Flood response process knowledge of Lower Sava Valley communities in Slovenia

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Abstract— This paper focuses on the learning process of the flood-endangered communities in the Lower Sava Valley in Slovenia. In past five years, the communities faced several floods, which occurred because of the rain in central and northeast parts of Slovenia. Floods differed by their severity. On the first hand, the least harming caused only higher water levels of the major rivers, which cause isolation of couple of households. On the other hand, the most harming floods caused roadblocks, flooding the entire areas and communities. Hydrological and meteorological data, describing river dynamics and rainfall was gathered from the Slovenian Environment Agency database, while data describing the severity of the flood events from the Administration for Civil Protection and Disaster Relief database.

To be able to simulate and assess floods` characteristics, we combined all gathered data into the singled database with the timeline of the flood events. We used data mining, process modeling and statistical methods to build up the simulation model, to compare simulation output with the real world data and to finally evaluate community learning process.

Through the past floods, communities had the opportunity to learn about flood characteristics, how to properly react and protect the endangered property. We identified emerged tacit knowledge, which made possible some communities to reduce flood risk. We conducted preliminary semi-structured interviews with people who live in the flood-endangered areas to get the insight on the perception of the floods. Further, we designed fuzzy knowledge assessment system to evaluate which of the communities demonstrated the highest learning experience.

We identified influence of the community knowledge on the response process and further try to optimize learning model, with the measures, extracted from the national strategic defense documents. The improved model revealed much higher self-reliance and flood resilience of the communities, when they are provided with more systematic learning about the floods and counter flood measures. Consequently, the whole flood response process workload significantly reduced according to the higher ability of the communities to resolve flood situation with no additional external support.

Keywords— community learning, disaster management, experiential learning, floods

I. Introduction

In the context of regional disaster management system, there is a significant emergency response demand in the communities during flood events. Major flood events between 2009 and 2015 revealed that floods rarely affected single households. Instead, communities are largely the ones that are being affected and in need of response. Therefore, the Slovenian system for protection from natural and other disasters provides support to the regions during disaster events by means of distress phone services, regional Civil Protection Commands which control response activities at the regional level, and Civil Protection Commands and fire brigades which take care of localized disaster events at the municipal level. The system is based on national strategic documents as well as regional and local operative procedures that are prepared based on past experiences with natural disasters at the regional or local levels.

Community experiential became an important pillar for supporting strategic operative policies. Communities learn through their own experience with flood risks. Households being part of the communities share the information they collect about local water conditions and their own endangerment with the responsible public bodies, such as Civil Protection and Disaster Relief Administration and local Civil Protection Commands. Experiential knowledge and reassessed information provided by the communities therefore influence the response part of the disaster management cycle, while the preparedness phase is approached only in form of available and trained response force.

The learning model of the flood-threatened communities of the south-eastern Slovenia revealed learning-related differences among the communities. These differences originate from the nature of a flood event which can involve several flood sources threatening a single community, while presenting no direct disaster risk for others. Consequently, experiential learning influences mostly by means of identifying past and ongoing disaster risks. At the same time, the change in the dynamics of flood events in the past five years requires more preventive and educational action to improve community self-reliant flood protection and to relieve flood response entities of the part of their workload. Such preventive and educational measures have been drawn in the years 2009 and 2010 but failed to be effectively applied on the flood-endangered communities, even though they would significantly raise flood resilience of the endangered communities.

II. Literature review

There is no doubt that global climate change has increased the frequency of extreme precipitation events and may cause many more floods in the future. This brings great human life and property losses by flooding fields, washing away housings, infectious diseases, etc. [1]. Flood risk is expected to increase in many regions of the world [2], which indicates heavier exposure to consequences caused by flooding. Repeated exposure to natural disasters, such as floods, renders people more resilient and facilitates social connectedness that enhances a sense of place [3]. A logical result of threat acceptance and rising resilience in the urban, suburban, and rural communities in flood-endangered areas is the development of risk management, capable of flexible adaptation and improvement [4].

Simulation models have become a widely used tool for risk assessment and disaster prevention. Authors find simulation modelling useful as a decision-support environment for space range safety [5], using it also to create typhoon compound disaster simulation [6], to address the inefficiency problems in the procurement operations in disaster relief logistics [7], and last but not least, for satellite-supported flood forecasting [8].

Within the general field of disaster modelling and simulation, flood prediction and computer model based assessment is a recognized methodological approach. Some authors argue such approach is a good method, to convert real world flood data into the computer program for better observation and visualization [9]. Others support the idea that there is a strong need to explore realistic flood simulation techniques that represent complex dynamic systems [10]. Many authors have viewed the issue of flood simulation and modelling from different perspectives. They used computational modelling to determine efficient coastal flooding protection [11], they found mixed probability distribution a useful tool to model fluctuations of the Caspian Sea [12], and successfully used computational modelling methodology to provide an efficient means of assessing the flood risk of a complex dike system [13].

Even though disaster risk management framework is under the jurisdiction of national and local governments from the financial [14], legal [15], and implementation [16] perspectives, suburban and rural communities tend to rely on their own experience and information sharing [17]. Suburban and rural communities are more likely to assess an ongoing situation and build their response based on their own social network, which includes trustworthy information sources [18]. In addition to such community networking, suburban and rural communities show sensitivity to the geographical origin of the external information concerning the ongoing flood situation. Communities are more receptive to the external information with local origin than information from afar [19].

Experiential community learning during and after flood events enhances disaster preparedness not only of private households affected by floods, but businesses and authorities as well [20]. Experiential learning is a learning process, where experience plays a central role [21]. For such learning process it is of great importance to be implemented in the community of interconnected partnerships [22] because community-based learning initiatives, which are experiential and action oriented, complement regular forms of learning [23]. They provide learners with the chance to participate in organized activities and to meet the needs of the community [24].

