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# 1 Multi-risk, multi-scale and multi-stakeholder – The contribution of a bow-tie analysis 2 for risk management in the trilateral Wadden Sea Region

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## 7 Abstract

8 Risk management processes increasingly call for enhanced stakeholder participation, and aim to  
9 integrate different risk perceptions, concerns and interests. Frequently, this goal is driven by the  
10 increased complexity of risk management processes, as risk management processes continuously have  
11 to deal with multi-risk situations including impacts resulting from risks of natural hazards and risks  
12 caused by misguided social or economic development. Although stakeholder participation is required  
13 by different policies, major challenges still arise from the question of how to perform multi-  
14 stakeholder participation in practice. In order to find answers, we tested the so-called ‘bow-tie  
15 analysis’ as a potential tool to facilitate multi-stakeholder participation with a major effort on  
16 integrating stakeholders risk perceptions and interest in the risk management processes. The bow-tie  
17 analysis is a commonly used risk assessment technique (IEC 2009) to analyse cause-and-effect  
18 pathways of risks, but its application in multi-stakeholder processes in risk management of natural  
19 hazards, especially in a European context, is rather new.

20 Using practical experiences from the trilateral Wadden Sea Region we demonstrate the bow-tie  
21 analysis’ contribution to coastal risk management processes in this coastal area by facilitating  
22 collaborative identification, comprehension and analysis of the management system. The use of a  
23 modified bow-tie analysis in collaboration with stakeholders from the Wadden Sea Region proved to  
24 be an appropriate framework for enhancing the understanding of risk management processes and  
25 fostered disclosure of different perceptions and concerns of multi-risk problematics. The bow-tie can  
26 be beneficial as a communication and co-construction tool in risk management processes in a multi-  
27 risk context.

28  
29 **Keywords:** bow-tie analysis, risk management, multi-stakeholder participation, Wadden Sea Region

## 30 Introduction

31 The world is becoming increasingly complicated. A risk is no longer only a risk; it can have  
32 multifarious forms and can have impacts in multiple sectors on multiple scales. In the context of a  
33 *world risk society* Ulrich Beck identifies such situations of accumulated risks<sup>1</sup> and the increased  
34 uncertainties evolving out a state of not knowing about the impacts and consequences as a key theme  
35 of contemporary society (Beck 2007; 2009). In this regard, dealing with natural hazards and  
36 environmental risks nowadays becomes a considerable challenge for risk managers, sectoral interests  
37 and authorities as much as for the society at large. These multi-faceted hazardous risk situations are  
38 often characterized by highly interlinked risks, unexposed differences between the causes and the  
39 consequences of threatening risks and a multitude of actors that affect or are affected by the risk  
40 management processes. There is growing awareness in risk management communities that these  
41 situations are no longer manageable by a single actor, such as the government (Evans 2012) – but  
42 require rather an enhanced involvement of multiple stakeholders in risk management processes to cope  
43 with these challenges.

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<sup>1</sup> Beck is referring to an accumulation of ecological, terrorist, military, financial, biomedical and informational risks that has an overwhelming presence in our world today (Beck 2009)

44 The call for stakeholder involvement is however nothing new in risk management processes –  
45 moreover, the growing awareness of multi-risk situations adds weight this call. Risks are understood  
46 from a sociological perspective, as mental constructs which originate in the human mind and emerge  
47 within societal frames<sup>2</sup> (Luhmann 1993; Renn 2008). In this understanding risk is bounded and  
48 influenced by perception, interests and political will and depends on social, political, economic and  
49 cultural contexts and judgments (Luhmann 1993; IRGC 2005). In consequence, risk management is  
50 not only a technical issue, but a social process taking place within a societal frame of constantly  
51 changing and uncertain boundary conditions. In this context different perceptions and understanding  
52 of risks are essential elements shaping these boundary conditions. It is crucial to consider what the  
53 single system’s “agents” perceive as risk and consider as the appropriate response at the individual  
54 level, especially in the context of multifaceted risk situations. From a complexity theory perspective,  
55 dealing with multi-faceted risk situations within society requires consideration of the non-linear  
56 behaviour of the system where emergent behaviour and surprises inherent to the system’s trajectory  
57 (Ratter 2012). Understanding society as a dynamic and non-linear system, multifaceted risk  
58 perceptions must be discussed and negotiated within the society in order to set the scene for public-  
59 policy and management objectives as well as to cope with multi-faceted, highly interlinked and non-  
60 linear risk situations.

61 On this basis, risk perception represents an essential element of risk management activities as much as  
62 multi-stakeholder participation to facilitate integration of risk perceptions. Although these issues are  
63 discussed in, often scientific, literature (e.g. in a governance context, Gall et al. 2014; Renn 2008;  
64 IRGC 2005; Wanczura et al. 2007; Greiving & Glade 2013), implementation in practice is proceeding  
65 rather slow for risk management processes. This is particularly true for coastal risk management  
66 processes where technical understandings of risk continue to dominate (Ballinger 2015). Cross-  
67 national strategies and policies, like the EU-Flood Risk Directive, the EU-Water Framework Directive  
68 or the recently updated Sendai Framework for Disaster Risk Reduction 2015-2030 are important steps  
69 in this context. However, practical guidance on how to perform effective stakeholder participation, are  
70 rare in these strategies, too. Available practical frameworks like the Standard 31000 of the  
71 International Organization for Standardization (ISO) could help remedy this situation, but are not  
72 applied or used as reference in the context of multi-risk situations in risk management, due to our  
73 knowledge.

74 The aim of this paper is orientated towards these challenges in coastal risk management and the  
75 following open questions: 1) how can risk perceptions as well as societal concerns and needs be made  
76 accessible to the risk management process in a multi-stakeholder participatory manner? 2) Which  
77 benefits and contributions could be expected by a multi-stakeholder involvement and which obstacles  
78 are arising?

79 We discuss these questions from the perspective of our practical experiences from supporting  
80 participatory activities in coastal risk management processes in the international Wadden Sea Region  
81 (WSR). In the context of the overall aim to facilitate enhanced stakeholder participation in trilateral  
82 risk management processes in the WSR we tested the so-called ‘bow-tie analysis’ as a tool to facilitate  
83 involvement of different stakeholders’ perceptions and foster multi-stakeholder participation in the  
84 risk management processes. Our discussions reflect upon the applicability, feasibility and  
85 effectiveness of the “bow-tie-analysis” contributing to the conceptual questions regarding the potential  
86 benefits of multi-stakeholder participation.

