The role of human control errors in an aviatic accident, Safety project report, Software Systems Safety Spring 2020

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1. Description of the accident

1.1 Introduction

This is a report on the crash of the Bombardier UBG-211 at Kathmandu Tribhuvan International Airport, Nepal, on 12th March 2018. The airship was owned and operated by US Bangla Airlines and it was executing an international flight from Dhaka to Kathmandu. The crash happened in the landing phase due to human errors. There have been significant human and material losses and no on-board mechanical or electronic systems were found to be malfunctioning in the day or before the accident.

1.2 History

The flight crew was made out of two pilots between which was a large experience gap — a pilot in command (PIC) with over 2800 hours of experience on that type of aircraft and a first officer (FO) with less than 250 hours on the type of aircraft. The systems on board and the aircraft have proven to have worked according to all nominal parameters, as this has been proven both before and after the accident.

The PIC's last flight to Kathmandu before the accident was on 16th February. The PIC came back from a 15 hours rest period between flights, while he hasn't slept enough, which made him tired and moody. When beginning the departure sequence, he was asked to provide, according to a new CAAB (Civil Aviation Authority of Bangladesh) regulation for international flights from Bangladesh, an additional flight clearance — ADC (Air Defence Clearance) Bangladesh — which the PIC was not aware about as neither him or his FO were briefed about. The ADC they provided was the regular one written in the Flight Plan. This obviously created some distress between the PIC, the ATC (Air Traffic Controller) and the operations department who had to issue the clearance.

The flight began at 0651, 12th March. In the climbing phase, the onboard systems exposed part of the conversation between another aircraft owned by US Bangla and the Operations on ground and, without verifying if UBG-211 was the recipient, the PIC engaged in the conversation, with a high vocal pitch that indicated distress which has been ignored by the ground control.

During the main flight period, the PIC has been engaged in a number of activities which required attention: monitoring of the flight systems, instructing the first officer about various flight aspects (exercising his position and experience as a flight instructor) and engaging in unnecessary flight conversation on rumours about himself, which in turn made him trying to

prove himself in front of the FO. This stress led him to smoke in the cockpit, which was forbidden according to company regulations (Company Standard Operating procedure).

At 0752 there was the first contact with Kathmandu Control. At 0810 the flight was handed over to Kathmandu Approach. Meanwhile, the PIC complimented the FO for her performance and insisted her abilities conformed to the standard, against the company rumors. The FO was trying repeatedly to change the topic to navigation related discussion. At 0758, the PIC, while being the pilot flying, instructed the FO to find the appropriate charts for the Kathmandu landing, indicating he did not have the Approach Charts. The PIC made a short briefing to the landing procedure referencing the FO's charts, not carrying a complete briefing of the complex workflow, even if this was the first time the FO was flying the segment. The flying pilot instructed the FO to clip the respective charts on her console, making important detailed information unavailable for himself, especially in the case they haven't reviewed the main approach chart.

At 0811, Kathmandu Approach instructed the aircraft to descend to 13500ft and hold over GURAS and the crew inserted HOLD in the FMS (Flight Management System). The Kathmandu Approach instructed descending twice, first at 0813 to 12500ft and then at 0816 to 11500ft and cleared the runway RWY 02 for VOR (VHF Omnidirectional Radio Range) approach. At this moment, the hold command should have been canceled, but both the crew members forgot to do that. At this essential moment, the PIC lit another cigarette, showing negligence. After reaching the GURAS intermediary point, the FMS turned the airplane left for the holding pattern which was noticed by the cabin crew, they corrected and reported to Approach Control. However, the PIC selected the heading angle of 207°, with a 5° difference from the desired 202° angle, that, combined with a wind of 28kt (knots), made the aircraft deviate right of their approach course, by 2-3NM northeast from the KTM VOR. At 0827, KTM Tower alerted the crew that the landing sequence was given for RWY 02, but the aircraft was heading to RWY 20, supposedly after getting the direction wrong. According to the Operations Manual Part C, they should have been through the landing checklist before even reaching the GURAS waypoint, action started by the PIC and conducted by the FO at 0822, missing that the landing gear was in an unsafe state (the PIC had confirmed the landing gear without checking its position). From 0823, the landing gear unsafe tone was on the deck speakers, while both the pilots ignored it, which resulted in the PIC asking for the landing checklist three times, the FO confirming it has been completed and them having difficulties in understanding themselves over the noise in the cabin. At 0825, the FO realized the landing gear was in the wrong position and began extending it, and the PIC requested the checklist the fourth time. Their following conversation revealed they were ambiguous about getting visual contact with the runway, while being unaware they already passed RWY 02.