Experiential learning is a very effective approach to disaster threatened learning communities [25]. Well-managed and applied experiential community knowledge can play a vital role through ensuring the availability and accessibility of accurate and reliable disaster risk information when required [26]. In general, people tend to ignore personal disaster risks, representing themselves as disaster immune [27]. Such optimism is present in communities that are threatened with low probability disaster risks and where people lack direct experiences [28]. Experiential learning thus improves risk perception in general and flood risk perception in particular ([29], [30], [31], [32]).

Experiential community learning which occurs as single-loop learning results on the one hand in changes of the community behaviour, strategies, and techniques [33]. On the other hand, it enhances partnerships among communities and public services, which are responsible for disaster preparedness and response [34]. Experiential learning enables a community to verify its expectations of the governing bodies' capabilities to implement efficient disaster response process through its ability to influence the response process [35]. Such mutual collaboration during disaster events is of high importance for a community in terms of developing its resilience and withstanding the burden of the ongoing emergency [36]. For this reason, community reactions have a crucial role in process optimization during disaster events [37].

Efficient disaster risk management is a shared goal of the community, national and local governments, and disaster responding services ([38], [39]). It is also a subject of active community participation in the disaster management cycle [40]. To achieve a solid and sustainable level of community-based safety, a community should encourage its individual members to participate in disaster management processes in order to develop knowledge based prevention capabilities and risk reduction [41]. An active community has strong learning abilities. Therefore, it can easily assess its needs, share information, and provide necessary public influence [42]. A learning community is capable of overtaking traditional organizational structures and mechanisms when addressing disaster and risk management [43] through a diverse range of organizational and professional resources that can be called upon to assist recovery [44].

III. Materials and Methods

The research methodology that made it possible to determine community-learning performance consisted of several stages. First, we gathered data from the Administration for Civil Protection and Disaster Relief. The data covered four flood events from 2010 to 2014, providing official responses for 185 distress events including 167 entities. We merged the data in a single database, using each distress event of each entity as an instance in the database. Further, we obtained the data on river flow rates and rainfall from the Slovenian Environment Agency, and merged that with previously created database, using the dates of the distress events as merging criterion. Finally, we used Google Maps and Google Earth

API to determine the altitude of each entity and the distance from the distress source. The attributes of the final database are presented in Table 1 and Table 2.

Table 1: Attributes of the final database 1

Date	Year	Distress type	Municipality	Community	Entity	Distance	Altitude
13.9.2014	2014	rainfall	KRŠKO	ARDRO PRI RAKI	ARDRO PRI RAKI 12	0	222.00
18.9.2010	2010	rainfall	BREŽICE	ARTIČE	ARTIČE 40	0	217.00
13.9.2014	2014	rainfall	BREŽICE	BREŽICE	BREZINA 4A	0	152.00
18.9.2010	2010	Krka	KRŠKO	BROD V PODBOČJU	BROD V PODBOČJU 21	58	145.00

Table 2: Attributes of the final database 2

Activity	Responders	Flow rate Jesenice	Flow rate Podobočje	Flow rate Širje	Flow rate Hrastnik	Rainfall Bizeljsko	Rainfall Sromlje	Rainfall Brege	Rainfall Smednik
Water pumping	Local fire brigade	2274.00	446.00	697.00	978.00	42.4	46.7	82.4	80.6
Water pumping	Local fire brigade	2048.08	135.54	859.74	1481.55	72.6	64.4	102	75.5
Water pumping	Local fire brigade	2274.00	446.00	697.00	978.00	42.4	46.7	82.4	80.6
Saving the animals	Local fire brigade	2048.08	135.54	859.74	1481.55	72.6	64.4	102	75.5

Further we designed flood simulation to be able to conduct flood response process optimization. The simulation design (Figure 1) is composed of four inputs. It also integrates the Tabular Application Development (TAD) methodology [45] and the Slovenian standard operating procedures for disaster response, designed as a decision tree. We also used the C4.5 data mining algorithm [46], due to relevant contribution of the data mining techniques within the computer simulations [47].

The first input consist of merged meteorological and hydrological data, which is used as a trigger for establishing command authorities of the local association of voluntary fire brigades and the local Civil Protection Service. The second input consists of classification rules based on which profile classes for the included entities (households from the flood-endangered areas) are formed. The third input includes the entities selected to participate in the simulation run. Entities' data is gathered in the TAD entity table. The final input consists of adjusted TAD activity table with activity flow notation of entities' daily activities.

