Mitigation strategy on the uncertainty supply chain of the fisheries sector in small islands, Indonesia

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CHRONICLE	ABSTRACT
	The geographical constrain of small islands associated with fisheries commodities, is due to the lack of insufficient infrastructure and socio-economy characteristics, in addition to the nature of fisheries commodities where the durability and inconsistency of quality and quantity of the particular region become very vulnerable to uncertainty of supply chain. This study aims to formulate a strategy to mitigate the existing effect of uncertainty supply chain in Southeast Maluku Regency. The data mining approach with naïve bayes was used to determine the clusters of areas with high to low interdependency in villages and sub-districts. In addition, the House of Risk (HOR) was used to identify the cause of risks and provided the most effective and efficient alternative strategy to mitigate the uncertainty of the fisheries' supply chain sector. Data were collected from 28 villages to obtain 322 datasets by using the purposive sampling technique and expert assessment method for the data mining process, and HOR, respectively. The result show that the village location, resources, and fishermen's ability to sell and buy their gear were the main determinant factors of interdependency. Furthermore, there were, at least, three clusters of interdependencies with the integration of a web-based system to help spread information to fishermen and aquaculture farmers. In conclusion, policymakers need to be more adaptable to the use of information technology to efficiently improve the welfare and performance of coastal communities, aside from constantly enhancing the region's infrastructure.

1. Introduction

In 2016 the fisheries sector of Southeast Maluku Regency contributed to the GRDP (Gross Regional Domestic Product) of 21.43%. It ranked third below government expenditure for wage and travel expenses at 24.08% as well as the trade and construction sector at 22.94%. However, the current stance of fisheries' contribution to the economy is still below the existing potential. The Arufura Sea, which is one of the largest and richest fish areas globally, is close to this region and consists of high potential for seaweed cultivation and well-known marine tourism across the globe. Therefore, the income generated from the fisheries sector makes it the number one contributor to the community and regional welfare. The value of money generated from the coastal areas in Southeast Maluku Regency was around IDR 243,070,000 per month (Picaulima et al., 2017). This amount is generated in conditions, with limitations to the capabilities and competence of coastal communities, especially the level of mastery and access to technology, without significant contributions from local governments (Teniwut & Teniwut, 2018). Conversely, an empirical study conducted by Teniwut et al. (2019) and Teniwut (2016), showed that the potential of fisheries in Southeast Maluku Regency is abundant.

The Southeast Maluku Regency Government has tried to take concrete actions by providing assistance and training programs. However, in reality, this was wrongly targeted because the local government does not carry out good framework and references to provide adequate assistance (Teniwut & Kabalmay, 2015). Some local government programs are not properly implemented, for instance, the seaweed processing plants which have failed in production. The fishing gear assistance programs are also shown by research from Teniwut and Teniwut, (2018) on government ability to implement central and regional roles that do not have a real impact on the fisheries sector. The ineffectiveness of these local programs was due to many factors that were not considered, such as the socio-economic conditions of the community (Teniwut et al. 2017a), technological capability, and mastery (Teniwut & Teniwut, 2018), water conditions (Hamid et al., 2017), infrastructure and markets (Teniwut et al., 2017b). Conversely, the demand for the fisheries sector as a driving force of the economy is greater due to the community's geographical and socio-economic conditions. These existing obstacles are currently analyzed by the coastal community all over the world and in archipelagic areas. The nature of fisheries commodities regarding the durability and inconsistency of quality and quantity supplied has geographical constraints. Therefore, the lack of insufficient infrastructure and socio-economy characteristics makes the region vulnerable to the uncertainty of the supply chain. The activities carried out in the fisheries sector are related to the location of producers, and processing plants. Furthermore, the distribution process is closely related to the transported equipment, such as natural disasters and seasonal factors. According to Harris et al. (2014), the agriculture sector includes many factors that make high uncertainty supply chain in the fisheries sector. Meanwhile, the high level of dependence on the fisheries sector as the economic driver of the poor and the main food supply were critical activities that caused the supply chain to be smooth (Barrett et al., 1999; Hinrichs & Lyson, 2008).

