A Disaster Management Framework based on the overview of the existent tools on top of a multi-criteria decision

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This work seeks for an understanding of systems used during disaster preparation and response based on three main concepts: literature review; system and tools usage; Analytic Hierarchy Process multi-criteria decision model applied with specialists. A framework based on the strengths of each of them is proposed to improve humanitarian operations.

Keywords: humanitarian logistics, software, multi-criteria analysis

Introduction

Humanitarian logistics (HL) is a modern area of logistics. Thomas and Mizushima (2005) define HL as a process of planning, implementation and effectiveness control, efficient flow of costs, storage and handling of equipment and materials, as well as information from the point of origin to point of consumption for the purpose to meet the needs of beneficiaries, in this case, people affected by natural disasters (e.g. tsunamis, floods, earthquakes) or man made disasters (e.g. landslides, nuclear explosions).

The importance of humanitarian operations lie with the significant number of disasters reported over the past decades. According to Guha-Sapir *et al.* (2013) in 2012 were recorded 357 natural disasters on the planet, a slightly smaller number than the average of 394 disasters recorded between 2002 and 2011. Additionally, there is a tendency to disseminate this kind of study and applications due the "human commotion" factor and also by the financial volume annually exchanged. According to IPEA - Applied Economic Research Institute from Brazil (2013), only Brazil spent 650 million dollars into international cooperation in 2010, an increase of 91.2% over the previous year, as described in the Brazilian cooperation report for international development.

Disasters often involve many actors with different profiles, cultures, interests, and methodologies that need to work together to provide an efficient response to the beneficiaries. According to Cozzolino (2012), the stakeholders can be classified as: NGOs (Non Governmental Organizations), aid agencies, donors, military, government, logistics operators, and other companies. Thomas (2003) also considers the media and beneficiaries as part of this classification. The challenge of coordinating all these actors is significant. According to Çelik *et*

al. (2012), disasters are complex problems, with a large degree of uncertainty, in a harsh and dynamic network, with extreme resource constraints (human and material), in environments where information may not be very reliable, even when available. Within this scenario, Van Wassenhove (2006) also noted that humanitarian organizations compete for media attention which is directly related to donations received and which, in turn, comprises a base shrinking of common donors.

Disasters are usually classified by four main phases: mitigation, preparedness, response, and rehabilitation or reconstruction (Van Wassenhove, 2006). The mitigation phase includes activities, projects or actions aimed to preventing or reducing the impacts of a disaster. The preparation phase involves the possible activities to be performed before the disaster occurs. The response phase is a reactive phase where the stakeholders work directly in saving lives and preserving the human and financial resources of the affected region. The last phase, called reconstruction, focuses on financial and social recovery of the affected region.

It is necessary, therefore, a greater understanding of the interactions between organizations involved in disasters and, thus, an improvement of management techniques related to the resources needed to ensure the success of an effective response to an extreme event in their respective phases. For Davidson (2006), the use of software can provide visibility of the humanitarian supply chain as they can capture the data of a certain (or all) transaction in a centralized way. In this context, there is a need for a centralized system that can be used by different entities in order to avoid waste or shortage of material, equipment and human resources, providing a global view of the multiple disasters needs, enabling better communication regarding the real situation of disasters through reports and performance indicators shared with all stakeholders, including the population.

This work seeks for an understanding of systems used during disaster preparation and response based on three main concepts: literature review; system and tools usage; Analytic Hierarchy Process (AHP), multi-criteria decision model applied with specialists in HL. A framework based on the strengths of each of them is proposed to improve humanitarian operations.

This paper is divided as following sections: Introduction, Methodology, HL Concepts, Disaster Management Tools Analysis, Multi-criteria Results, Conclusion, Acknowledgments and References.

Methodology

The research used in this paper can be classified into descriptive and methodological. According to Vergara (2005) a descriptive research exposes characteristics of a given population or certain phenomenon, having no commitment to explain the phenomena it describes, although a basis for such an explanation. The same author defines methodological research as the study to capture tools – is thus associated with ways, forms or/and procedures to achieve certain result.

The study was also developed based on secondary sources (books, articles, journals, dissertations, university studies that are directly or indirectly related to the theme proposed in this study) and primary sources, where a so-called Requirement Analysis Phase was performed through interviews with experts from organizations, public agencies, universities or organizations that the core activities are related to HL.