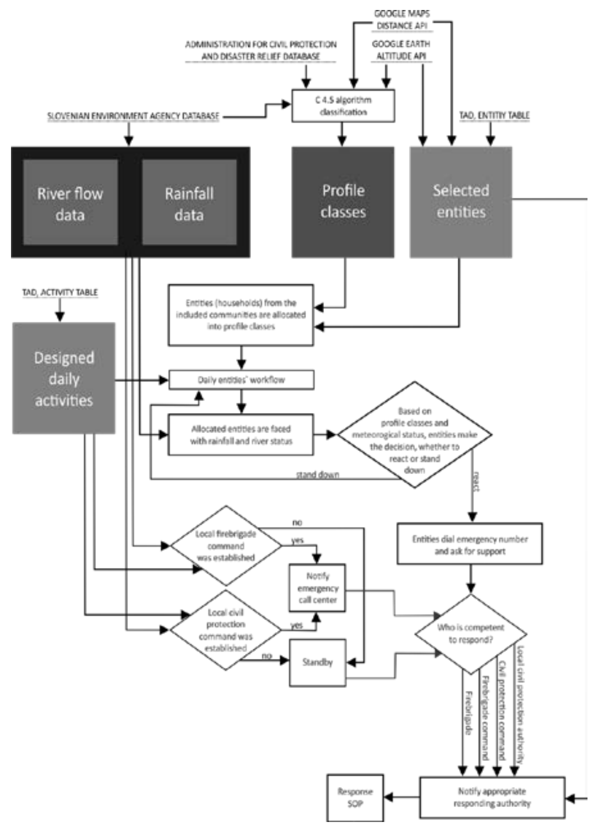

Fig. 1 simulation design

The simulation run is executed in three stages. In the first stage, the entities are allocated into classes, which specify during what type of meteorological and hydrological conditions the respective entities will become flood-endangered. Further on, they do their daily activities according to the TAD activity table, until the rainfall and river status trigger an alert. The second stage begins with the entities' decision to call an emergency centre or the Civil Protection Service and ask for response according to the flood threat they are exposed to. At the same time, command authorities of local disaster response services are being established according to potentially critical rise of the river flow rates. The operator at the distress call centre or the Civil Protection officer who has received the call decides which is the most adequate responding authority, based on the situation, and forwards the information to the competent response service. As part of the third stage of response services, either a local Civil Protection Service or one of local fire brigades respond to the distress call in line with standard operating procedures. In our research, the term ‘standard operating procedures’ refers to official documents prepared by local government and response services, which must be consistent with the national standard operating procedures.

The following step included semi-structured interviews with people who were part of the households that are represented in our database as entities. We selected 22 participants from flood-endangered entities. Participant recruitment criteria were: they had to be actively involved in at least one flood event, they had to live in one of the households affected by the detected distress sources, and they had to have open access to all the information about the ongoing situation, along with their family members and other members of the household. The participants were young adults and adults (13 male, 9 female) with the average age of 39.63 and standard deviation of 12.19. The aim of the interviews was to detect how entities perceived their own learning about floods, circumstances, and response actions of responsible services. We used an interview framework in a matrix form presented in Table 3 and analysed results with paired t-test.

Table 3: Interview framework

	Risk awareness	Disaster risk information	Household response	Knowledge source
Before the first event	x	x	x	x
During the first event	x	x	x	x
After the first event	x	x	x	x
Before the following event	x	x	x	x
During the following event	x	x	x	x
After the following event	x	x	x	x

To be able to conduct knowledge perception measurement we developed a scale to determine whether disaster risk awareness improved through the flood events, what was the information source of the entities, how household responded to the flood, and what was the perceived knowledge from the first flood events.

In the third step, we used multivariate tests, that according to Liu et al. [49], received much attention in the field of flood analysis. We used multivariate analysis of variance to compare rainfall and river flow attributes recorded in the four flood events. To be able to find a similarity of the flood events through flow rate and rainfall measurements, we used Wilk`s lambda as a probability distribution. We compared the data by year of occurrence, trying to discover which attribute (flow rate in the first case and rainfall quantity in the second) influenced the difference most significantly. Based on the events’ similarity, and learning rules from the third step we further on designed a fuzzy system [48] presented in Figure 2, which served as a tool for measuring the learning performance of flood-endangered communities.

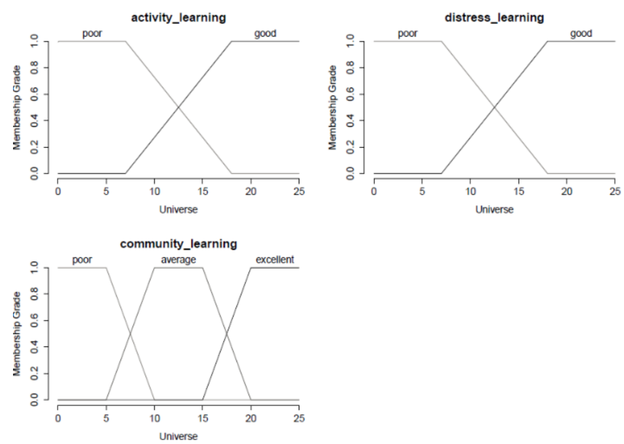

Fig. 2 fuzzy system

Finally, we designed optimization algorithm (Figure 3) that simulates additional systemic community learning, besides the experiential learning. We collected optimization rules basis from the Resolution of national security strategy of Republic of Slovenia [50] and the Resolution of national program of protection against natural and other disasters from year 2009 to year 2015 [51]. The optimization algorithm foresees several educational prevention measures, to be able to increase resilience and self-reliance of the flood-endangered communities: Improvement of general flood preparedness; Systematic modernization of training programs; New educational programs for pre-school and school children; Encouragement of measures that rise prevention, protection and security awareness.

We applied simulation of educational prevention measures on the flood events` data, including following process dimensions: communication time, travel distance, number of process architectures, number of process patterns, number of activities, number of entities in distress, total number of executed standard operating procedures, and number of different standard operating procedures during one event. We took into account severity level of every single assessed flood event. According to recorded occurred damage, scope of the flooding and response force activity workload, we determined event horizon when an individual household becomes incapable of providing self-reliant flood protection and must request for emergent response.

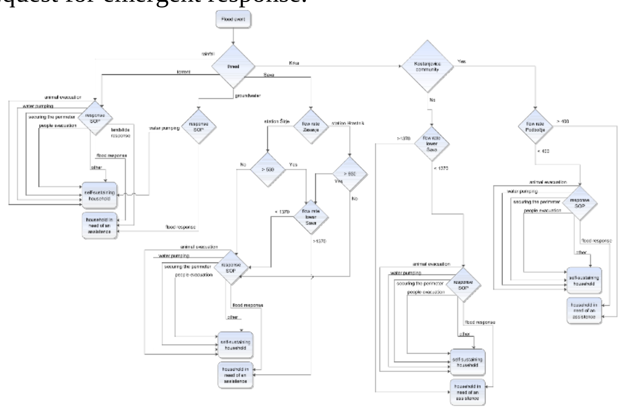

Fig. 3 learning process optimization algorithm design

IV. Research Area and Flood Events

We conducted our research in the Lower Sava valley, a geographic region in the eastern part of Slovenia, included in the Lower Sava statistical region (Figure 4), which consists of three major municipalities: Brežice, Krško, Sevnica, and a minor municipality of Kostanjevca na Krki. According to the Statistical Office of the Republic of Slovenia [52], the Lower Sava statistical region which covers an area of 885 km2 has a population of 70,215 and the population density of 79,3 per km^2.