The villages in Southeast Maluku Regency are traditionally dependent on one another due to the use of a customary system in the management of marine resources, also known as the "petuanan laut" and "pela" relationship (Hamid et al., 2020). In addition, the uneven distribution of wealth and welfare between villages leads to high levels of inter-village dependency, which has contributed to the uncertainty of the fisheries supply chain. The condition of the archipelago region is associated with the varying distance between villages. Furthermore, big cities in the region, utilize a spatial approach to provide advantages (Teniwut et al., 2019; Watson et al., 2010; Balaguer et al., 2011; Fernandes and Pinhho, 2017; Vroom et al. 2010; Specht, 2007; Arévalo and Fernández-Palacios. 2003). Spatial analysis is more powerful when combined with other analytical methods, such as data mining, which is used to obtain useful information (Hand, 2007). This capability provides useful analytical results in accordance with the archipelago's geographical conditions, when combined with a spatial approach. The use of data mining with spatial has been widely used in crime mapping (Wang et al., 2013), construction (Shirowzhan et al., 2020), meteorology (Gholami et al., 2020), health sector (Kao et al., 2017), land-subsidence (Pourghasemi & Saravi, 2019), oil industry (Gongquan & Keyan 2011), agriculture (Silva et al., 2016), and fisheries sector (Teniwut et al., 2019). The research conducted by using two or more analytical approaches obtained robust and compelling results that are comprehensive and also known as multi-methodology. Mingers (2006/2010) combined analytical methods to answer various research questions. However, in this study, the level of interdependency between villages in this region was measured using various data mining approaches. It was also visualized with spatial analytics to determine the cause of supply chain as well as the uncertainty risk in the region. Furthermore, the MCDM approach, known as the House of Risk (HOR) introduced by Pujawan and Geraldin (2009), was also utilized in this research. The HOR approach is an adaptation of the QFD used to identify the sources of risks that arise from alternative solutions that are efficient and effective. Many studies have used this method in various fields of fisheries (Teniwut, 2019; Anggrahini et al. 2015), and production (Widiasih et al., 2015; Ma et al., 2018).

Therefore, this research aims to mitigate the risk of uncertainty in the fisheries sector's supply chain in Southeast Maluku Regency. It is divided into two parts with the level of dependency between villages in the supply chain process identified in the first section by using data mining and spatial analytical approaches. Meanwhile, the second section identified the sources and risks inherent the HOR approach to effectively calculate the uncertainty of the supply chain in the fisheries region. This paper is structured into five sections. The first, introduces the topic with the materials and methods presented in the second section. The study results were determined using the data mining and analytical methods in Section 3.1, while the HOR was determined in Section 3.2. Discussions and conclusion were carried out in sections 4 and 5.

2. Material and Method

2.1. Study Location and Data Collection

Southeast Maluku Regency is located between 50 12' 19,427" – 60 06' 18,275" South Latitudes and 1320 21' 39,082" – 1330 15' 31,442" East Longitudes. It is geographically bounded by the Banda, Arafura, and Tual Municipality and Banda Seas in the North, South, West, and East, respectively. Maluku regency consists of 11 subdistricts and 193 villages, with majority located on the coast (Statistic Indonesia, 2020). The fisheries sector, which comprises of captured, aquatic, and processed marine tourism, is the main economic resource of coastal communities. This study selected villages based on those that are highly dependent on the fisheries sector, with the geographical conditions used to determine the percentage of villages per sub-district. A total of 28 villages were scattered in 11 sub-districts, with data obtained from 359 respondents. Approximately 322 data were valid for the mining purposes, while the expert's assessments with cross-validation were used to determine the HOR, as shown in Fig. 1.
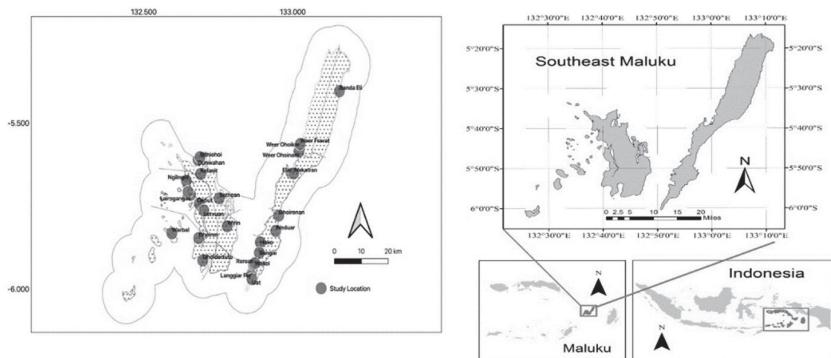
Fig. 1. Study Location