At 0829, KTM tower asked the aircraft to confirm which runway they will be trying to land, to which it had been answered by the PIC that they will be landing on RWY 02. The tower control then gave instructions for approaching RWY 02 requesting a check when they sighted

another aircraft that was in the final landing phase on the RWY 02, however, US Bangla's aircraft continued going right in the direction of RWY 20. After the first aircraft landed, at 0832, Tower Control gave the choice to the PIC for which runway to land on. The aircraft continued to go northeast, passing even RWY 20.

The PIC announced he had the runway in sight and requested landing clearance which he received, but the aircraft was still positioned in a wrong way from the runway and, at 0833, after visually spotting the close ground maneuver, the Tower Controller cancelled the landing clearance in distress. Now going in a westerly direction, the aircraft pulled up over a building area of the airport, going just over the ATC Tower, while the tower controllers ducked down in fear the aircraft would hit the top of the tower.

At 0834 UTC, the aircraft touched down on the left side of the RWY 20, with an angle of 25° with the runway axis, then steered southeast of the runway, through the inner perimeter fence and stopped 442 meters from the touchdown point. The aircraft caught fire 6 seconds after touchdown, which created the majority of the casualties. The plane fragmented into parts during the stopping part, with both the landing gear and wings being broken and the rest of the people and equipment being burned by the fire. The firefight efforts began 16 seconds after, and firefighting and emergency services reached the crash site within two minutes.

1.3. Losses

From the human losses standpoint, there have been 51 deaths (4 crew and 47 passengers) and 20 seriously injured passengers. 28 of the deceased have been Bangladeshi and 22 Nepalese. It is assumed that most passengers should have survived the impact, but the fire made it impossible for them to escape and brought everyone in critical condition (if it hadn't killed them). The aircraft was completely destroyed by the impact and subsequent fire and the aerodrome's perimeter fence has been partially destroyed.

1.4 Other relevant aspects

There has been discovered post-accident, that US Bangla's Operations Manual stipulated an erroneous distance of 16 nautical miles from the GURAS waypoint until the Kathmandu airport, which is actually 17 nautical miles. However, the crew has been using Jeppesen charts for all approaches including the Tribhuvan airport, where the distance has been shown correctly.

US Bangla's doesn't have any written policies on crew pairing, the pairings are generally respected with the exception of overnight sickness. They keep their number of spare pilots engaged in their positions even if they are not flying US Bangla's airplanes by borrowing them to another airline as an official accord against payment.

The PIC has been in the Bangladesh Air Force until 1993 when he was discharged due to depression. In 2002, after being declared fit to fly on civilian aircraft, he was considered clear of any symptoms of depression. From 2002 to 2017, there have been no mentions about symptoms of depression in any of his medical exams. The PIC had a smoking habit that the airline policies explicitly forbidden against a fine. In self-reports along the years, the PIC had contradictory declarations — in the period 2012-2014 he mentioned never smoking, in 2015 he mentioned quitting smoking in 2010 and from 2016 he mentioned never smoking once more. This contradictory behavior can either show inconsistent behavior (which is opposite to colleagues and friends declarations on him) or a bad company culture.

The accident report, following the CVR audio records, states that the PIC was stressed about a female colleague's criticism of his skills as his teacher and he was trying to direct the majority of the conversation towards the fact this kind of talk hurt him emotionally (we can assume he was taking pride into his flight experience and frequent instructions he gave to other airline employees). He even went to the length of saying he was so hurt that he would resign from the company he loved and remain unemployed, despite the fact that he had a family to support. This exacerbated his distress as he began being insecure of his financial future with the responsibilities he felt. The visible (or audible) effects of this have been that the PIC was talking almost non-stop throughout the duration of the flight, with the FO being a silent or respectful listener as the situation went. The cabin discussion revolved around this situation, him trying to teach the FO flight sequences (when he was extremely calm and composed) and going through the landing procedures (somewhat in an incomplete way).