Fig. 4 the Lower Sava statistical region, Slovenia

The region has a good logistic infrastructure (railway, highway, airport), with Slovenia's only nuclear power plant (NEK) as one of its main features, along with thermal tourism centre, that is, the Čatež health resort. The number of enterprises in the respective year was 4,535 and their combined turnover totalled €3,171 million.

The geographic region of the Lower Sava valley (Figure 5) lies between the Gorjanci Hills on the southern side and the Sava Hills on the northern side of the valley. It is riddled with numerous permanent streams as well as intermittent springs and streams. Two major rivers that cross the valley are the Sava and the Krka. The Sava which is the longest river in Slovenia (220.72 km) flows through the Lover Sava valley and enters the Pannonian Basin under the town of Brežice [53]. According to the Slovenian Environment Agency [54], the Sava discharges water from an area of 10,746 km2. By the size of its basin, the Krka is the largest river that empties into the Sava, taking up 21.4% of the Sava's catchment area. The two rivers join in the municipality of Brežice, near the town of Brežice.

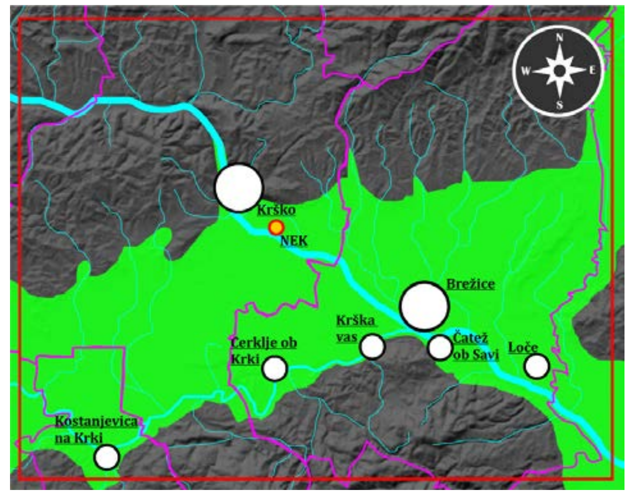

Fig. 5 geographic region: The Lower Sava valley, Slovenia

Between 2010 and 2014, the communities in the Lower Sava valley experienced four flood events (Figure 4) with different severity levels and different impacts, owing to different metrological and hydrological conditions during the events. There are five flood sources in the valley. In addition to the Sava and the Krka as two major rivers, the streams that carry water from the hills quickly grow into torrents with a threatening power within few days of continuous rain. The rain itself can cause considerable problems when meteoric water starts to overwhelm the low positioned planes with impermeable soil layers. The communities and the infrastructure located low and near the river can experience groundwater flooding, which usually affects the underground parts of buildings, such as basements, engine rooms, garages, workshops, etc.

Flood experts believe that the flooding of the Krka in the communities in the municipality of Brežice, which are located within the 8 km area before the confluence with the Sava, is highly dependent on the Sava and its flow rate. High flow rates of the Krka alone represent a threat for the western communities, such as the town of Kostanjevica na Krki in the municipality of Kostanjevica na Krki. However, eastern communities from Cerklje ob Krki to Krška vas may face high water levels but with no severe consequences. There are two major reasons behind such hydrological dynamics. Firstly, the town of Kostanjevica na Krki is built on an island which acts as a natural barrier against the Krka flow. At the same time, there is a large primeval forest to the northeast of the Kostanjevica island, which acts as a retention area during floods and prevents water from draining out of the area. The second reason lies in the ratio between the flow rates of the Sava and the Krka once they exceed the average rate. The power of the Sava's flow starts to block the Krka's flow, drastically increasing the drainage capacity of the latter. As a result, the Krka floods the communities that are located near its bed and close to the confluence with the Sava.

V. Results

Primary simulation logic which runs the first and the second stage of the simulation is based on the decision tree classification with precision of 94.21%. We executed the simulation using the original data gathered from the four flood events as the input, subjected to decision rules. The red outline in Figure 5 represents the area (longitude and latitude) in which the respective entities are located. Within the simulation run, all entities were exposed to meteorological and hydrological conditions as recorded during the actual flood events. Such simulation scenario enabled data comparison, representing the overall flood response process and the classification-generated simulation output. The simulation output of the first and the second stage included entities, allocated into several classes according to the expected flood threat. The entities were merged into communities based on their geolocation and the geographical borders of local communities.

A comparison of the Pareto charts with the original data and simulation output (Figure 6) reveals satisfactory matching of simulation results with the original data. The nearest matching was identified between real data and simulation output of the meteorological and hydrological conditions that represented no flood threat to the communities. A comparison regarding ground water, the Sava, and rainfall as potential flood threats indicated there was a minor derogation between both data types, with the simulation run occasionally classifying more entities as endangered compared to the classification based on real data. A comparison regarding the communities endangered by the Krka revealed a similar derogation yet in the opposite way. According to the simulation, several entities were classified less endangered compared to real data classification.

The simulation output of the third stage was based on previously allocated entities. It comprised the information on which responding organization engaged in the emergency response, how many times and in what community. The output chart shows response process workload of the emergency responders. In the bubble chart, the X-axis displays communities and the Y-axis displays responding units.