According to Yin (2010), the most important advantage of a triangulation (three sources of evidence: interviews, document analysis, and survey) is the development of converging lines

of research. Thus, any finding or conclusion of this study is more convincing and accurate if based on several different sources of information, following corroborative research style. This study considers three fundamental pillars to achieve the main goal: (i) theoretical foundation; (ii) review and use of disaster management tools; and (iii) interviews with humanitarian logisticians. Figure 1 demonstrates the three evidence information used to present a disaster response tool framework.

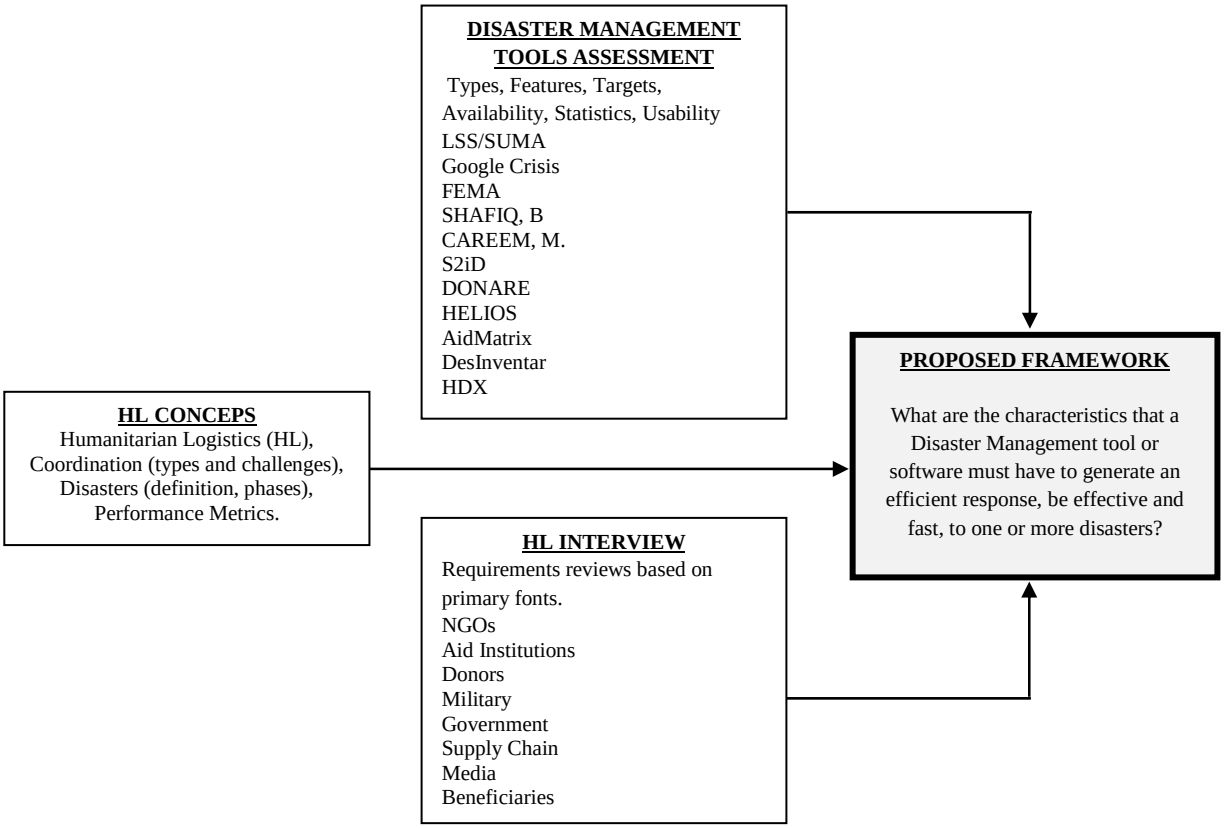

Figure 1 – Research methodology diagram

The HL concepts aimed to review the key fundamentals of HL, by reading articles, theses, journals and dissertations in order to contextualize qualitatively and quantitatively the main topics related to this research (definition and classification of disaster, optimization techniques, performance measures, coordination and loss and damage definition).