2.2. Analysis Method

2.2.1. Naïve Bayes

The naïve Bayes algorithm is based on the assumption of attribute independence, simplifying the Bayesian model (Zhang, 2005). The NB is one of the most widely used algorithms due to its robustness, therefore, assuming each predictor is conditionally independent, it tends to calculate the probabilities of a particular class (Duda, 1973). The Bayes theorem on the Naïve Bayes algorithm occurs when combining prior and conditional probability to calculate each possible classification (Bramer, 2007). Let T represent data sample with no class, where R is the hypothesis. P(R|T) is the probability P(R), P(T) and P(R|T) is the posterior representing the confidence in the hypothesis after T. The basic relationship formula of NB is calculated as follows (Catal et al. 2011):

$$P(R|T) = \frac{P(T|R) \cdot P(R)}{P(T)} \tag{1}$$

As for the basic idea of NB theorem is:

$$P(W_i|T) = \frac{P(T|C_i) \cdot P(C_i)}{P(X)} \tag{2}$$

Suppose there is a set of v samples where S_i is represented as an n-dimensional feature vector $\{T_1, T_2, \ldots, T_n\}$, T_i corresponds to attributes $A_1, A_2, \ldots A_n$, respectively. Furthermore, in k classes of $c_1, c_2, \ldots, c_k$ there are additional unknown data samples of T, used to predict the highest conditional probability $P(C_i|T)$, where $i = 1, 2 \ldots, k$. The probability distribution of NB is utilized with the application of a regression problem. However, the NB is not a 'Bayesian' method that analyzes the frequentist interpretation strategy (Ng et al., 2014).

2.2.2. House of Risk

The House of Risk (HOR) model is an integration of the Failure Modes and Effects Analysis (FMEA) with the Quality Function Deployment (QFD). There are two stages in the method, namely HOR1, which is used to identify the sources and risks that occur and HOR2 used to calculate and choose alternative solutions that are efficient in mitigating the uncertainty associated with the risk of the fisheries supply chain in the region (Pujawan & Geraldin, 2013). In HOR1, first identify the "risk events" in each of these processes-based on the *Plan, Source, Deliver, Make*, and *Return*, as shown in Table 1 *(Model Supply Chain Operations Reference)*. Ei (risk events) showed that the risk was analyzed from a scale from 1 to 5, which represents the largest severity of each event. This was followed by identifying the Aj and assessing the likelihood of occurrence, as shown in Table 2. It also determines the relationship between risk agent and Rij with a value of 0, 1, 3, and 9, which indicates no, low, moderate, and high correlation. The formula for HOR1 is as follows:

$$ARP_j = O_J \sum_i S_I R_{IJ}. \tag{3}$$

In HOR2, the analysis started with selecting the highest risk agent which is more than 70%, as shown in Fig. 2. In addition, the risk mitigation is obtained using the *Preventive Actions* (PAk) as shown in Table 3. The total effectiveness (TEk) is calculated with the following formula:

$$\text{TEk} = \sum ARP_j E_{jk} \ \forall k. \tag{4}$$

The difficultness (*Dk*) in level with Likert or sufficient scale is used to calculate the total ratio effectiveness using the mitigation action and highest rank (*Rk*) formulas follows:

$$ETDk = D_k TE_k. \tag{5}$$

Table 1
Risk events

SCOR	Sub Process	Risk Event	Code	W
Plan	Production Planning	Changes in weather and season	E1	5
		Inconsistent production	E2	5
		Limited and damaged equipment	E3	7
	Inventory Planning	improper inventory system	E4	9
		Lack of demand and market information inside and outside the region	E5	9
Source	Distribution	Very limited buyers	E6	6
		Inconsistent supplier performance	E7	5
Make	Production	Inconsistent results due to pests	E8	7
		The catching range is not optimal not comparable with the equipment	E9	9
		Forced to premature harvest	E10	7
Deliver	Delivery	Too far distance between the market village and the supplier	E11	7
		Limited transportation	E12	9
		Shipping costs are quite high	E13	7
Return	Return Policy	There is no product return policy	E14	7
		There is no refund policy when there is a discrepancy in the order and damage	E15	9