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<sup>2</sup> In contrast to a technological perspective, in which risks are defined as the algorithmic calculation: risk = threat x vulnerability x cost (c.f. Ratter 2013).

87 **The Wadden Sea Region's multi risk and multi-scale situation**

88 Risk management in the WSR faces the challenge of a multi-faceted, highly interlinked risk situation.  
89 The case study of the WSR is particularly suitable to discuss the challenges of including risk  
90 perceptions and of opening the process of risk management to a broader audience. Within this  
91 situation multiple stakeholders of different sectoral affiliation, involved in risk management processes  
92 at different scales, are confronted with the common task to cope with risks and impacts, affecting the  
93 local, regional and national scale.

94 The trilateral WSR comprises the coastal area along the European North Sea coast including the  
95 seaward areas of the Wadden Sea and the low-lying, tidal coastal regions behind the dykes along the  
96 North Sea coastline of the Netherlands, Germany and Denmark. At the seaward side, the WSR  
97 represents a coherent intertidal ecosystem characterized by a shallow body of water, tidal flats and  
98 wetlands (Enemark 2005). At the landward side the WSR can be characterized as a largely rural area,  
99 encompassing several important small- and medium-sized towns. For the work presented here we refer  
100 to the WSR defined as the Wadden Sea with its islands and sands and the relevant parts of the  
101 Exclusive Economic Zones of the three countries, as well as the landward side the three Dutch  
102 Wadden Sea provinces, the German counties along the coast and the Danish Wadden Sea  
103 municipalities (Wadden Sea Forum 2013). Due to its similar ecological characteristics as well as  
104 similar social and economic structures within the Dutch, German and Danish parts of the WSR the  
105 entire Wadden Sea coast is affected by similar risks in a similar way. Periodic storm surge events of  
106 different levels of destructiveness have caused huge losses of live and goods in all three countries over  
107 the centuries. Since the last hazardous storm surge events in 1953 and 1962, significant  
108 transformations in storm surge management has been conducted, especially in the Netherlands and in  
109 Germany (von Storch et al. 2008, Gerritsen 2005, FAK 2009), underlined by a technical superiority of  
110 coastal protection measures. Beside the high water level, the WSR is exposed to storm events, causing  
111 major damages to settlements, infrastructure and economic sectors (e.g. winter storms Lothar 1999 and  
112 Kyrill 2007). Increase in mean sea level during the last decades on a global (Church et al. 2001) and  
113 on a regional scale (Wahl et al. 2011) as much as a projected on-going increase for the coming decades  
114 (Church et al. 2001; Katsman et al. 2008; IPCC 2013; Katsman et al. 2011) will have an effect along  
115 the entire coastline of the WSR. It is expected that effects of storm surge events in the WSR are  
116 intensifying (Woth et al. 2006, Weisse et al. 2014) and additionally hydrological risks result from  
117 inland flooding events. In the WSR different rivers run into the North Sea<sup>3</sup> which temporarily cause  
118 flooding as a result from extensive inland run-offs. With regard to climate change, heavy rainfall  
119 events are projected to increase in Northern Europe (IPCC 2007).

120 However, risks and challenges in the WSR do not only result from natural hazards and hydrological  
121 threats; furthermore, additional socio-economic challenges in the region lead to a multi-faceted risk  
122 situation. Different concentrations of population (densely populated cities, sparsely populated rural  
123 areas) and a diverse accumulation of economic values (high accumulation e.g. in harbour areas, areas  
124 of industrial use) create different levels of vulnerability since large parts of the WSR lie at sea level or  
125 even below. At present, an estimated 3 million inhabitants live in the WSR (Kabat et al. 2012).  
126 Traditionally, the WSR has been an important agricultural area (Kabat et al. 2012); today additional  
127 important economic sectors in the WSR are tourism, the energy sector (on-shore, off-shore wind and  
128 solar energy) as well as fishery and port industry and management (Wadden Sea Forum 2004; van  
129 Dijk et al. 2016). These sectors are directly or indirectly affected by risks from natural hazard events  
130 as much as by socio-economic risks such as demographic change. All three countries suffer in large  
131 parts from population decline and an aging society (van Dijk et al. 2016) and this declining trend is

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<sup>3</sup> In the Netherlands, there are the IJssel and the Reiderdiep, the river Ems at the border between the Netherlands and Germany, in Germany the Weser, Elbe and Eider rivers and in Denmark, the river Ribe Å has already caused some flooding events in the past.

132 projected to continue in the next decades (Wadden Sea Long-Term Ecosystem Research et al. 2014).  
133 These demographic developments create urgent needs for enhanced management strategies to cope  
134 with these changing conditions.

135 Current risk management processes of these risks and challenges discussed above are bounded to  
136 national, regional and local, mostly administrative scales, with multiple institutions assuming partial  
137 responsibility. The existing structures underline the fact that impacts occur and are managed according  
138 to their impacts within rather than across different scales in the WSR. Even if risk management  
139 processes necessarily relay on responsibilities and activities taken on several levels, these structures  
140 have nevertheless led to the development of a ‘silo mentality’ as sectoral administrations operate in  
141 relative isolation from each other (Ballinger 2015, 1999). Within these structures, the multi-risk  
142 problematic is difficult to address. Without undermining existing multi-scale management processes  
143 we see a need to address the integration of stakeholders and their perception on this multi-risk  
144 situation on a cross-national, trilateral level. The trilateral level is the scale where the interlinkages  
145 become more easily apparent. In the following we will describe the already existing multi-stakeholder  
146 setting in the WSR in order to further discuss how multi-stakeholder participation as much as the  
147 involvements of their different risk perceptions was facilitated with the bow-tie analysis in the  
148 trilateral context.