The review of disaster management tools and software was based on the study presented by Blecken (2009) that focuses specifically in defining the features and functionalities of supply chain management tools. This research was extended considering disaster response tools (such as donation systems, notification systems, centralized database). Through a research conducted on the Internet, reading articles/theses and interviews, a set of eleven tools were evaluated. This study was limited to identify whether the tools have or do not have certain functionality (future studies can be done in order to define a criteria to evaluate each functionality).

According to Leiras *et al.* (2014), a closer collaboration between theory and practice contributes to develop applied researches aligned with real-world problems. Interviews with experts therefore have as main objective to validate if the bibliographic research is in accordance with actual cases and additionally to identify possible contributions to the theme. The

interviewers were defined in order to have a representative for each type of stakeholder, as defined by the authors Cozzolino (2012) and Thomas (2003) described in the introduction of this paper.

In order to present a consistent and evolutionary study, the interviews were divided in three main phases: review of existing tools to be evaluated, review and define the functionalities needed for an efficient disaster management tool and finally a multi-criteria analysis of the functionalities defined.

Multi-criteria analysis

Developed by Tomas L. Saaty at the beginning of the 70s, the AHP is one of multi-criteria methods used to support the decision-making problems with multiple criteria. Saaty (1990) describes that the use of hierarchical process allows the trial focus separately on each of several essential properties of the target question to a better decision making. Taking this concept as basis, the aim in choosing this method is to understand how the HL specialists attribute their priorities (hierarchy) in relation to the features and functionalities needed for a disaster management tool.

The Expert Choice software was selected for this evaluation in order to guarantee the quality of the model and to enable participation and analysis of multiple interviewers. The numerical scale proposed by Saaty (1990) was used to compare the functionalities of the model, as shown in Table 1.

Table 1 – Saaty fundamental rating scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other.
5	Much more important	Experience and judgment strongly favor one over the other.
7	Very much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed.

Humanitarian logistics concepts

Most of disaster definitions are based on its magnitude in terms of the number of people directly or indirectly affected, IFRCRCS - International Federation of Red Cross and Red Crescent Societies (2002) defines as a situation or event which overwhelms local capacity, requesting national or international level for external assistance, 10 or more people reported killed, 100 people reported affected, a call for international assistance and/or declaration of a state of emergency. For ECLAC – Economic Commission for Latin America and the Caribbean (2009), the damage occurs immediately or shortly after the phenomenon that caused the disaster and are

defined as impacts on physical assets (e.g. infrastructure); the losses occur immediately after a disaster and cause changes in flows and economic processes, and only finish when there is full recovery of the economy (e.g. production, services) and the reconstruction of assets lost.

The process of mitigating the uncertainties during the four phases of a disaster is a major challenge in achieving an effective response to a disaster, such as: the best pre-positioning of stocks during the preparation phase, intensity of the event during the preparation phase, the predictability of demand during the response phase and the duration of the social economic impacts during the recovery phase. Balcik and Beamon (2008) reported that the main challenges for a better response on HL are: (i) unforeseen demand in terms of time, location, type and size; (ii) lack of resources in terms of supplies, people, technology, transport capacity and money; (iii) high risks associated with on-time deliveries and; (iv) the occurrence of fast searching in large quantities, but with short lead times for a wide variety of sources.

Academic studies related to HL are relatively recent, as reported by Leiras *et al.* (2014), but it has grown in terms of quantity and relevance in recent years. In their literature review, these authors investigated 228 articles related to the topic and the main conclusions ratified the need for further studies for disaster recovery phase and showed the need for closer links between academy and humanitarian organizations in order to generate more applied researches. The authors agree that a closer collaboration between these agents can lead to further development of applied research in the tactical and operational decision-making levels, where deep understandings of real-world problems are required.

Balcik *et al.* (2010) describe the coordination relationship between different actors working in the same environment. The authors report the existence of two types of coordination: (i) vertical coordination, which refers to the extent to which an organization coordinates activities at different levels of the chain (e.g. if an organization works in conjunction with a transportation company to complete delivery of their goals/ goods); and (ii) horizontal coordination, which refers to the degree to which an organization cooperates with other organizations in the same level within the chain (e.g. coordinated with a second NGO providing relief goods and/or services). The main factors that affect both types of coordination according to Balcik *et al.* (2010) are: (i) diversity and number of actors involved; (ii) expectations of donors and funding structure; (iii) competition for donors and the effects of the media; (iv) unpredictability; (v) shortages and/or excess funds and; (vi) coordination costs.