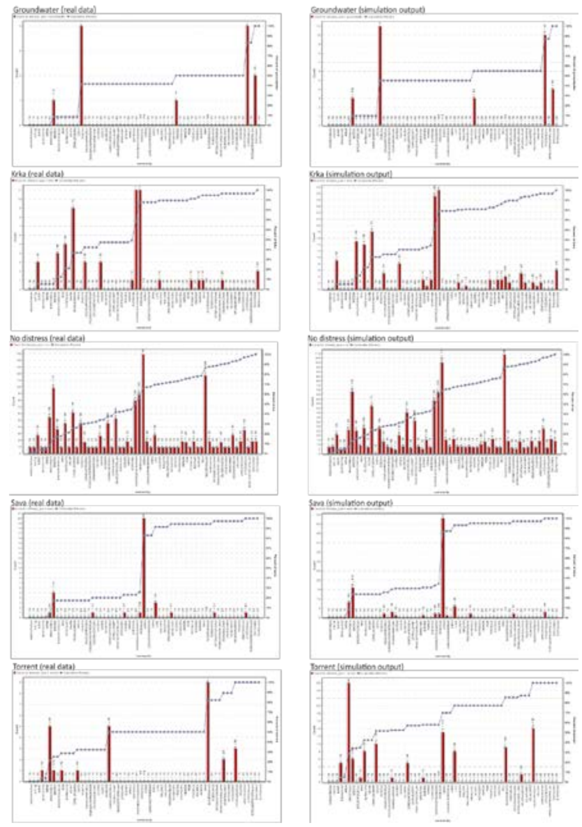

Fig. 6 pareto chart comparison of the original data and simulation output

Bubble sizes and bubble colour indicate responding frequency and entity in distress, respectively. The criterion in selecting the units of the primary, secondary, and tertiary response forces was the distance between the entity in distress and a particular unit. The primary response force during flood events is shown in Figure 7.

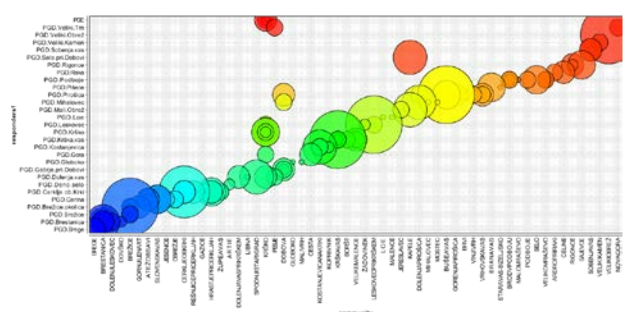

Fig. 7 response process workload of the primary response force

We can clearly relate the responding units to the community. The closest responders reacted to a distress within the community. The most notable derogation was identified with the Professional Fire Brigade (PGE), which responded also out of the community where it is geographically located.

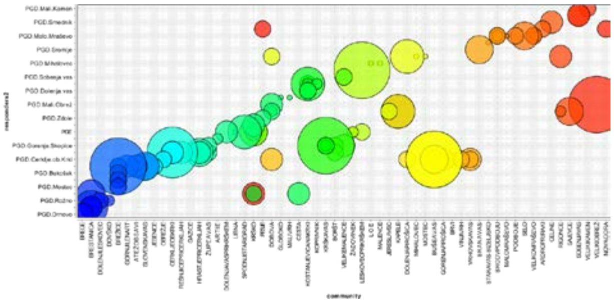

Fig. 8 response process workload of the secondary response force

In the case of the secondary response force (Figure 8), the response process workload is geographically more dispersed. A simulation revealed that the workload of the units engaged in response process went beyond the associated communities and their primary response scope. An even more dispersed response would be present in the case of tertiary response force engagement (Figure 9).

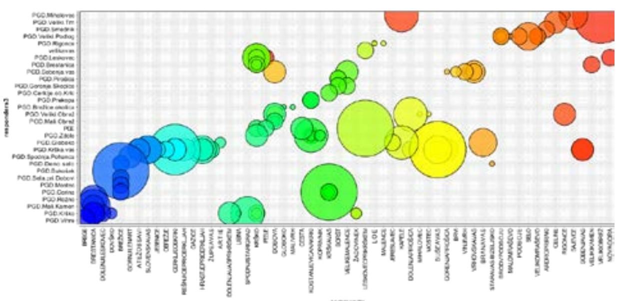

Fig. 9 response process workload of the tertiary response force

Compared to the primary response force, the tertiary lacks strong community-based relation, meaning that the responding units would service entities in distress on a much broader scale than their normal scope is.

After the extraction of required data from the available databases, appropriate processing and simulation, the next important step in the research was preliminary semi-structured interviews conducted with participants from the flood-affected communities. Based on the collected answers we designed a nominal scale, presented in Table 4.

Table 4: Interview data nominal scale

	Detected variants				
Field of inquiry	1	2	3	4	5
Disaster risk awareness	No	Present	Moderate	Influe ntial	High
Disaster risk information source	Media	Observatio n	Governm ent agencies	Public service s	/
Household response	Observ ation	Preparedn ess	Response	Recov ery	Risk reduct ion
Knowledge source	Past experie nces	Ongoing experience	/	/	/

We continued with paired t-test (Table 5) to discover any similarities between the fields of inquiry before, during, and after the first and the second flood event. The results of the test revealed that the only significant difference discovered was disaster risk awareness before the first and the second flood events. Other fields of inquiry, including knowledge source, were not significantly different. An analysis of the interview data, including t-test, revealed that during and after the floods, the households in the flood-affected communities used mostly real-time experiential learning, based on the ongoing situation. Before the floods, their knowledge source was mostly past experiential learning.

