Knowledge Driven Community Self-reliance and Flood Resilience
Study of the Communities in the Lower Sava Valley, Slovenia

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Abstract: In this position paper, we focus on the learning issues of the flood-endangered communities, situated in the Lower Sava Valley. The main issue and position expose characteristics of the loosely coupled system in the context of learning and knowledge management. We detected learning anomalies within the assessed flood response system, which we selected as a research example of the loosely coupled system. Therefore, we conducted a statistical analysis of the flood data and designed a fuzzy knowledge evaluation system, to be able to grade community learning. Finally, we designed learning improvement mechanism that would significantly contribute to the flood response system effectiveness and higher community self-reliance and flood resilience.

1 INTRODUCTION

Floods in Slovenia became a constant threat during the autumn and spring periods in the past few years. Even though devastating floods used to affect the Lower Sava Valley only ones per 100 years, communities in the region faced four floods between 2010 and 2014. Comparing the four floods by the ferocity and hydrological data, two of four floods could be titled as the “hundred years waters” – very devastating floods.

The flood response system consists of professional and voluntary response units including civil protection, fire brigades, military, police and other technical services. The system emerges ad hoc, when the flood forecast announces alarming flood possibilities. Overall system, which is directly influenced by the floods, exists of entities in need for protection and entities that provide necessary support in order to minimize possible life loss and damage to property.

Within the system, there is limited information flow and no traceable knowledge flow that would include all entities` fractions of the system. On the first hand, flood responding entities possess a wide range of explicit knowledge how to react during the distress situation, how to use the equipment, how to organize the work, etc. Such knowledge is a part of several formal and tight subsystems, which are capable of autonomous operating, even though during the floods, they merge in the overall response system. On the other hand, entities in need of support, that form communities, possess mostly tacit knowledge, gained through the participation in the events during one or more floods.

The overall flood protection system contains a lot of explicit knowledge, but without open access to all entities included. It contains also constantly updated tacit knowledge, but with no proper mechanism to gather and codify it. Consequently the overall system produces flood response process, which is not capable of reaching its optimum, due to lack of efficient knowledge management approach.

2 ISSUE AND POSITION

Formal and successful organizational system, as described by Ionita (2011), is strongly dependant on its business process architecture. Business process architecture enables execution of its daily activities and consequently makes possible to reach the set outputs. Even though such a system is tight and stable, it must be capable of flexible adaptation when necessary. Contrary to formal and modern organizational system, a system that emerges during floods is loosely coupled and faces an unstable process architecture. Process architecture as a descriptor of the system`s structure includes elements like inputs, outputs, entities, activities, procedures,

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information flows, etc. Within the loosely coupled system, process architecture is subjected to dynamic change, due to frequent and spontaneous interaction among entities, information flows, and process patterns. Consequently, there is no guarantee to foretell, how the final process model will settle and make process execution possible. Taking in the consideration haste of the system`s emergence and its short-term operation, such system evolves with a tendency to reach a desired process output and afterwards disintegrates into few tight organizational systems.

Niu (2010) advocates the significance and the influence in the relation between the knowledge and the system`s adaptation. According to Martinez-Leon and Martinez-Garcia (2011) less formal and less centralized organizational systems enhances the organizational learning process. Open, less rigid, loosely coupled organizational system on the one hand creates an open environment that encourages organizational learning, but on the other hand creates also a need to assess more complex, less transparent and harder to follow learning process. Tennant and Fernie (2013) found learning within the loosely coupled system similar to the underdeveloped knowledge management approach in the industrial enterprises. In both cases, learning adapted to the process and changed with activity flows in a reactionary and interventionary manner. Firestone and McElroy (2004) argue that rapid change in the process architecture not only boosts new variants of work processes, but also learning processes and processes for managing knowledge.

Even though several authors detected and described learning processes within the loosely coupled system, we found no tangible and wide knowledge interaction within the assessed flood response system. We detected two different learning processes with no traceable interaction. First learning process occurs within formal and tight subsystems in the loosely coupled system. Learning takes place within the scope of the subsystem before its integration into the overall flood response system. The knowledge gained through such a learning process is explicit, specific and differs on the kind of the learning subsystem. No traceable interchange among entities with such knowledge or other entities is detected. Second learning process occurs when the flood endangered communities face direct flood threat. They are subjected to the experiential learning, emerging tacit knowledge about one or several floods. There is no traceable knowledge interchange among flood-endangered communities and among other entities, as well.

Even though the Resolution of national security strategy of the Republic of Slovenia (2010) and the Resolution of the national program of protection against natural and other disasters from year 2009 to year 2015 (2009), contain guidelines which would practically establish knowledge interchange between both groups, no such attempt has been recorded yet. Implementation of a knowledge interchange mechanism would on the first hand enabled the smooth transfer of the knowledge among different entities within the system, and on the other hand, it would significantly optimize the flood response process, executed by the loosely coupled system.