Management disaster tools features analysis

During the coordination of a disaster there are many tools, whether computer or manual, used to prevent or improve problems such as lack of information, excess donations, unpredictability, operating costs and coordination, among others. Blecken (2009) performs an assessment of nine tools, six designed specifically for humanitarian supply chains (SUMA (Suministros Management System Humanitarian), LSS (Logistics Support System), Helios, Sahana, LOGISTIX, UniTrack) and three commercial tools (Orion-Pi, EnterpriseOne, mySAPSCM). These tools were evaluated according to following features: design, planning and implementation of supply chain, available documentation, accountability, software setup, and costs.

Based on Blecken (2009) study and after reviewing the literature and applying interviews with HL specialists, a set of eleven tools were evaluated in this study. Six of them directly related to HL: Integrated Disaster Information (S2iD), SUMA/LSS, FEMA – NEMIS, Sahana, Donare and HELIOS. Additionally, Google Crisis and Aidmatrix were assessed as support tools

to meet functionalities not present before, specifically for: usability, modularity and alert management. Two applications dedicated exclusively to historical data information have also been described, they are: HDX (Humanitarian Data Exchange) and DesInventar (Disaster Inventory System). The tool UICDSe was added to this research, since Shafiq *et al.* (2012) proposed interoperability concept through a standardized service layer, called web services. The Unitrack and LOGISTIX tools evaluated by Blecken (2009) were excluded from this analysis because they are private and not easily accessible in terms of documentation. The commercial systems presented by Blecken (2009), Orion-Pi, EnterpriseOne and mySAPSCM, were also not considered to be strictly tools of commercial use and not directly related to the HL.

The evaluation process of the tools in this paper was divided into two groups: analysis of documents and information available on the Internet (Aidmatrix, Donare, FEMA - NEMIS, S2iD, UICDSe) and analysis of documents, information on the Internet plus tool usage (Google, HELIOS, Sahana, SUMA/LSS, HLX, DesInventar.

Most of functionalities evaluated in this paper were proposed by Blecken (2009): supply chain design, planning and execution, documentation, reports, controlling, cross-linking, offline/online access, modularity/adaptability, usability, direct costs (software and hardware), and indirect costs (training, maintenance). Careem *et al.* (2005) suggested new features such: registration and management volunteers and notification management (allow sending any type of message related to the disaster – twitter, text messages, mail, facebook). Additionally, four new functionalities were added based on the interviews with specialists: (i) security levels according to marketing best practices; (ii) measuring donor or humanitarian entities based on fulfillment of agreed commitments; (iii) multi-user, meaning different hierarchical levels of access according to the user profile (administrator, volunteer, region) and possibility to manage multiple disasters; and (iv) historical database for: queries, comparisons and predictability studies. The functionality of interoperability proposed by Shafiq *et al.* (2012) is also considered in this evaluation.

Disaster management tools assessment

This section describes the assessment results generated in this study. The following criteria were used for each characteristic of the selected tools: (•), means that the tool has this feature; (o) means that the tool does not have this feature.

According to Figure 2, the prototype UICDSe proposed by Shafiq *et al.* (2012) is the one with the best features, quantitatively and qualitatively, for a disaster management system. Indeed, the search for a service-oriented tool, allows each aid organization to continue use its own tools. UICDSe also proposes to create rules and decision models to previously calculate disaster needs.

The Sahana system demonstrates its management skills, combining the volunteers' registry and planning to support the supply chain. Additionally, it innovates by creating the possibility of generating notifications by sending text messages, email and twitter.

The tools FEMA and SUMA/LSS were developed over time, so they have reached a degree of maturity and have enough documentation available (training, videos, reports). In addition, both have great financial support of the US government and the United Nations. The successful uses of both tools are widely proven through various disaster references.