Table 5: Mean, standard deviation values and paired t-test of interview data

					Paired t-test		
Field of inquiry			**First flood event**	**Second flood event**	**t**	**p**	**Interpretati on**
Before	Disaster risk awareness	Mean	2	2.45	-3.578	0.002	Significant
		SD	0.74	0.58			
	Disaster risk information	Mean	1.68	1.95	-2.027	0.056	Not significant
		SD	0.47	0.82			
	Household response	Mean	1.36	1.41	-1.000	0.329	Not significant
		SD	0.48	0.49			
	Knowledge source	Mean	1.32	1.05	2.806	0.11	Not significant
		SD	0.47	0.21			
During	Disaster risk awareness	Mean	3.27	3.5	-1.418	0.171	Not significant
		SD	1.09	0.94			
	Disaster risk information	Mean	2	2.41	-2.001	0.59	Not significant
		SD	0.52	0.72			
	Household response	Mean	2.41	2.41	0	1	Not significant
		SD	0.72	0.72			
	Knowledge source	Mean	1.91	2	-1.559	0.162	Not significant
		SD	0.29	0			
After	Disaster risk awareness	Mean	2.68	2.68	0	1	Not significant
		SD	0.92	1.06			
	Disaster risk information	Mean	1.09	1.14	-0.568	0.576	Not significant
		SD	0.29	0.46			
	Household response	Mean	1.82	1.91	-1	0.329	Not significant
		SD	1.34	1.62			
	Knowledge source	Mean	1.91	1.82	1	0.329	Not significant
		SD	0.29	0.49			

The interviews also provided information on the similarity between the respective flood events in terms of their implications for the communities. Implication similarity information was based on distress source affecting the community. To be able to get an objective comparison, we conducted a multivariate analysis of variance using flow rate data and rainfall data. Table 6 compares Wilk`s Lambda values from flow rate multivariate analysis of variance testing. The results of the comparison of flood events in the year 2012 vs. 2014 and 2013 vs. 2014 show significant difference only for the Podbočje station flow rate. Furthermore, nearly significant difference was identified with regard to the Hrastnik station flow rates in the year 2010 vs. 2013 and 2012 vs. 2013. There was no significant difference in the comparison between 2010 vs. 2012 and 2010 vs. 2014. Figure 10 provides an overview of flow rate measurements during all four flood events, with recorded differences in the river flow rates.

Table 6: River flow data, Multivariate analysis of variance

		Jesenice station, flow rate		Podbočje station, flow rate		Širje station, flow rate		Hrastnik station, flow rate	
Year	**p**	**Wilk`s λ**	***F-value***	**Wilk`s λ**	***F-value***	**Wilk`s λ**	***F-value***	**Wilk`s λ**	***F-value***
2010 / **2012**	0.05	0.463	0.594	0.5322	0.4262	0.4612	0.5991	0.4392	0.6626
2010 / **2013**		0.1406	2.6741	0.6564	0.2135	0.1752	2.2127	0.05837	4.8703
2010 / **2014**		0.4884	0.5275	0.3651	0.9218	0.4267	0.7012	0.14	2.684
2012 / **2013**		0.2091	1.8656	0.7397	0.1184	0.357	0.9553	0.07379	4.2283
2012 / **2014**		0.9823	5e-04	0.009884	11.312	0.9175	0.0114	0.2932	1.2656
2013 / **2014**		0.2491	1.5448	0.03464	6.4582	0.4425	0.6528	0.4221	0.7159

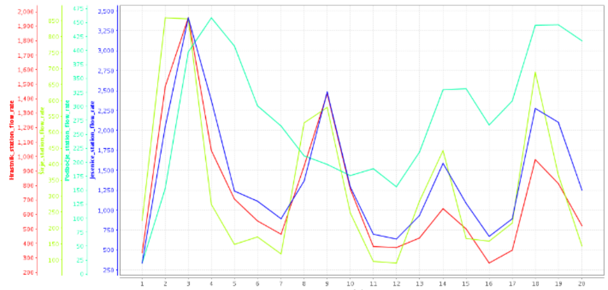

Fig. 10 flow rate measurements during flood events

Based on the distress types affecting the flood-endangered communities we also included rainfall measurements in our research. Rain is, as opposed to river flow rate, the main source of distress situations caused by torrents and meteoric water. We conducted a multivariate analysis of variance, using rainfall measurements from the meteorological stations close to the flood-affected communities. As we can see in Table 7, no rainfall measurement was identified, which would make a clear distinction among the respective flood events. Therefore, we were able to determine, relying also on the measurement plot in Figure 11, that the most notable similarities were observed between the events in 2010 vs. 2014 and 2013 vs. 2014.

Table 7: Rainfall data, Multivariate analysis of variance

		Bizeljsko		Sromlje		Brege		Smednik	
Year	**p**	**Wilk`s λ**	***F-value***	**Wilk`s λ**	***F-value***	**Wilk`s λ**	***F-value***	**Wilk`s λ**	***F-value***
2010 / **2012**	0.05	0.2164	1.8009	0.1809	2.1483	0.2095	1.8623	0.1953	1.9973
2010 / **2013**		0.3229	1.11	0.3925	0.8169	0.3217	1.1155	0.3583	0.9499
2010 / **2014**		0.3715	0.8962	0.5047	0.4877	0.6111	0.28	0.6233	0.261
2012 / **2013**		0.4814	0.5452	0.2351	1.6483	0.4438	0.6488	0.2283	1.7019
2012		0.5559	0.3777	0.239	1.6184	0.3442	1.0108	0.3301	1.075

year	2014 / 2013	2014 / 2013	2014 / 2013	2014 / 2013	2014 / 2013	2014 / 2013	2014 / 2013	2014 / 2013
p								
	0.9379	0.0065	0.7901	0.0758	0.5736	0.3441	0.6519	0.2195

	year	2014 / 2013	2014 / 2012	2013 / 2012	2014 / 2010	2013 / 2010	2012 / 2010
	p	0.05					
Kostanjevica	Wilk`s λ	0.8443	0.3538	0.2728	0.6476	0.5038	0.2242
	F-value	0.0412	0.9687	1.3869	0.2255	0.49	1.7355
Planina	Wilk`s λ	0.8694	0.337	0.2708	0.7688	0.637	0.2576
	F-value	0.0288	1.0429	1.3994	0.0925	0.2406	1.4859
Cerklje	Wilk`s λ	0.6869	0.378	0.3252	0.8246	0.4857	0.2397
	F-value	0.1747	0.8711	1.0987	0.0525	0.5342	1.6131

