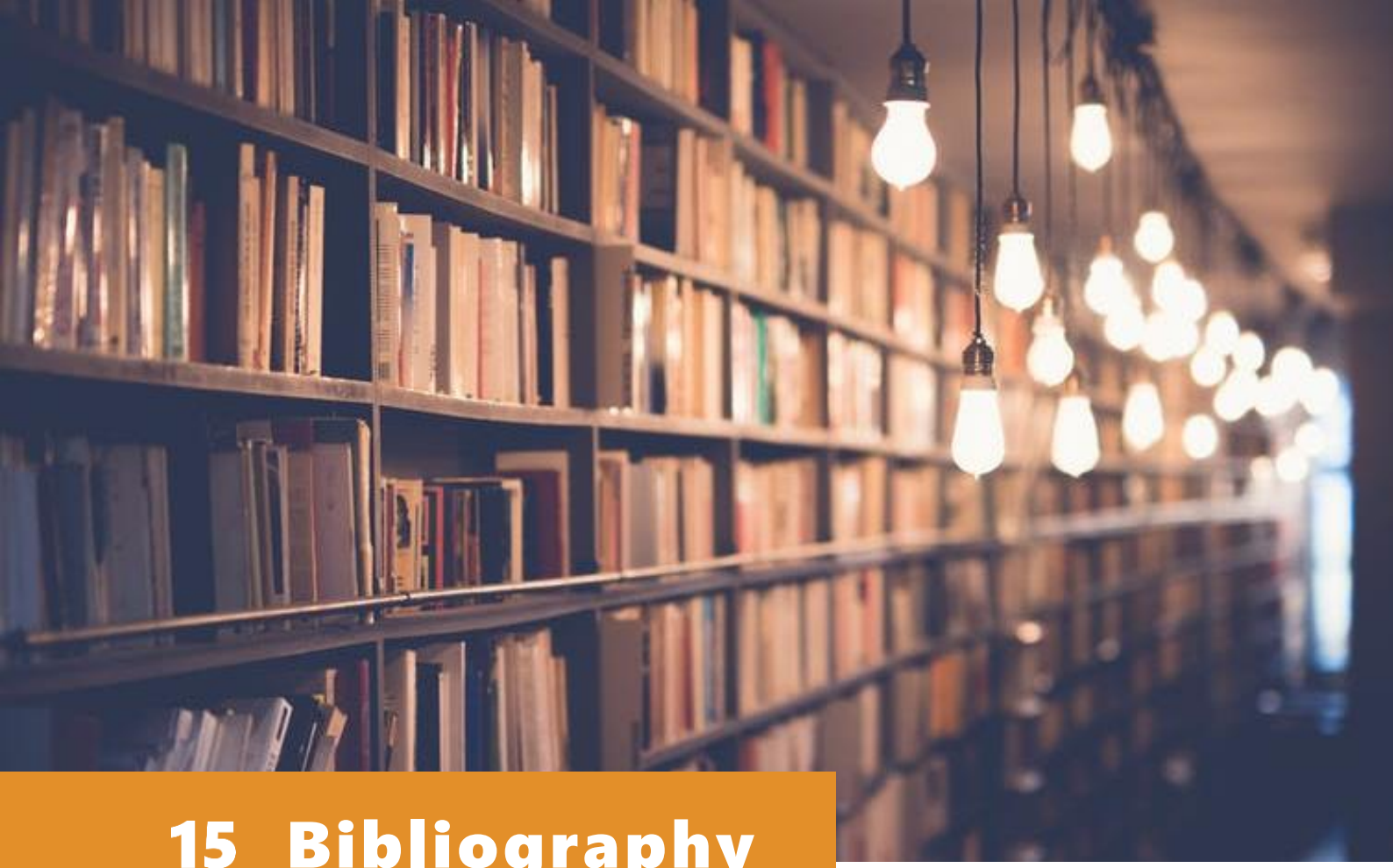
The results that are found within this research are results that are gathered within a single case study. These results might not be applicable for other cases, since each case has its own characteristics and institutional context. Within further research, the found results should be tested within other cases on more respondents that are defined by a different institutional context too.

14.9.3 Research into the effects of velocity on decision quality through other factors

Within this research, the effects of velocity on the decision quality are addressed through the measurement of the effects of velocity on the factors that influence a trade-off. The effects of velocity on other intermediate values should be researched to improve the understanding of the impact of velocity on the decision quality, also through other intermediate variables. There should be paid attention to the differences that occur between researches that address the effects of velocity on decision quality and which factors cause these differences.

14.10 CONCLUSION

Results are found within this research to the effects of velocity on the trade-off between speed and accuracy in the decision-making process. During this research, a scope is chosen, and assumptions are made. Insights are found, but further research is required to gather a deeper understanding about the effects of velocity on decision quality.



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