FUNCTIONALITY	S2iD	SUMA/LSS	FEMA	SAHANA	UICDSe	DONARE	HELIOS	GOOGLE	AidMatrix	DesInventar	HDX	TOTAL
Supply Chain Design	O	O	●	O	O	O	●	O	O	O	O	2
Supply Chain Planning	O	O	●	O	●	O	●	O	O	O	O	3
Supply Chain Execution	O	●	●	●	●	●	●	O	●	O	O	7
Documentation	●	●	●	●	●	●	●	●	●	●	●	11
Reports	●	●	●	●	●	●	●	O	●	●	●	10
Controlling	●	O	●	O	O	O	●	O	●	O	O	4
Cross-linking	O	●	●	●	●	●	●	●	●	O	O	8
Offline / Online Use	O	O	●	●	●	●	●	●	O	●	●	8
Modularity / Adaptability	O	●	●	●	●	●	●	●	●	O	O	8
Usability	●	●	●	●	●	●	●	●	●	●	●	11
Direct Costs (Software & Hardware)	●	●	●	●	●	●	●	O	O	O	O	7
Indirect Costs (Training, Maintenance)	●	●	●	●	●	●	●	O	●	O	O	8
Volunteer Register	O	O	O	●	●	●	O	O	●	O	O	4
Notification Module (SMS, twitter, facebook)	O	O	●	●	●	O	O	●	●	O	O	5
Interoperability	O	O	O	●	●	O	O	O	O	O	O	2
IT Security	●	O	●	●	●	●	●	●	●	O	O	8
Multiuser and Hierarchical Users	●	O	●	O	●	O	O	O	O	O	O	3
Donor Evaluation	O	O	O	O	O	O	O	O	O	O	O	0
Historical Database	●	●	●	●	●	O	●	●	O	●	●	9
Total of functionalities with YES	9	9	16	14	16	11	14	8	11	5	5	
Total of functionalities with NO	10	10	3	5	3	8	5	11	8	14	14	

● YES, functionality is present O NO, functionality is not present

Figure 2 – Software functionality evaluation

Donare tool was developed to fix the weaknesses of SUMA software; its main contribution was to carry out a web-based system, where people can access it remotely by Internet. Regarding functionalities, it is important to highlight the possibility of registration of volunteers and donors.

The innovative HELIOS tool allows grouping specific functionality in modules that can be used separately according to the disaster stages. One of the disadvantages of this tool is the cost of maintenance, which is justified for the sake of improvement and necessary corrections, but limits its use in many countries. On the other hand, it is an open source platform, enabling improvements that can be performed remotely by each country, in this case the country concerned must provide human resources for such activity.

The Aidmatrix, although does not comply with many features needed for disaster management system, provides extremely efficient and reliable aids that are used by humanitarian aid organizations that are not able to develop similar tools.

Google tools have focused primarily on disaster management, but are auxiliary tools. All are extremely intuitive, practical and with free access for use in a disaster. Two other positive characteristics are related to its usability and customization, all of them can be configured according to user needs and characteristics of each disaster.

The DesInventar and HDX software are mainly built to create a centralized information base. Whereas the DesInventar seeks to generate unified and standardized information in order to be able to compare different locations, the HDX search centralize any kind of information about certain region, not worrying much about the formatting of this information.

Finally, S2iD requires improvement to meet the general needs of a disaster management system. Some important steps have been done, such as the digitization of Disaster Reports filed on paper and the creation of an electronic interface to complete new Disaster Reports. The

system, however, is not able to perform the supply chain management, an essential characteristic to support the beneficiaries.

Multi-criteria analysis

The interviewers were defined in order to have a representative for each type of stakeholder, defined by the authors Cozzolino (2012) and Thomas (2003). As this is an ongoing study, the AHP results presented herein were applied in the following stakeholders: academy, NGOs, donors and aid agencies. Government, military, logistics operators, media and beneficiaries' interviews and AHP results will be presented in a future research.

The AHP process was divided in three levels: (i) main target, as a disaster management tool; (ii) three sub-groups, Resource Management and Planning, Communication Management and Information Technology; and (iii) the corresponding functionalities of each sub-group. This division in three sub-groups was done based on the critical factors to achieve the success defined by Pettit and Beresford (2009) in order to have a better and focused decision process by the interviewers, as presented in Table 2.