#### 149 **Facilitating stakeholder participation in the risk management process**

150 A basis for a multi-stakeholder collaboration on the trilateral level in the WSR is already given since  
151 1978 by the Trilateral Wadden Sea Cooperation (TWSC) (Kabat et al. 2012) as much as by the multi-  
152 stakeholder platform Wadden Sea Forum (WSF) founded in 2002. The latter is an independent,  
153 voluntary multi-stakeholder platform, serving as a trilateral advisory and consultation body to the  
154 TWSC (Wadden Sea Forum 2013). It brings together stakeholders from Denmark, Germany and the  
155 Netherlands, representing the private economic sectors of agriculture, energy, fisheries, industry and  
156 harbour, and tourism, non-governmental organisation of nature and environmental protection as well  
157 as representatives from local and regional governments of the three Wadden Sea countries. National  
158 governments are represented as observers (Wadden Sea Forum 2005; 2010). Originally the focus of  
159 the WSF was on sustainable development, but since the TWSC agenda has incorporated the new topic  
160 of risk management (CWSS 2014), the WSF has correspondingly extended its activities. This paper  
161 presents the collaborative research and experience gathered in the context of the EU-funded research  
162 project ENHANCE – Enhancing risk management partnerships for catastrophic natural hazards in  
163 Europe (see <http://www.enhanceproject.eu/>). The focus was to support the WSF’s endeavour in  
164 developing its newly declared objective and strategy as a multi-stakeholder platform for coastal risk  
165 management processes on a trilateral level.

166 The support of the WSF was put into practice as a series of three collaborative workshops with the  
167 WSF members. The workshops were conducted as one and a half day meetings, stimulating active  
168 stakeholder involvement in form of a combination of working in small groups and exchange and  
169 feedbacks in plenary discussions. Between 15 and 20 stakeholders participated in each of the three  
170 workshops, portraying a broad and balanced picture of most of the sectors and administrative levels  
171 from the three countries represented in the WSF. Within the workshop series the ‘bow-tie analysis’  
172 was a major element, applied as a methodical tool to involve and discuss stakeholders perceptions of  
173 the multi-risk problematic in the WSR as much as to further facilitate multi-stakeholder participation.  
174 We chose the bow-tie analysis due to its capabilities to support an improved understanding of risk  
175 management, to differentiate between the system’s elements and increased awareness of interlinkages  
176 between different risks. Furthermore, we appreciate the bow-tie’s capability to integrate multiple

177 causes and consequences in relation to a central event, and to assess a given system of management  
178 control.<sup>4</sup>

179 By focussing on the bow-tie capacities described above, we are aware of the fact that our activities of  
180 the collaborative bow-tie exercise address just a part of the entire process understood by the term risk  
181 management in a technical sense. In general, risk management is understood as “coordinated activities  
182 to direct and control an organization with regard to risk” (ISO 2009). Following the definition of ISO  
183 31000<sup>5</sup>, the process of risk management includes the “systematic application of management policies,  
184 procedures and practices to the activities of [related to the essential elements of] communicating,  
185 consulting, establishing the context, and identifying, analyzing, evaluating, treating, monitoring and  
186 reviewing risk” (ISO 2009). The activities supported by the bow-tie analysis address predominantly  
187 the elements of establishing the context, identifying risk and priorities, as well as supporting activities  
188 of risk analysis and evaluation. The addressed stakeholder perceptions are part of a comprehensive risk  
189 analysis together with an additional qualitative and quantitative analysis. The presented bow-tie  
190 exercise is considered as a contribution to facilitate the inclusion of stakeholders’ risk perception into  
191 the risk analyses beside other available data.

## 192 **The Bow-tie analysis**

193 The bow-tie analysis is a commonly-used risk assessment method. It is listed by the International  
194 Organization for Standardization (IEC 31010 risk assessment techniques) as an appropriate risk  
195 management technique to implement risk management processes following the ISO 31000 framework  
196 facilitating the analysis, assessment and evaluation of risks. More in detail, the bow-tie analysis  
197 facilitates and supports the differentiation between the causes of a risk, the damaging event, and its  
198 resulting consequences. The bow-tie is used to visualize causes and effect pathways of risks (IEC  
199 2009). This in turn provides the basis to analyse the system of management controls as much as  
200 identifying gaps and areas for an improved management. Existing experiences with the bow-tie  
201 analyses demonstrated that in most cases a multidisciplinary team is required for its proper  
202 implementation (Rausand 2011).

203 The origin of this method dates back to cause-and-consequence diagrams developed in the 1970s.  
204 Since the early 1990s the oil company Shell has made significant contributions to enhancing the use of  
205 the method and the visualisation in the bow-tie diagrams have been actively used in safety reports for  
206 the petrochemical industry in the UK and later in the US (Salvi & Debray 2006). Over the last decade,  
207 the approach has spread outside of the oil and gas industry to aviation, mining, maritime safety,  
208 chemical and health care. Application of the ISO standard in environmental management is still in its  
209 early stages (Creed et al. 2016). This is particularly the case for risk management of natural hazards  
210 with few existing examples in Europe.