Table 2
Risk Agents

Risk Agent	Occurrence	Code
The instability of demand	9	A1
Low inter-region connectivity	9	A2
Lack of accuracy of local government aid	5	A3
Availability of quality seeds	5	A4
Season changes	7	A5
Science and technology not adequately adapted	9	A6
Conflict between villages	4	A7
Dependent on the local distributor	5	A8
Lack of managerial ability	9	A9
Uncompetitive selling prices	7	A10
Insignificant impact of NGOs, Research Institutions and Universities	3	A11
The geographical location of each village	7	A12

Table 3
Preventive Actions

Code	Preventive actions
PA1	Build markets per cluster based on geographical location
PA2	Build an integrated inventory per area
PA3	Increase transportation access between regions
PA4	Build web-based integrated systems to update market and price information consistently
PA5	Build BUMD such as Regional owned-enterprise to ensure consistent demand for raw fishery products
PA6	Local Governments assist in searching for buyers outside the region.

3. Result

3.1. Naïve Bayes and spatial analysis

The comparison results associated with the performance levels of several data mining algorithms are shown in Table 4. Furthermore, the result shows that the Naive Bayes had better indicators than other methods with a higher level of accuracy at 81.8%, compared to four other methods, namely deep learning (78.1%), logistics regression (77.1%), support vector machines (75.9%), and generalized linear models (75.9%). In addition, several other indicators show the same results.

Table 4
Performance Indicator Comparison

Criteria	Algorithm				
	NB	DL	LR	SVM	GLM
Accuracy	81.8%	78.1%	77.1%	75.9%	75.9%
F Measure	74/6%	67.1%	62.7%	61.0%	59.9%
Sensitivity	76.5%	66.8%	54.3%	47.0%	46.6%
Classification Error	18.2%	21.9%	22.9%	24.1%	24.1%

*NB (naïve Bayes); DL (deep learning); LR (logistic regression); SVM (support vector machine); GLM (generalized linear model)

The prediction results with naïve Bayes are used to examine the dependence level of villages in this region, as shown in Table 5. However, the potential of marine resources owned by the market value is 0.114, 0.079, and 0.064, which are used to significantly determine whether a village is dependent or not in relation to the fisheries sector. The prediction results obtained from naïve Bayes is shown in Fig. 2, where the heatmap illustrates the distribution of clusters in villages that were highly dependent on fishing activities. It can be seen that the villages in Kei Besar Selatan and Barat sub-districts are the regions with the high and moderate levels of dependency, respectively.

Table 5

Weight determinant factors of villages in Southeast Maluku Regency

Rank	Attribute	Weight
1	Location relatively too big cities and other villages	0.114
2	Village marine resources	0.079
3	Where the community sell their product	0.064
4	Duration of community work on the fisheries sector	0.057
5	Role on fisheries activities	0.026
6	Relationship with the community within and outside the village	0.024
7	Where community buy their fisheries equipment	0.010
8	Income	0.004
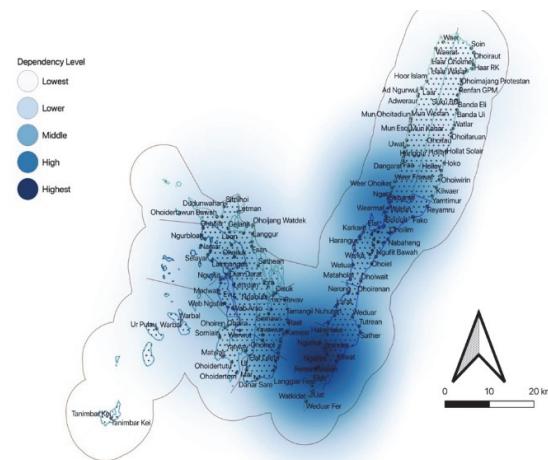
Fig. 2. Heatmap of the dependency area of each village in Southeast Maluku Regency