Table 2 – Sub-group categories applied in AHP process

Critical success factors (Pettit and Beresford 2009)	Sub-group
Strategic Planning, Resource Management, Transport Planning, Capacity Planning, Human resource Management, Supply Chain Strategy	Resource Management and Planning
Information management, Supplier relations	Communication Management
Technology utilization, Continuous improvement	Information Technology

AHP results

Table 3 shows the AHP results for the three sub-groups. The main focus reported by the HL specialists, except for donor, should be in the Communication Management. Donor results show a focus in Resource Management and Planning and Information Technology.

Table 3 – Main sub-group AHP results

Stakeholder	Resource Management and Planning	Communication Management	Information Technology
Aid agencies	0.1260	**0.4580**	0.4160
NGO	0.3270	**0.4130**	0.2600
Academy	0.1050	**0.6370**	0.2580
Donor	**0.4810**	0.1140	0.4050

Table 4 shows the AHP results for the functionalities of each sub-group. It is marked in grey background color the two most important functionalities evaluated by each stakeholder. According to the specialists' answers, it can be observed that Supply Chain Execution, Centralized Database and Usability are the functionalities that must be in the Disaster Management Tool.

Table 4 – Functionalities AHP results

	Functionality	Aid agencies	NGO	Academy	Military	Donor
Resource Management and Planning	Supply Chain Design	**0.233**	0.112	0.04		0.114
	Supply Chain Planning	0.143	0.077	**0.137**		0.114
	Supply Chain Execution	0.098	**0.338**	**0.137**		**0.265**
	Controlling	0.076	**0.263**	0.128		**0.202**
	Direct Costs	0.061	0.073	0.08		0.043
	Indirect Costs	0.041	0.061	0.068		0.023
	Modularity / Adaptability	**0.329**	0.032	**0.387**		0.065
	Volunteer Register	0.019	0.044	0.022		0.174
Communication Management	Documentation	0.036	**0.323**	0.072		0.025
	Reports	0.105	0.13	**0.184**		0.135
	Donor Evaluation	0.071	0.095	0.03		0.13
	Historical Database	**0.302**	0.06	**0.184**		**0.25**
	Notification Module	**0.257**	0.041	0.05		0.038
	Offline/Online Use	0.23	**0.351**	**0.48**		**0.422**
Information Technology	Interoperability	0.062	**0.533**	0.22		0.071
	Cross-linking	0.07	0.058	**0.124**		**0.197**
	Usability	**0.384**	**0.184**	**0.561**		0.042
	IT Security	0.14	0.073	0.061		**0.58**
	Multiuser	**0.344**	0.152	0.035		0.111

Conclusion

This study aimed to show the features and concepts of a set of disaster response tools. The need for a tool that allows a proactive and fast action plus predictable studies, by the government and humanitarian organizations, in disaster situations is indispensable to support, quickly and efficiently, the victims of these extreme events. This study is partially concluded since it is missing stakeholders' interviews. Although, it contributes defining the main functionalities and features needed for a more efficient disaster response tool. The prioritization of the functionalities should be concluded further when all interviews are done. It also shows a lack of communication between the HL stakeholders once several tools were created in an independent way according to specific needs and none of them have all functionalities developed.

Based on the study presented above, focusing in the three major AHP results (Supply Chain Execution, Historical Database and Usability) a possible disaster management framework should contain: the usability and customization power (adaptability) of Google, the centralized database information from HDX/DesInventar and the supply management of LSS/SUMA. As secondary needs: the notification techniques and volunteers management of Sahana, the Aidmatrix donation applications, the data entries of Si2D, the modularity of the HELIOS, the infrastructure, auxiliary tools and coordination ability of FEMIS and finally the interoperability feature described in the UICDSe. In order to have a more accurate result, it is suggested to expand the number of interviews and add new tools such Adashi (incident command software).

Finally, due the absence of a centralize historical database it makes difficult comparisons and predictability about disasters, as consequence it makes difficult a proactive work in phases of mitigation, preparedness and recovery, and affecting considerably resilience projects and plans, as well as increase costs generated by a disaster. It should be noted, however, that there are tools that complement each other, making the end result satisfactory to the disaster response phase.

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