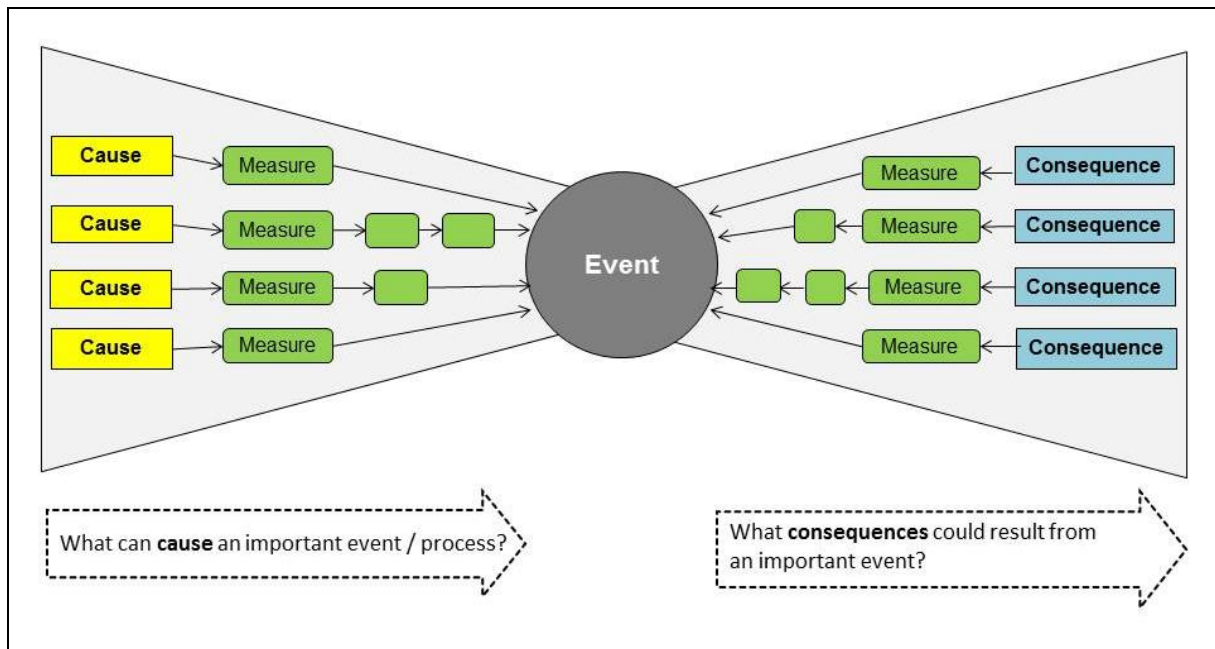
211 In practice, the bow-tie analysis is particularly beneficial due to its capability to structure and visualize  
212 the essential elements of risk (events) in the bow-tie diagram: causes and consequences as much as the  
213 measures in place to adapt to the cause and to mitigate the consequences (see Figure 1). The resultant  
214 structuring supports stakeholders in achieving an overview of the risks, their causes and consequences;  
215 in gaining an understanding of risk pathways and their interrelations; as well providing a basis to  
216 discuss management actions. The bow-tie diagram facilitates the visualization of the complexity of  
217 risks in one image in a schematic, clearly structured manner. Within a setting of a multidisciplinary  
218 multi-stakeholder team, bringing together different perspectives, interests and risk perceptions on a

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<sup>4</sup> In IEC 31010 the bow-tie analysis is highlighted as one of two tools (out of more than 30 risk assessment tools), which is able to assess a given system of management control; and it is highlighted as the only method which is able to integrate multiple causes and consequences in relation to a central event: the bow-tie analysis (IEC 2009)

<sup>5</sup> The Standard 31000 of the International Organization for Standardization (ISO) provide a framework for management of any risk characterized by a strong focus on practical implementation of risk management processes (Creed et al. 2016, p. 410).

219 multi-faceted risk situation the (visual) differentiation between different system elements as much as  
 220 the traceability of risk pathways are essential contributions of the bow-tie analysis to an enhanced  
 221 understanding of system structure in risk management.  
 222



223  
 224 **Fig.1** Schematic overview about the essential elements of the bow-tie diagram (based on IEC 2009). The centre represents  
 225 the event / challenge (e.g. a storm surge) society has to cope with and which has the potential to cause damage to society or  
 226 the environment. Causes of the event are described in the yellow boxes on the left side of the diagram; measures to adapt to  
 227 these causes are included in a 'barrier-position' (green box) between the cause and the event. The right side of the diagram  
 228 depicts the consequences of the event (blue boxes), mitigating measures minimizing or preventing the consequences from  
 229 occurring are included as a 'barrier' between the event and the consequences.

230 **Framework for the Wadden Sea Region**

231 Usually the bow-tie-analysis is applied to analyze the management control system in place for a well-  
 232 known risk. In this case the risk is predefined as a starting point, causes and consequences due to the  
 233 existing knowledge from technical risk assessment as much as existing strategies and measures are  
 234 added to the diagram as a means to detect potential lacks and room for improvement in the  
 235 management control system.

236 For the Wadden Sea context we adapted the procedure to complete the diagram and facilitated a  
 237 transformation of the bow-tie analysis into a bow-tie process: We adapted the original procedure to  
 238 our needs by filling the diagram *exclusively* with input from stakeholder *perceptions* on the multi-risk  
 239 situation – which of course include their individual level of knowledge and experience. In addition, no  
 240 further results of qualitative or quantitative analysis were introduced at this stage, since the exercise is  
 241 explicitly focused on disclosing, integrating and structuring stakeholders' perceptions. We used the  
 242 structuring capacity of the bow-tie analysis to order the stakeholders perceptions and to visualize risk  
 243 pathways by distinguishing the stakeholder inputs between risks, causes and consequences of risks. In  
 244 this process the risk event (centre of the diagram) is not predefined at the beginning. Furthermore, the  
 245 structuring capacity of the bow-tie facilitates joint identification of the central challenge(s) for risk  
 246 management in the trilateral WSR. In this form the bow-tie offers valuable insights into stakeholders'  
 247 understanding and interpretation of the risk situation and pathways. In this exercise it is not the aim to  
 248 evaluate whether the arguments and interlinkages between causes and consequences are logical or  
 249 factually correct or wrong. The bow-tie process facilitates societal understanding of the multi-risk  
 250 situation, from which current processes and measures could be evaluated as much as suggestions for  
 251 improvements could be identified. In this manner, we transformed the bow-tie analysis into a bow-tie

252 process. This bow-tie process underlines our understanding of risk management as an iterative,  
253 continuous process dependent on continuous stakeholder participation.

### 254 **The bow-tie process in the Wadden Sea Region**

255 In practice, the bow-tie exercise with the WSF was part of a series of three collaborative workshops. In  
256 this setting, the first workshop created the basis for the bow-tie process. The first workshop was  
257 focused on bringing together stakeholder perceptions of risks that are threatening the coastal  
258 communities and the environment in the WSR and delivers an overview of their level of urgency for  
259 the trilateral stakeholder group. As a result a list of perceived risks threatening the coastal  
260 communities was put together and subsequently ranked by the WSF's members. In a descending order  
261 the risks are a) storm surges and changes in climatic conditions, b) demographic change, c) risks  
262 resulting from imbalanced development and d) conflicting spatial uses between different user interests  
263 in the WSR, e) economic and ecological risks (e.g. shipping and oil tanker accidents), f) economic  
264 crises on global and regional level, g) risks and uncertainties with regard to emissions (especially  
265 CO<sub>2</sub>), h) pollution of rivers and the North Sea, i) loss of biodiversity and increase of alien species in  
266 the WSR. The subsequent discussions in the first workshop indicated the most urgent needs for  
267 improved management processes with regard to b) demographic changes (aging society, emigration of  
268 young and qualified people) and d) conflicting spatial uses.