None of the cabin crew were under the influence of any narcotic drugs, alcohol or other toxic substances, according to the tox report. The only substance found was the result of the PIC smoking plain tobacco. However, the toxicological analysis was not focused on prescription medication for treatments on depression or anxiety, so we cannot say anything about that.

TIA (Tribhuvan International Airport) has been recognised since then as one of the most dangerous airports in Asia (according to CAAN, the Civil Aviation Authority of Nepal[2]) and the one of the most hated passenger airports (by CNN[3]).

The flight controllers have not been visually following the aircraft after giving the flight clearance, until the moment they observed it was going to RWY 20 instead of the RWY 02. After the exchange of messages between the TWR and PIC resulted in him confirming he would land on RWY 02, the Tower Duty Controller took over the OJT controller and **mistakenly** cleared the flight to land on RWY 20, **assuming** it would be in the PIC's field of view. After this, the Tower Duty Controller has been replaced by the Tower Supervisor Controller.

At no point in the landing sequence there has been any attempt to gain altitude in order to get a better view of the airport and regain situational awareness, which is a standard procedure.

2. Identifying related accidents

We can consider an **accident** to be an unplanned event that results in loss of human life, human injury, property damage, environmental pollution or mission loss. As a control problem, we can consider accidents to be errors in **enforcing the safety constraints** or not following the appropriate control actions.

Using the following severity scale, we could classify the accidents as having the following severities:

Severity Level	Human damage	Equipment damage	Airport damage
3	Loss of life	Complete equipment loss	Airport shutdown for more than a standard working period
2	Severe injuries	Major system damage	Airport heavy damage and delays
1	Minor injuries	Minor system damage	Airport minor damage and delays
0	No/insignificant injuries	No significant damage	Airport delays

Those being said, this specifically described event can be classified as displaying the following system-level accidents, resulting from the single crash event:

1. [Human damage: 3] Loss of human life
2. [Equipment damage: 3] Complete airplane and equipment loss
3. [Airport damage: 2] Airport major runway damage and delays

3. Identifying hazards

Hazards that contributed to the unsafe system states included and are not limited to the following:

1. The ATC does not consider previous commands when issuing new flight commands.
2. The ATC does not visually follow an aircraft after issuing the landing clearance.
3. The landing checklist procedure is not used properly before the waypoint.
4. The landing gear is not verified to be in the right position before a landing.
5. The flight system unsafe tones are ignored by the cabin crew.

6. The pilot flying does not have the appropriate landing charts in view.
7. The cabin crew does not attempt to gain altitude when missing location awareness.
8. The cabin sterile operations manuals are not followed.
9. The pilot flying assumes too many responsibilities, without delegating to the FO.
10. The airline company does not execute effective psychological tests on its pilots.
11. The airline company does not give enough rests between flights to their crew pilots.
12. The operational manuals are not correct, up to date and consistent with other flight support material.

4. Resulting safety constraints

The following safety constraints from the physical system constraints can be identified:

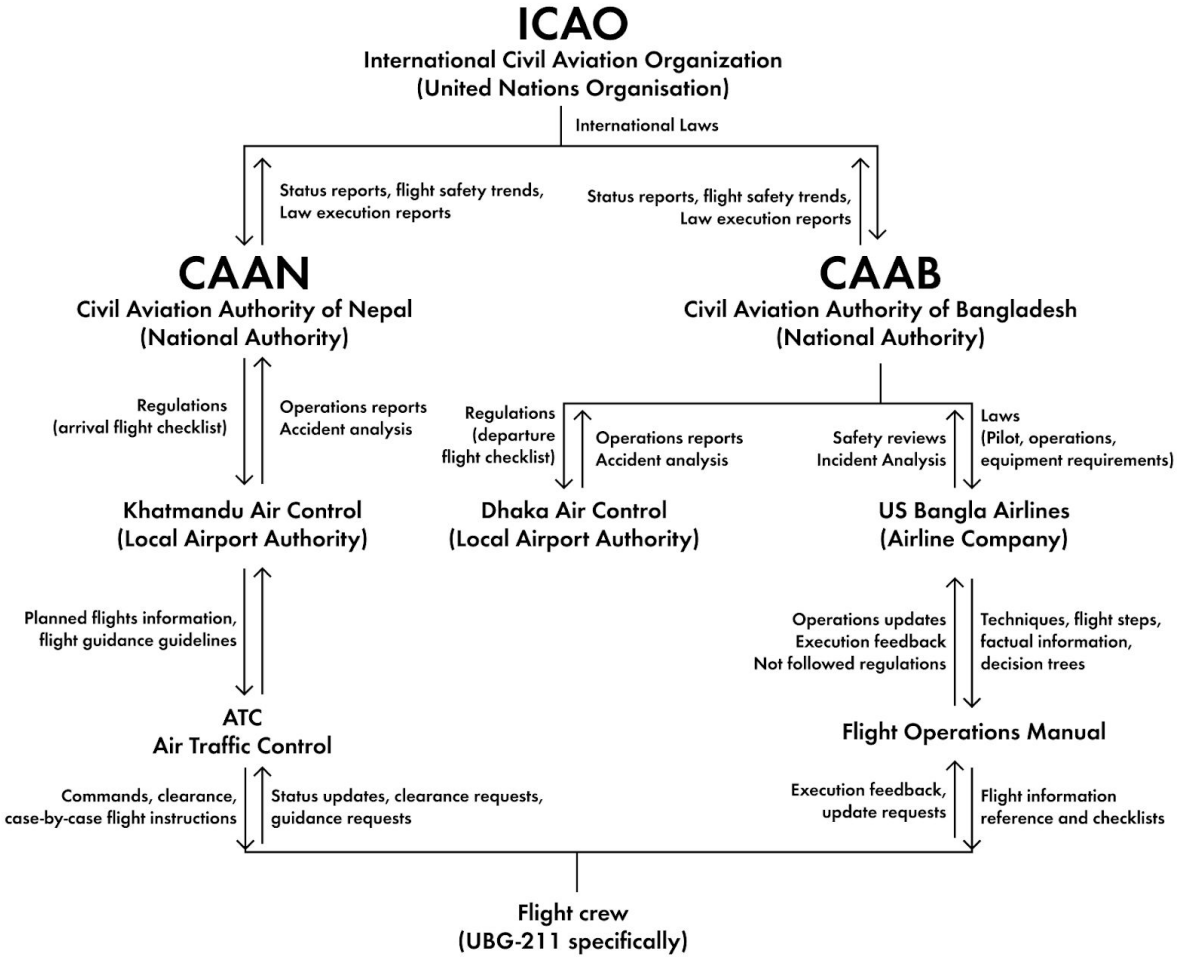
1. The ATC must ensure they command a safe change from one state to the next. [H1]
2. The ATC must visually follow the aircraft after issuing a landing clearance. [H2]
3. The landing checklist must be checked before the waypoint. [H3]
4. If the landing checklist is not completely checked before the waypoint, it must be done as soon as possible to ensure a safe landing. [H3]
5. The lowering the landing gear action must be followed by checking if the landing gear has reached the extended state. [H4]
6. The flight system unsafe tones must be accompanied by a clear visual display alert. [H5]
7. The flight system unsafe tones must not be ignored. [H5]
8. The pilot flying must have sufficient information at hand during landing to verify every landing procedure's parameters. [H6]
9. The cabin crew must ask the ATC for clearance in trying to gain altitude when missing location awareness. [H7]
10. The ATC must command gaining altitude, when traffic conditions permit it, to an aircraft that seems to be missing location or situational awareness. [H7]
11. The cabin crew must respect the cabin sterile operations manual. [H8]
12. The pilot flying must delegate responsibilities to other cabin crew members to avoid task overload. [H9]
13. There must not be a steep gradient in experience between cabin crew members. [H9]
14. Inexperienced pilots must not pilot passenger flights that are known to be difficult. [H9]
15. The airline company must execute effective psychological tests on its flying crew. [H10]
16. The airline crew must give enough rest between flights to cockpit crew. [H11]
17. The airline must have a backup pairing for the cockpit crew in case they are deemed too tired to fly before a flight. [H11]
18. The airline must have proper documentation linking to keep operations manuals consistent. [H12]

19. The airline must regularly verify that operations manuals have proper, correct instructions. [H12]

5. System control structure

Apart from the above physical system constraints, we must include a set of requirements regarding the organisational command and control structure of the safe operations of a passenger airplane flight. We must mention there is no set correct control structure for any specific complex system-controlled action, and that we only propose (or augment) an already existing model (or part of it).