3.2. House of Risk

Based on the results of the HOR obtained in Table 6, the highest ARP value for the risk agents was A6 (4293), followed by A9 (4239), A12 (2373), A2 (2349), A1 (2160), A5 (1071), A4 (600), A11 (396), A8 (394), A3 (345) and A7 (268). Furthermore, the Pareto diagram in Fig. 3 shows that a total of five risk agents contributed to 77% of all sources with the uncertainty of the fishery supply chains between villages in this region, namely A6, A9, A12, A2, and A1. Table 7 shows the results of HOR2, which were alternative policies and steps taken by the regional government with a significant role in handling and mitigating the uncertainty of the supply chain in the region. The result showed that the highest alternative ETD value was PA4, with integrated web-based systems to update market and price information consistently followed by PA6, PA2, PA5, PA3, and PA1. The selected alternative policy is financially feasible and rational to carry out to avoid burdening the local governments, with the ability to mitigate the risk of supply chain uncertainties fisheries in this region.

Table 6

HOR 1

Business Process	Risk Events	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	Severity of Risk Events	Value
Plan	E1					9		1					3	S1	5
	E2			3	9	9				9	3	3		S2	5
	E3			9	3		9			3		3	3	S3	7
	E4			3			9			9		3		S4	9
	E5	9	3	9			3					3	9	S5	9
Source	E6	9	9				9		9	3	3			S6	6
	E7	3				9				3	3		3	S7	5
Make	E8	3		3	9		9			9		3		S8	7
	E9						9			3				S9	9
	E10				3		9	1	3	9	9	3		S10	7
Deliver	E11	3	9					3	3	3	3		9	S11	7
	E12	3	9	9				3	3		3		9	S12	9
	E13	3	9	3				1	3		3		9	S13	7
Return	E14								1	9	3			S14	7
	E15								3	9	3			S15	9
Occurrence		9	9	5	5	7	9	4	5	9	7	3	7		
ARP		216	2349	345	600	107	429	268	394	423	159	396	237		
Priority		5	4	11	8	7	1	12	10	2	6	9	3		
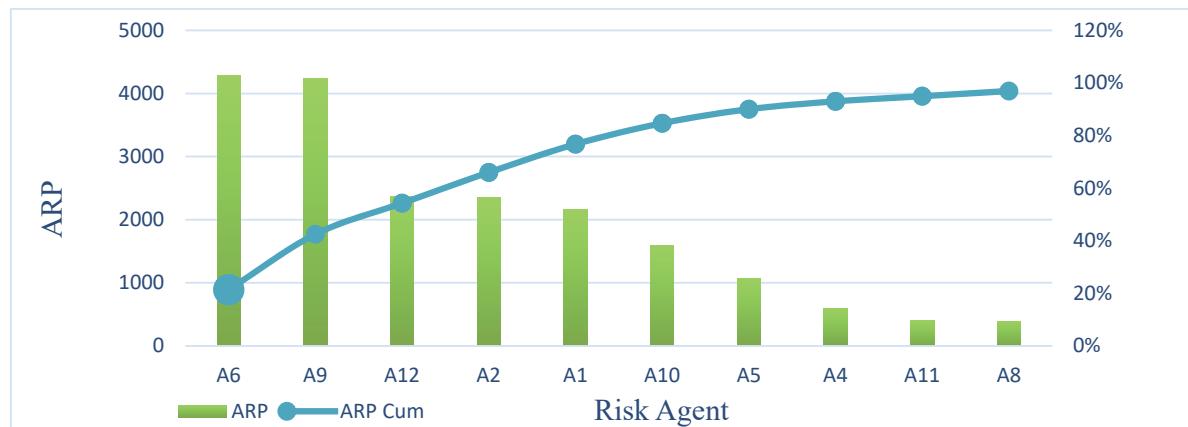
Fig. 3. Diagram Pareto HOR1

Table 7
HOR2

Risk Agent	PA1	PA2	PA3	PA4	PA5	PA6	ARP	Code
A6		9		9	9		4293	ARP6
A9		9	3	9	9	9	4239	ARP8
A12	9	3	9	9		9	2373	ARP10
A2	9	3	9	9	3	9	2349	ARP9
A1	9		9	9	9	9	2160	ARP2
TE	61.938	90.954	74.655	138.726	86.004	100.089		
D	5	4	5	3	5	3		
ETD	12.388	22.739	14.931	46.242	17.201	33.363		
R	6	3	5	1	4	2		