269 The first workshop, therefore, created an overview about the most challenging risks and the identified  
270 potential ways to deal with them. For the achievement of the goal to comprehensively embed  
271 stakeholder perceptions as an essential element in the risk management process, we further facilitated  
272 an exchange about the detailed stakeholders' concerns, perspectives and personal assessment.  
273 Intensive discussions about their perspective and understanding of risk pathways have been facilitated  
274 by applying the bow-tie process. Based on the first workshop results, three bow-tie diagrams have  
275 been developed and discussed with the WSF members. The bow-tie diagrams are concentrated on the  
276 major challenges of 'demographic change', 'climate change resulting in environmental changes' and  
277 'imbalanced development in the WSR' which represent the central event in each diagram (see Figures  
278 2-4). Each diagram visualizes a breakdown of the stakeholders' input for the causes, consequences and  
279 adaptive or mitigating measures related to each challenge, as much as they visualise the identified  
280 links between the bow-ties at the decisive points. Figures 2-4 visualizes the resulting bow-tie diagrams  
281 produced with the software Bow-tie XP CGE Risk Management Solutions. Stakeholders' input on  
282 adaptive and mitigating measures are included but hidden in these figures for readability reasons.

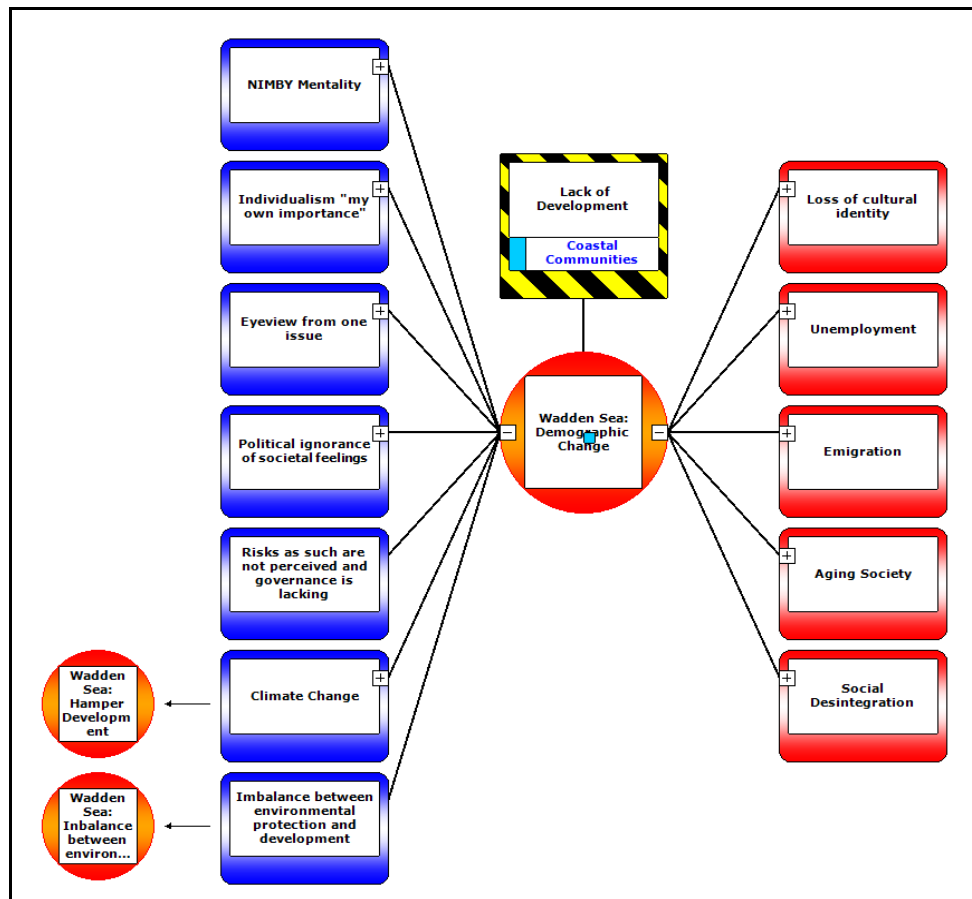
283 In the following we discuss the WSR bow-tie diagrams based on the results of the WSF workshops.  
284 The focus here lies on the methodical benefit of the bow-tie process. The examples underline the bow-  
285 tie's capabilities to disclose the most urgent risks to be addressed by risk management processes, to  
286 detect the current availability and needs of measures and enable stakeholders to detect obstacles in the  
287 existing risk management process.

### 288 **Demographic change – detect and unravel the most urgent risk**

289 The first bow-tie addresses the risk of demographic change in the WSR (Figure 2). It provides a good  
290 example how the bow-tie facilitates and support the disclosure of most urgent risks. The bow-tie  
291 diagram reflect stakeholders concerns of a lack of balanced development as a major driving force of  
292 demographic change affecting coastal communities in all three countries in a similar, mostly negative  
293 way (see Figure2). The risk pathway of demographic change makes clear that mainly societal  
294 processes cause demographic change in the WSR. The stakeholders perceived an increased NIMBY  
295 mentality (Not In My Back Yard), increased individualism, as well as limited and egoistic thinking as  
296 essential elements of these social processes. Several different issues were identified as consequences –  
297 including increased unemployment, out-migration especially of young and highly qualified people, an  
298 ageing society and increased social disintegration. Unravelling the risk pathway for the risk of



299 demographic change expressed the different societal processes which lead to stagnating development  
 300 and increasing concerns in coastal communities. In this context, risk management means more than  
 301 merely implementing technical measures. Dealing with processes of societal change is an important  
 302 part of comprehensive risk management in order to successfully manage risks and uncertainties.  
 303 Regarding the capabilities of a bow-tie process, the bow-tie on demographic change highlighted its  
 304 benefit as a structuring as much as a communication tool. By structuring the stakeholders' input as  
 305 causes and consequences, the resulting picture supports an understanding of risk pathways and  
 306 provides a basis for discussion on risk management strategies and measures.  
 307