The goal of a passenger flight operations system is **transporting passengers and their goods from a departure airport to a destination one, in time, safely, with no physical losses, be they to the passengers, equipment, or airport**.



The above diagram contains both commands and feedback mechanisms, regarding regulations (system and subsystem requirements) and feedback mechanism (regarding the

execution or lack of execution of said laws and regulations and reports about overall system status or specific incidents). To be more specific:

- ICAO, the International Civil Aviation Organisation, under the umbrella of the United Nations, is the highest aviatic lawmaker in terms of reach and should have access to national data and trends in order to build up a set of international laws applicable to each air defense national organisation.
- National Aviation Authorities must provide ICAO status reports, safety trends, law execution reports and create a set of regulations and manuals directing each airport's operation under their authority. More than that, they must pass down laws on technical, equipment and operations of airline public and private companies.
- Airport Air Control must provide flight guidelines and planned flight information (as well as the necessary equipment for current operations) to the Air Traffic Control towers for both arrivals and departures. Also, Airport Control must send operations reports and accident analysis back to national authorities.
- Airlines themselves must respect national and international laws and create operation manuals specific to their flight personnel and equipment which respect those laws and help flying safely at every step. The manuals themselves are subject to update requests and feedback on practiced versions of the techniques.
- The flight crew must respect a number of authorities at any time in the flight, but generally, they are subject to a departure Air Traffic Control and an arrival Air Traffic control, while continuously following the operations manual as a reference for each flight segment. They usually send status updates, clearance and guidance requests and follow ATC commands to keep safety distance between themselves and other close flights.

6. STPA: identifying unsafe control actions

In the following section we are analysing violations of the identified safety constraints, for the documented accident of the Bombardier plane. For this we will be following the System-Theoretic Process Analysis (STPA), starting with listing the unsafe control actions, classified by their type. Those are the following:

Control Actions not provided causing hazard

- UA1: ATC hasn't visually followed the aircraft after issuing the landing clearance. [SC2, H2]
- UA2: The cabin crew hasn't checked the landing gear state after issuing the lowering command to the equipment. [SC5, H4]
- UA3: The cockpit crew hasn't tried gaining altitude to regain location awareness. [SC9, H7]

- UA4: The ATC hasn't tried issuing a 'gain altitude' command when the guided aircraft had space and lacked location awareness. [SC10, H7]
- UA5: The pilot flying did not delegate responsibilities. [SC12, H9]
- UA6: The airline company has not executed effective psychological tests. [SC15, H10]
- UA7: The PIC has not had enough rest and wasn't replaced on the flight. [SC16, SC 17, H11]

Control Actions provided causing hazard

- UA8: ATC provided the descending command without commanding to cancel the hold. [SC1, H1]
- UA9: The pilot flying gave the landing charts to the other cockpit member. [SC8, H6]
- UA10: There was a steep gradient between PIC and FO. [SC13, H9]
- UA11: An inexperienced FO was flying one of the most difficult flights. [SC14, H9]

Control Actions provided at the wrong time

- UA12: The cabin crew went through the landing checklist after reaching the waypoint or immediately after. [SC3, SC4, H3]

Control Actions not followed

- UA13: The flight system unsafe tones have been ignored. [SC7, H5]
- UA14: The cabin crew hasn't followed the cabin sterile operations manual. [SC11, H8]
- UA15: The operations manuals of the airline had wrong data. [SC18, SC19, H12]

7. STPA: identifying causes for unsafe control actions

Just like multiple safety constraints have been violated by a single unsafe action, multiple unsafe actions are caused by a single cause. We'll try to indicate a set of minimal causes for the above unsafe control actions.