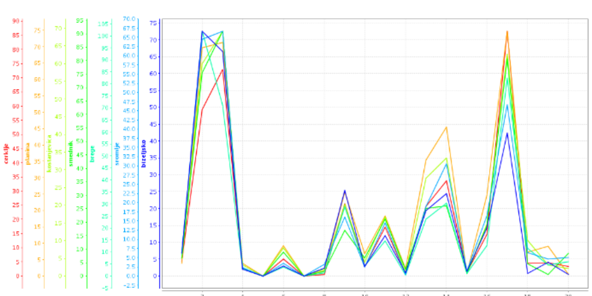

Fig. 11 rainfall measurements during flood events

We developed the criteria for fuzzy evaluation of the community learning based on the insights into experiential learning and risk awareness from the t-test and event similarities from both multivariate analyses of variance. At the first stage of the evaluation, we divided the complete set in 5 subsets, based on distress type. The structure of every subset was A = {B, C, D, E}, where A represents the distress type subset, B the subset of detected distress during the first flood event, C the subset of detected distress during the second flood event, D the subset of primary activities during flood events, and E the subset of secondary activities during flood events.

The second stage included the evaluation in which learning performance was measured based on the following five criteria:

$x1 \in B \cdot x2 \in C \Rightarrow L1 = \{1\}$

$x1 \in B \Rightarrow L2 = \{1\}$

$x2 \in C \Rightarrow L3 = \{1\}$

$x3 \in D \cdot x3 \in E \Rightarrow L4 = \{1\}$

$x4 \in D \cdot x4 \in E \Rightarrow L5 = \{1\}$

$L = \{L1, L2, L3, L4, L5\}$

The subset X = {x1, x2, x3, x4} represents data typical for a single entity, while the subset L = {L1, L2, L3, L4, L5} represents its learning grades. To be able to place grades of the entities into the community perspective, we summed them into community subsets as in (1) and further weighted them with weighting rules presented in Table 8.

$$CS_n = \left\{\sum_{L1n}^{n} L1, \sum_{L2n}^{n} L2, \sum_{L3n}^{n} L3, \sum_{L4n}^{n} L4, \sum_{L5n}^{n} L5\right\} \Rightarrow$$
$$CS_n = \{CL1_n\, CL2_n CL3_n CL4_n\, CL5_n\} \quad (1)$$

Table 8: Weighting criteria

	CL1n		CL2n		CL3n		CL4n		CL5n	
Value ranks	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight
High rank	3	8	<=16	8	<=16	8	>10	15	>1	15
Middle rank	2	4	< 6	4	< 6	4	10	10	1	10
Low rank	1	1	1	1	1	1	<10	10	-	-

We applied the weighted subsets to the previously designed fuzzy system and obtained the results, which revealed the most successful learning communities (Figure 12). Among 59 communities, only 10 demonstrated a learning success that was above ‘poor’.

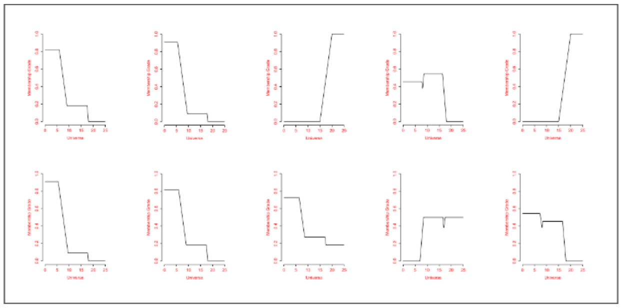

Fig. 12 fuzzy system plot of the most successful learning communities

In the final stage, we simulated learning and prevention optimization of the flood-endangered communities. We took into the consideration comprehensive set of the predefined optimization measures, to be able to predict self-reliant community flood protection. In Table 9, we present significance of the differences between as-is repose process state and to-be repose process state. Paired t-test of the both states process output data revealed significant differences in every category, except responders’ travel distance. To be able to interpret ate the results; we must address assessed process data categories. With the process optimization we reduced: communication time to 66,67%, responders` travel distance to 43,28%, number of process architectures to 61,6%, number of process patterns to 68,33%, number of activities to 66,13%, number of entities in distress to 60,73, total number of executed standard operating procedures to 55,81% and number of different standard operating procedures to 63,74%.

Table 9: Mean, standard deviation values and paired t-test of AS-IS and TO-BE process states

				Paired t-test		
Field of inquiry		**AS-IS process state**	**TO-BE process state**	**t**	**p**	**Interpretation**
communication time	Mean	32,80	21,86	4,996	0.000	Significant
	SD	27,941	23,856			
responders` travel extend	Mean	7,45805	3,22800	1,512	0.136	Not significant
	SD	21,6256 17	5,445419			
number of process architectures	Mean	1,92	1,17	5,873	0.000	Significant
	SD	1,535	1,162			
number of process patterns	Mean	9,53	6,51	5,629	0.000	Significant
	SD	4,125	5,447			
number of activities	Mean	37,63	24,88	3,824	0.000	Significant
	SD	40,283	36,129			
number of entities in distress	Mean	3,24	1,97	4,369	0.0000	Significant
	SD	4,313	3,523			
total number of executed standard operating procedures	Mean	5,10	2,85	4 0	0 0	ig ni fi c a
	SD	6,627	4,795			
number of different standard operating procedures	Mean	2,90	1,85	6,923	0.000	Significant
	SD	2,347	1,937			

Even though t-test presented difference between as-is and to-be states of responders` travel extend as “not significant”, the optimization algorithm reduced the extend of travel for 56,72%, which is the highest optimization rate within the simulation. The insignificance cannot be attributed to the travel extend reduction, but to the comparison of the data distribution in the as-is and to-be states of the process output. This phenomenon can be attributed on the one hand to the fact that the optimization algorithm reduced the travel extend mainly due to less communities, which requested for emergency assistance in the to-be state. On the other hand, the significant differences arise mainly from the process changes in the communities, which were not excluded from the to-be state, while their data distribution significantly changed.