308  
 309 **Fig. 2** Bow-tie diagram dealing with stakeholders concerns about demographic changes in the WSR; information on adaptive  
 310 and mitigating measures are hidden; diagrams were produced with the software Bow-tie XP CGE Risk Management  
 311 Solutions

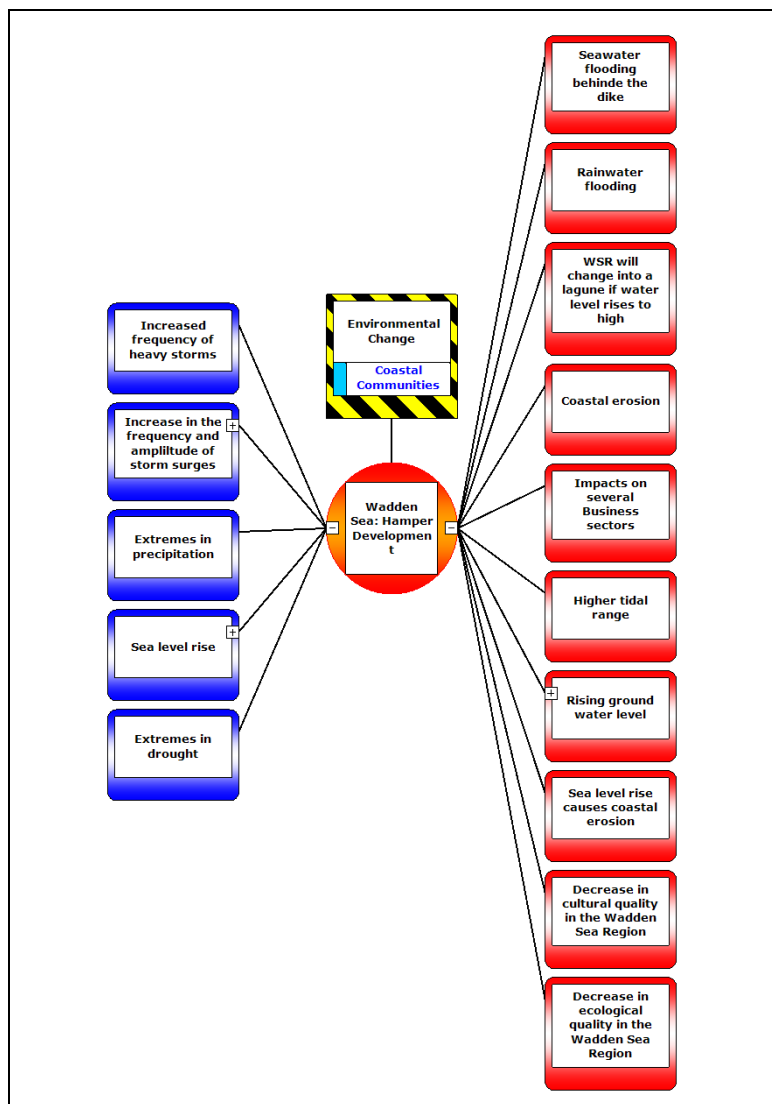
312 **Environmental changes – assess availability and identify needs of measures**

313 The second bow-tie reflects the stakeholder concerns about the threat of climate change in the WSR  
 314 which might result in environmental changes affecting the WSR communities (see Figure 3). By  
 315 focussing on the issue of storm surge management, this bow-tie process presents an example how the  
 316 bow-tie supports the stakeholders in taking stock of current existing measures and identifying  
 317 requirements for new measures in the future.

318 As a general result, the bow-tie process underlines stakeholders' concerns about changed  
 319 environmental conditions due to climate change, since they might (negatively) influence social,  
 320 economic and natural development in the WSR. The stakeholders identified increased frequency and  
 321 amplitude in storm surge events, increased precipitation and rising sea levels as causes hampering the  
 322 development in the WSR. Consequences resulting from these negative changes are perceived as  
 323 increased coastal erosion, rising ground water levels and potential change of the WSR into a lagoon if  
 324 the water level rises too high, flooding events, impacts on business activities in the area (e.g.

325 agriculture, tourism, etc.) as well as a perceived decrease in the ecological and cultural quality of the  
 326 WSR. Taking a closer look at the stakeholders' input on storm surge management, the bow-tie  
 327 visualizes the fact that dealing with the causes of storm surge risks means applying mainly adaptive  
 328 measures. These adaptive measures have already been implemented in terms of technical coastal  
 329 protection measures. The discussions with the WSF and other studies (comp. Gonzalez-Riancho et al.  
 330 2015; Ratter & Sobiech 2011) made clear that there is consensus and deep-seated trust in traditional  
 331 engineering measures (such as dykes, flood barriers etc.) representing an adequate defence against  
 332 disastrous storm surge events as well for the decades to come. In this context the bow-tie process  
 333 further underlined the main challenges in storm surge risk management result from the consequences  
 334 of storm surge events, under current and future climate conditions. Different measures are already in  
 335 place for mitigating these consequences, but within the bow-tie process discussions with the  
 336 stakeholders clearly emphasized the need for improved and additional measures.  
 337 The example of storm surge management highlighted the bow-tie's capacity to detect the availability  
 338 and the needs of measures in currently applied risk management processes. The visualizing capacity of  
 339 the bow-tie process highlighted the imbalance between applied measures (many adaptive, fewer  
 340 mitigating measures). The structured overview provides a sound basis through which new or improved  
 341 measures and strategies can be discussed and evaluated and potential barriers in the current  
 342 management processes can be detected.