4. Discussion

This region comprises of the archipelago with a wealth of high marine resources. However, not all villagers in this region take the fisheries business as a regular source of income, despite the fact that it is one of the economy's backbones, especially in coastal communities. The high rate of fish consumption for households and manufacturing industries is very important for the local fisheries sector to have a smooth chain level. The infrastructures have experienced good communication in the transportation of other supporting instructors in the region. In addition, the existing geographical conditions still experience difficulties in accessing fast and smooth transportation in the distribution of fishery products. Therefore, the socio-economic characteristics of coastal communities in this region tend to overcome the risk of uncertainty in the supply chain of fisheries. The study obtained two main clusters that are highly dependent on neighboring villages related to fishing businesses. These two clusters are distributed in four subdistricts, with the first cluster region spread across Kei Besar Selatan Barat. These districts have a dependency on their surrounding areas due to the location at the edge of Kei Besar Island with potential and residents that regularly carry out fisheries activities. This area is quite far from buyers' and sellers' location, with the residents experiencing difficulty in buying seeds for quality seaweed cultivation and distributes fishery products that are obtained smoothly and adequately. The second cluster in Kei Besar and Utara Barat Subdistricts have access to transportation, which is better than the first area. However, this cluster comprises of a limited number of buyers in the surrounding area. This is a similar problem also faced by the second cluster and used to improve coastal communities' welfare. Therefore, it is better to distribute the fishery products obtained in the market and minimize the acquisition costs of equipment that is carried out in an effort to attract buyers and sellers. Therefore, in addition to increasing the income of coastal communities, it also minimizes the risk of supply chain uncertainty in this region. The main causes of the high level of dependence on coastal communities and the risk of supply chain uncertainty are science and technology. These two factors are influential and have not been properly implemented in carrying out business activities in almost all regions in Southeast Maluku Regency. They are also used to schedule fisheries activities that are not appropriately carried out, which cause special harvests for aquaculture in accordance with current demand. The location of captured fishes is close to the village, which tends to be inconsistent, due to the use of equipment and technology not adjusted to the standards. The ability to adopt technology and good knowledge in conducting fisheries is still not maximized in addition to the low managerial ability, which causes the sustainability of the business owned to be quite disturbed. Presently, the geographical location and infrastructure are limited to the source of problems faced by all sectors in the region. However, fisheries businesses emphasize the importance of a consistent market both inside and outside the region. This plays a huge potential to fisheries resources with consistent market force coastal communities to improve their performance. The limited number of buyers makes the supply of fisheries commodities very inconsistent, in a fairly limited amount of time. The results of the study offer six alternative policies in accordance with the empirical conditions of this region. Out of the six alternative policies, the study found that local government integrated web-based integrated systems to update market and price information consistently. This helps to

determine the markets outside the region and contributes to building an integrated inventory per area. According to Taylor and Fearne (2009), information is essential for the food market and fisheries. Allievi et al. (2015) stated that the importance of efficiency in all strategy is also related to technology. Therefore web-based information systems are used to meet the criteria. Although this study proposed a long-term permanent solution for the fisheries sector and coastal communities, a regional owned-enterprise is built using BUMD to ensure consistent demand for raw fishery products. This tends to act as a guide for coastal communities to be more consistent in conducting fisheries business, and increasing the supply of quality fisheries.

5. Conclusion

In conclusion, this study has utilized the multi-methodology approach to mitigate the risk associated with the fisheries sector's supply chain uncertainty in Southeast Maluku District. It was divided into two parts with the data mining approach and naïve Bayes used in the first section to predict clusters, which are vulnerable points due to the high dependency of these villages on neighboring and large cities. The Naive Bayes approach used also found determinants of the level of dependency and uncertainty in the supply chain of the fisheries sector in the region. Furthermore, the villages' geographical location is an important factor used to determine the dependency of clusters in this region. The closer the sellers and buyers are to the fishery equipment, the lower the uncertainty associated with the supply chain risk. The second method approach used is the MCDM House of Risk (HOR) approach with mitigation for the risk of uncertainty that is financially efficient for regional governments. Web-based integrated systems are built to update market and price information consistently and act as an alternative to mitigating the fisheries supply chains in the region. However, it is more efficient compared to other available alternatives.

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