Optimization algorithm affected every included process dimension. Figure 13 represents dependencies between all pairs of process dimensions that were shown to be significantly different when in as-is or to-be state. Blue colour indicates as-is state, and red colour indicates to-be state.

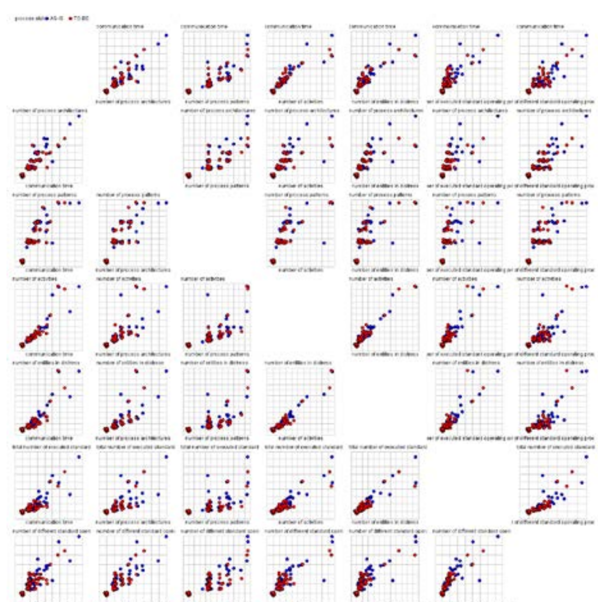

Fig. 13 scatter matrix of AS-IS and TO-BE process states` data

Plot clearly reveals similar dependencies between dimensions in both states, while dispersion clearly reduces in to-be state, revealing successful process optimization. When compared to other dimensions, we can also notice similar dependencies between following dimensions: numbers of activities and number of entities in distress; number of process architecture and number of process patterns; total number of executed standard operating procedures and number of different standard operating procedures. Detected similarities could represent further optimization possibilities through the yet unclear interdimensional connections.

VI. Conclusion

The flood events which we included in our research scope have been proved to differ in several important aspects. Not every flood event affected all communities in the same manner and with the same consequences, providing different learning possibilities and resulting in different learning performances. Due to such differences and increased frequency of floods–especially those caused by groundwater or rainfall–over the past five years, new communities have now been exposed to flood risks. These communities are located either at higher altitudes or are farther away from the rivers that represent a major flood threat. Most households in these communities have faced a serious flood exposure for the first time, which raised their awareness of disaster risks but could not provide them with satisfactory experiential learning possibilities.

The communities that demonstrated the highest engagement in the experiential learning frame among other things influenced the public services called to respond during disaster events. The flood-endangered communities facing a direct flood threat during at least two flood events with similar characteristics, showed high levels of correspondence and information capacity. In fact, experiential learning encouraged the information flow which is stored and further assessed for disaster risk analyses and response plans of local civil protection authorities.

At the same time we identified a negative community integration trend of the responding units in cases when the latter were used as the secondary or the tertiary responding forces. Due to geographical and social connections between a responding unit and its primary responding area, one should consider to what extent it is still rational to deploy responding units as secondary and tertiary forces. Their responding scope is strongly of local nature, which includes local knowledge of the respective hydrodynamics, rainfall, and past torrent issues. The members of such responding units are villagers who know which households are usually threatened and also which measures families usually take to protect themselves. They have the insight in how families living in the flood-endangered areas deal with flood events as a result of their social, demographic, and communal status.

Experiential learning eventually results in the emergence of new knowledge, which is used locally for improving and upgrading standard operational procedures. Such knowledge is an important support to the educational and prevention measures, described in national security documents of Republic of Slovenia. But field experience as the only source of knowledge soon become inadequate to plan and provide better and more effective flood protection. Therefore, more systematically applied planned educational and prevention measures are of high importance, to be able to reduce flood risk vulnerability and rise community flood resilience through the better self-reliance. With this research, we detected significant differences in the flood response process, where on the one hand experiential learning is the only knowledge source, and on the other hand, prevention and flood protection education increase communities` self-reliance. Flood response process optimization in average reduced the process workload for 38,11% and reduced number of communities in need for emergency responders` support for 28,81%. We also detected yet unknown similar dependencies between different response process dimensions, which could provide us with the new knowledge and prevention based process optimization opportunities. Similar to the findings of the presence of minorities` education in Slovene strategic documents [55], natural disaster education is also represented in such documents only in selective manner. Consequently, in both cases educational outputs are far from optimal. Taking into account the work of Adam et al. [56], if only few of flood endangered communities would receive more systematic flood protection education, there is a possibility that knowledge would gradually spread to other communities integrated into the flood endangered social area. The new obtained knowledge would soon become social capital [57], highly significant for the reduction of the state`s responsibility [58] to intervene with official disaster response system even during the minor floods. Such approach towards higher self-sufficiency and flood resilience could be considered as a late part of the Slovenia`s transition, slowed by the complex networking of the involved subsystems [59] and limited by the structures of social and cultural environment [60], even though gradual model to societal transformation already took place on the other fields [61].

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