343



344

345 **Fig. 3** Bow-tie diagram representing causes (left) and consequences (right) concerning the threat of environmental changes  
346 due to climate change affecting the coastal communities in the WSR, information on adaptive and mitigating measures are  
347 hidden; diagrams were produced with the software Bow-tie XP CGE Risk Management Solutions

### 348 **Imbalanced development – detect obstacles in current management processes**

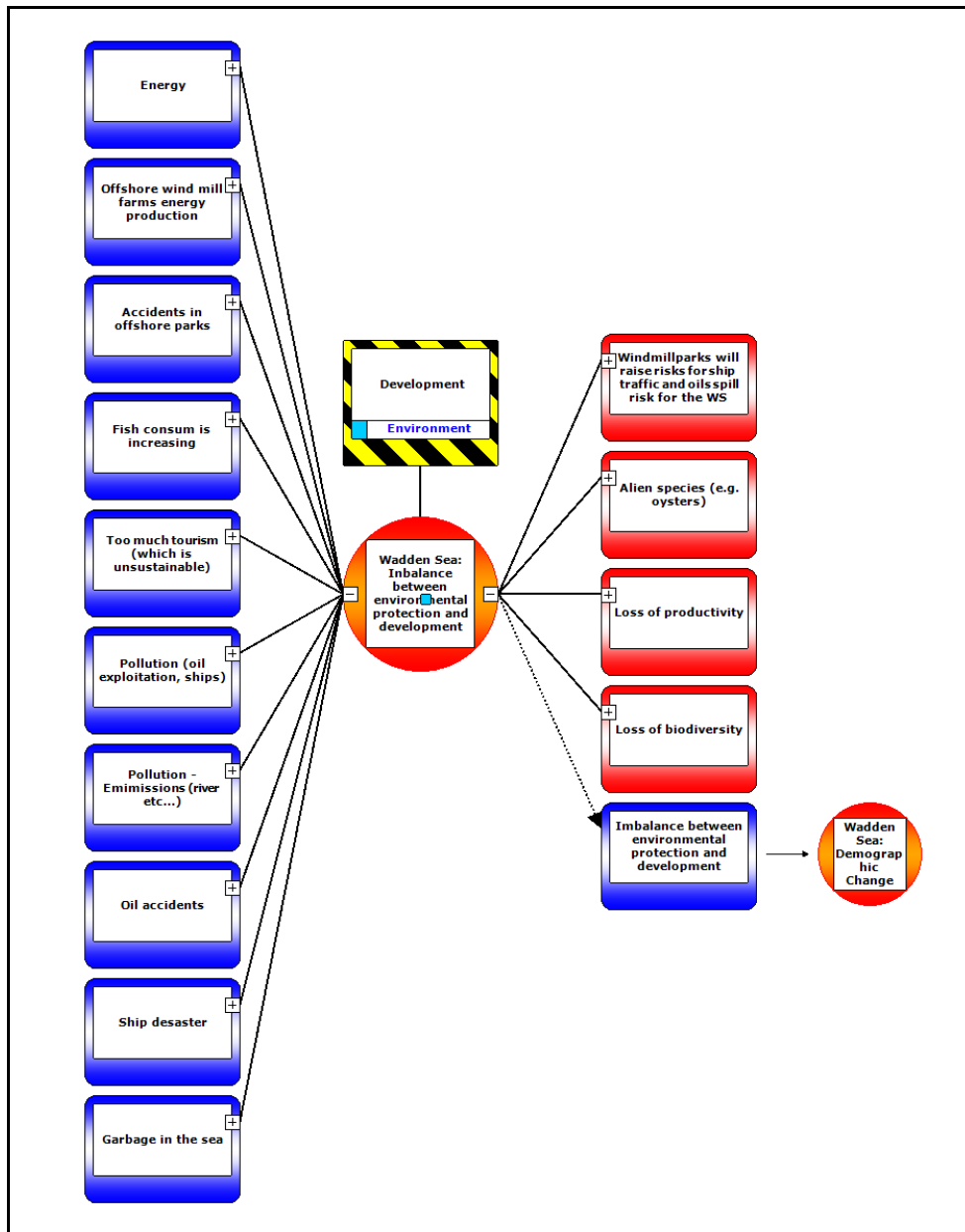
349 The third bow-tie discloses risk pathways of the major challenge ‘imbalanced development in the  
350 WSR’, mainly referring to the prospect of uncoordinated, unsustainable development in the region  
351 (see Figure 4). This bow-tie is a good example to demonstrate the bow-tie’s capacity to examine  
352 existing strategies and measures as much as to detect obstacles in the current risk management  
353 process.

354 The bow-tie process highlighted stakeholders’ concerns regarding an imbalance between different  
355 lines of development, including social, economic and ecological development. The causes of  
356 imbalanced development are related to intensified sectoral activities, e.g. in the energy, fishing, or  
357 tourism sector. Furthermore, different sources of pollution, e.g. oil spills, shipping accidents,  
358 emissions and marine pollution concerned the WSF members. As a consequence, loss of productivity  
359 and biodiversity as well as an increase in alien species in the WSR are suspected. Increased ship traffic  
360 and greater risks of oil spills were also feared.

361 Concerns regarding an imbalanced development are closely linked with the WSF’s endeavour to  
362 facilitate sustainable development in the WSR, in which “economic activity supports social  
363 development and safeguards healthy ecosystems and cultural landscapes throughout the WSR” (WSF  
364 2013, p.12). In this context the WSF developed an Integrated Coastal Zone Management (ICZM)  
365 strategy to foster sustainable development by defining objectives for overarching issues for all sectors  
366 in the WSR as well as for some specific developments (WSF 2013).

367 The bow-tie diagram (Figure 4) shows most of the risk pathways as the issues addressed by the  
368 already existing ICZM-strategy of the WSF. This obviously close link enabled the participants to  
369 distinguish between measures already in place and measures which need to be elaborated. The bow-tie  
370 process helped the WSF to examine their existing ICZM-strategy with regard to the status of the  
371 strategy’s implementation and effectiveness. The workshop highlighted an increased need to transform  
372 the recorded goals into practice. Furthermore, the bow-tie process made clear that the ICZM strategy is  
373 not sufficiently known and visible in the different sectors in order to be considered for practical  
374 implementation of risk management measures. This example demonstrated how the bow-tie process is  
375 supportive in detecting whether already existing strategies and measures are sufficiently established  
376 and efficient or neither of the two. This might help the WSF to detect further action points as well as  
377 obstacles hampering the implementation process of existing strategies.