3 BACKGROUND INFORMATION

To be able to understand how communities in the flood response system perceived floods and how they learned from them and about them, we collected general information about the flood threatened area, together with hydrological and meteorological data, describing all 4 floods.

3.1 General Information

A good part of a Lower Sava region occupies Krško-Brežice field, which is a valley, surrounded by Gorjanci Hills on the southern side and Posavje hills on the northern side. Two bigger municipalities (Krško and Brežice) are situated in the valley and one smaller (Kostanjevica na Krki). 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.

According to the Department for hydrological prognosis of the Slovenian environmental agency (2012), flooding of the Krka River in the communities, in the municipality of Brežice, which are located within the 8 km area before the confluence with the Sava River, is highly dependent on the Sava River and its flow rate. High flow rates of the Krka River alone represent a threat to 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 River 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 River and the Krka River 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 River floods the communities that are located near its bed and close to the confluence with the Sava River.

3.2 Flood Comparison

We compared hydrological and meteorological data of four floods (period of four days) through the multivariate analysis of variance and by the simple quantitative comparison of variables. Table 1

Table 1: MANOVA, river flow data.

		Jesenice station, flow rate		Podbočje station, flow rate		Širje station, flow rate		Hrastnik station, flow rate	
Year	**p**	**Wilk`s λ**	***F***	**Wilk`s λ**	***F***	**Wilk`s λ**	***F***	**Wilk`s λ**	***F***
2010 / 2012	0.05	0.463	0.594	0.5322	0.4262	0.4612	0.5991	0.4392	0.6626
2010 / 2013		0.1406	26.741	0.6564	0.2135	0.1752	22.127	0.05837	48.703
2010 / 2014		0.4884	0.5275	0.3651	0.9218	0.4267	0.7012	0.14	2.684
2012 / 2013		0.2091	18.656	0.7397	0.1184	0.357	0.9553	0.07379	42.283
2012 / 2014		0.9823	5,00E-04	0.009884	11.312	0.9175	0.0114	0.2932	12.656
2013 / 2014		0.2491	15.448	0.03464	64.582	0.4425	0.6528	0.4221	0.7159

Table 2: MANOVA, rainfall data.

		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 / 2014		0.5559	0.3777	0.239	1.6184	0.3442	1.0108	0.3301	1.075
2013 / 2014		0.9379	0.0065	0.7901	0.0758	0.5736	0.3441	0.6519	0.2195

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

compares the Wilk`s Lambda values from flow rate MANOVA testing. The results of the comparison of flood events in the year 2012 vs. 2014 and 2013 vs. 2014 show significant difference only in the Podbočje station flow rate. Furthermore, nearly significant difference was identified with the 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.

We used also rainfall data, analyzed with the multivariate analysis of variance and by quantitative comparison. MANOVA (Table 2) revealed no significant difference in the variance among 4 day rainfall measurements during floods. Therefore, we determined similarities, based on quantitative comparison, which revealed similarities between the events in 2010 vs. 2014 and 2013 vs. 2014.

3.3 Community Learning Evaluation

We integrated the results of the flood similarity, into the fuzzy system, implemented in the R programming environment. To be able to create an evaluation data set, we gathered the emergency response data from the database, governed by the Slovene Administration for civil protection and disaster relief. We extracted the data, which included flood response in communities, during the floods, previously detected as similar.

We divided the data into community sets. The structure of every set was following: S = {A, B, C, D, E}.

- Subset A represents the distress source,
- Subset B represents the number of distress cases during the first flood,
- subset C represents the number of distress cases during the second flood,
- subset D represents the primary response activities during both flood events,
- subset E represents the secondary response activities during second flood event.

The following stage of the evaluation included the categorical evaluation in which learning performance of the communities was measured using the condition of the same distress source during both flood events, and following five criteria:

- $x1 \in B \cdot x2 \in C \Rightarrow L1 = \{1\}$, distress is detected during both flood events;
- $x1 \in B \Rightarrow L2 = \{1\}$, distress is detected only during the first flood event;
- $x2 \in C \Rightarrow L3 = \{1\}$, distress is detected only during the second flood event;
- $x3 \in D` \cdot x3 \in D`` \Rightarrow L4 = \{1\}$, primary response activities are the same during both flood events
- $x4 \in E` \cdot x4 \in E`` \Rightarrow L5 = \{1\}$, secondary response activities are the same during both flood events.