378  
379 The WSF exercise is able to demonstrate the methodical benefits of the bow-tie process. In general,  
380 the bow-tie process supports an understanding of the complexity of the multi-risk situation. The bow-  
381 tie process supports a global overview on a complex multifaceted risk situation as well as at the same  
382 time enabling the participants to disclose risk pathways at the specific (local) level. The bow-tie  
383 process steered the stakeholders’ focus on the fact that risks are interlinked and interdependent.  
384 Cascading effects between the different risk clusters can influence the risk management performance  
385 and have to be taken into account in risk management processes. The latter was visualized in the bow-  
386 tie diagram by the linkages and connections between the three bow-ties, e.g. the bow-tie diagram on  
387 imbalanced development highlights several interlinkages and feedback to consequences mentioned in  
388 the cluster of demographic change. In addition to the global view on the multi-risk situation the bow-  
389 tie process allows a more detailed look at the measures and activities in place at different levels. In the  
390 WSR we made use of this fact by identifying and determining current responsibilities for different risk  
391 management tasks together with the WSF stakeholders. The discussions helped to identify the  
392 potential role of the WSF in risk management on the trilateral level.



393  
 394 **Fig. 4** Bow-tie diagram evolving around the worries of an imbalanced development and conflicting social, economic and  
 395 environmental interests; information on adaptive and mitigating measures are hidden; diagrams were produced with the  
 396 software Bow-tie XP CGE Risk Management Solutions

397 **Discussion on the use of the bow-tie analysis**

398 The call for enhanced stakeholder participation is not only part of a democratic process it also includes  
 399 the enhanced consideration of multiple differences, perceptions and interpretations of risks and their  
 400 impacts on different actors, sectors or institutions. Our experience with the WSF demonstrated the  
 401 advantages of a bow-tie process, as a beneficial framework to facilitate stakeholder involvement. The  
 402 bow-tie process, as presented for the WSR, underlined the method's potential to support  
 403 communication and co-construction in a multi-stakeholder context. In this context the bow-tie process  
 404 supports the structuring of risks by a systematic identification of risks, causes and consequences and  
 405 significantly enhances communication about awareness of risks and their management in the  
 406 stakeholder group (compare IEC 2009). The structured discussions facilitate stakeholders to gain  
 407 enhanced understanding of the complexity and interrelationships of different risks, causes and  
 408 consequences, facilitate an overview about the current state of management measures and enable  
 409 stakeholders to detect needs from improved measures as much as to detect obstacles in the current risk

410 management process. In this context, the bow-tie exercise with the WSF demonstrated the beneficial  
411 contribution for risk analysis and risk evaluation (following ISO 2009).  
412 Nevertheless, the schematic visualization of the structuring processes within the bow-tie diagram also  
413 gave room for critique and showed some limitations. The complicated structures of risk pathways the  
414 bow-tie diagram allows to a limited extent only the visualization of feedback effects between the  
415 different elements. Feedback and feedback loops, however, are important for the examination of  
416 complex and highly interlinked processes between different risks. The WSF stakeholders also  
417 criticised the scientific-look and model-like character of the bow-tie diagram, which requires intensive  
418 dedication and demands flexibility on the part of the stakeholders towards new ways of thinking as  
419 well as their willingness to invest time and mental training. These reservations notwithstanding the  
420 WSF stakeholders were willing to invest time and dedication in the bow-tie process. Such a  
421 comprehensive commitment of the stakeholders we would argue is an essential precondition for the  
422 bow-tie process and a driver for successful stakeholder participation. The interactive bow-tie process  
423 supports stakeholders to communicate their perspectives to others in a structured way as well as to  
424 learn about other perspectives. Discussions in the bow-tie process make the whole risk management  
425 cycle and its single elements more transparent and comprehensible for the stakeholders.  
426 Based on the presented experience in the WSR we encourage actors in coastal risk management to  
427 take up the bow-tie process as a communication tool supporting disclosure of the variety of  
428 perceptions and perceived cause-effect-relationships, which is an essential part of a comprehensive,  
429 complementary and widely-accepted grounding for risk management processes.

## 430 **Conclusion**

431 The aim of the paper was to methodologically contribute to the rising demand for multi-stakeholder  
432 involvement in coastal risk management processes and to demonstrate the applicability of stakeholder  
433 involvement in risk management. We addressed the question as to how risk perceptions as well as  
434 societal concerns and needs can be made accessible to the risk management process in a multi-  
435 stakeholder participatory manner. The case study of the trilateral WSR instructively demonstrated how  
436 the bow-tie analysis, performed as a bow-tie process, was put into practice. This process supported the  
437 structuring of the multi-risk situation in the WSR was clustered around the challenges of ‘demographic  
438 change’, ‘climate change resulting in environmental changes’ and ‘imbalanced development in the  
439 WSR’. The bow-tie process in the WSR supported the detection of urgent management needs to  
440 improve existing risk management and of obstacles in current risk management processes.  
441 We were able to underline the bow-tie process capacities to enhance stakeholders’ understanding of  
442 risks and risk management processes, fostered structured discussion on risk pathways, to pave the way  
443 for stakeholders to give feedback about the performance and efficiency of actual management  
444 processes as much as to strengthen stakeholders’ commitment in risk management processes.  
445 Enhanced understanding and rethinking of risk management processes are emphasised as one of the  
446 positive implications that multi-stakeholder participation might contribute in enhanced risk  
447 management. And at the same time, enhanced understanding of risk management processes facilitates  
448 clearly structured discussions to continuously define and verify the role and contribution of multi-  
449 stakeholder involvement in these processes. The inclusion of multiple stakeholder perceptions can  
450 stimulate communication and discussion which in themselves are main benefits of multi-stakeholder  
451 involvement in risk management processes. Negotiations are as much a learning process for  
452 stakeholders as for the decision-makers involved – enhancing awareness and acceptance of risk  
453 management measures and policies within the stakeholder community. Our findings emphasize that  
454 making stakeholders’ voices heard and including their perspectives and concerns in a risk management  
455 process is an essential contribution of multi stakeholder involvement to facilitate decision-making for  
456 successful risk management processes. In the sense of the guiding principles of the Sendai  
457 Declaration, stating that “disaster risk reduction and managements depends on coordination

458 mechanisms within and across sectors and with relevant stakeholders at all levels [...] and a clear  
459 articulation of responsibilities across public and private stakeholders” (United Nations ISDR 2015, p.  
460 8), we demonstrated with the WSR case that such strategic principles can be put into practice.

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