The subset X = {x1, x2, x3, x4} represents data typical for a single entity (communities are built out of entities, which are in reality flood endangered households), while the subset L = {L1, L2, L3, L4, L5} represents its learning grades. To be able to place the grades of the entities into the community perspective, we summed them into community subsets $CS_n = \{\sum_{L1n}^{n} L1, \sum_{L2n}^{n} L2, \sum_{L3n}^{n} L3, \sum_{L4n}^{n} L4, \sum_{L5n}^{n} L5\} \Rightarrow CS_n=\{CL1n, CL2n, CL3n, CL4n, CL5n\}$ and further weighted them with the weighting rules presented in Table 3.

Table 3: 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	-	-

The community learning analysis provided us with the insight, how poor is the overall learning process of communities about floods in order to protect themselves and gain higher resilience. Out of 59 communities, only 10 were graded with the grade higher than poor. Most communities, even though they faced two similar floods in a period of four years, have not used the first experience to learn about how and when the flood would threaten them and how to protect their property against rising water.

Those communities, which demonstrated learning process, graded between good and excellent, gain their knowledge based only on the experiential learning. No other, more formal knowledge source or learning process that would provide them with knowledge that is more explicit, took place.

4 PROPOSED SOLUTIONS REGARDING THE ISSUE

We propose a solution to the identified state, which consists of the learning mechanism integration, based on the guidelines, extracted from the national security and natural disaster protection strategic documents of the Republic of Slovenia.

4.1 Solution Methodology

We designed a simple simulation model, which acts as the learning mechanism. It provides communities with the knowledge interchange, that enables learning and in response to the floods with higher self-reliance and flood resilience.

We designed an optimization algorithm using R programming environment. The algorithm uses for the input, data, gathered from the Administration for civil protection and disaster relief. Further, it divides the data in 5 threat source categories, predicts whether geolocation of the endangered entity faces flood risk and calculates whether levels of river flows are below or above the critical flooding level.

We integrated insights and guidelines from the strategic documents through the discriminatory criteria in the algorithm. The algorithm used the discriminatory criteria to exclude from the emergency response those entities, which would on the premise of the learning and education capacity be capable to provide self-reliance until the critical flood levels.

4.2 Results

With the simulated learning mechanism integration, we reduced: communication time to 66,67%, responders` travel distance to 43,28%, the number of process architectures to 61,6%, the number of process patterns to 68,33%, the number of activities for 66,13%, the number of entities in distress in 60,73, total number of executing standard operating procedures to 55,81% and the number of different standard operating procedures to 63,74%.

T-test (Table 4) of the data revealed significant differences between the state with the integrated learning mechanism and without it. Therefore, it confirms the importance of additional community knowledge and importance of better, more systematic approach to the flood response learning, to be able to provide more effective flood response system and gain higher community self-reliance and flood resilience.

Table 4: t-test of the flood response process with and without learning mechanism.

				Paired t-test		
Field of inquiry		**AS-IS process state**	**TO-BE process state**	**t**	**p**	**Interp.**
communication time	Mean	32,80	21,86	4,99	0.0001	Significant
	SD	27,94	23,85			
responders` travel extend	Mean	7,46	3,23	1,51	0.14	Not significant
	SD	21,62	5,44			
number of process architectures	Mean	1,92	1,17	5,87	0.0001	Significant
	SD	1,53	1,16			
number of process patterns	Mean	9,53	6,51	5,629	0.0001	Significant
	SD	4,12	5,45			
number of activities	Mean	37,63	24,88	3,824	0.00001	Significant
	SD	40,28	36,13			
number of entities in distress	Mean	3,24	1,97	4,369	0.0001	Significant
	SD	4,31	3,52			
total number of executed standard operating procedures	Mean	5,10	2,85	4,407	0.00001	Significant
	SD	6,63	4,79			
number of different standard operating procedures	Mean	2,90	1,85	6,923	0.00001	Significant
	SD	2,35	1,94			

5 CONCLUSION

Overview of the as-is state referring to flood preparedness of the communities in the Lower Sava Valles in Slovenia reveals us low self-reliance during flood events, which consequently leads to the lower flood resilience. Communities dispose with the situational knowledge, obtained through the experiential learning. Learning evaluation clearly revealed that such knowledge is insufficient in order to provide solid flood resilience. Therefore, optimization of the as-is state in the form of simulation-applied strategic guidelines, revealed how significantly better natural disaster educational measures would improve flood self-reliance. Through better education, communities would have the capacity to establish own flood protection, based on internal cooperation, using simple and easy available material and technical resources. Consequently, the official flood responding force could divide its resources in a more optimal manner and relieve their workload. The vast majority of the responding force represents firefighters - volunteers. Even though, their main mission is to intervene in fire incidents, they became an operative force of local civil protection establishments. Better educated and flood prepared communities would create the possibility to become a civil protection auxiliary response force in the general natural disaster protection system.

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