1. An emotionally disturbed, stressed, tired pilot has been the pilot flying on a difficult flight. [UA2, UA3, UA5, UA6, UA7, UA9, UA13, UA14]
2. An over experienced PIC tried to show his superior skill to an inexperienced FO in a difficult flight. [UA3, UA5, UA9, UA10, UA11, UA12, UA14]
3. The Kathmandu ATC didn't have a proper workflow for an aircraft crew missing situational awareness. [UA1, UA4, UA8]

4. The airline was not having a responsible management scheme — missing training, operational manual reviews, transmitting safety awareness and responsibility. [UA2, UA6, UA13, UA14, UA15]

In the referenced accident report, these four causes have been identified to be in the top 5 causes for the accident, and have been followed by a number of subsystem causes or causes that originated in these four, like: "Lack of assertiveness of the ATC" or "Lack on the part of the ATC to alert the crew of their actual position". However, there is one more **essential cause** that we couldn't identify from the report but only read about in the causes, that which there was:

- "A lack of simulator training dedicated to the visual approach for RWY 20 to the pilot flying."

8. Safety controls

As a result of the accident investigation, a number of safety recommendations have been sent to different parts of the in-place control structure. We will mention the most prominent.

To CAAB. *Creating a system to monitor the physical and psychological medical states before the renewal of a piloting license and during all subsequent examinations.* We can see how this would combat the first cause identified, strengthening the quality of the crew and lowering the chances of UA5, UA6 and UA14, especially. If there was no disruption between pilots in the current analysed flight, there procedures that were already in place would have been respected and, even in the case of the loss of situational awareness, there would have been more time to assess the situation and next steps. However, what happened was that the cockpit crew had not reviewed the landing procedure, had to manage the unsafe alarm sounds and have a single, task-overloaded experienced flying pilot.

To CAAN. *Creating a training programme for the ATC to be more assertive in issuing commands and clearances and especially vigilant when handling abnormal situations.* The fact that the ATC ignored, time after time, clear signs that the aircraft pilots lost situational awareness and, instead of restricting their options and giving strict directions, they only increased their pool of choices (by giving clearance to land for both runways), had a large impact on the landing. Even in the last moments, as stated in the report, they could have taken the pilot authority and imposed a standard missed approach procedure, gaining altitude in order to restart the landing state.

To the airline. There are quite a few recommendations to the airline, regarding different steps before and after the flight. To mention a few:

- *Creating a standard method to assess the mental state, emotional distress and financial issues of pilots.*

- *Creating a system to ensure proper implementation of the sterile operations manual rules in the cockpit.* This is quite a difficult task, as the rules have already been in place, and the PIC, having quite a long experience, was aware of them, but he didn't hesitate in breaking several times, repeatedly, the rules.
- *Create a policy to de-roster any crew member physically unable to fly because of stress, fatigue or emotional disturbance.* This would bring the most value to both the crew members and safety of the flight, however increasing operational costs for small airlines. We strongly advise to include this as a necessary step before each flight: a verification of the state of the employees, the possibility of self-reporting tiredness and the availability of replacement rosters.
- *The operator should revise their training process to include visual approach on the RWY20 on the simulator, for both experienced and new pilots.* The simulation on all possible scenarios for one difficult airport, close to the mountains, seems a clear must for operating an airline, however, it was missing from the training of the pilots. At one point, one might say that an inexperienced pilot should not fly a difficult route, but the only way a pilot who did not fly a specific route until one point might take up on that position is that they are trained over and over in the simulator on that specific route. If something like this is not implemented, then, at one point, pilots who were previously flying those routes will need to retire and the airline will be pushed to either use a couple of inexperienced pilots without ever having flown that route or gradually accommodated on the simulator or drop the route, decreasing gradually passenger flights to those locations.

From or point of view, the two most important controls that could have helped in an accident like this, from the above (not to disregard the importance of the others), would be the latter two, having a backup pilot roster and having simulations for difficult landings for all pilots flying that route. The fact that US Bangla was missing such practices might show that they didn't have in place a strong safety culture, made clear and put into a continuous feedback loop. This opinion is supported by the fact they ignored the PIC's smoking habits that the report mentions they were aware of and that they didn't inform their crew before the flight of any regulation changes regarding the ADC.

Other airlines might be in similar situations, especially regarding international flights, which are both longer and require more experience, and they might implement the missing controls into their safety strategy to avoid a similar tragedy to the 2018 Bombardier crash.

9. Appendices

9.1. Abbreviations

ADC	Air Defence Clearance
ATC	Air Traffic Controller
CVR	Cockpit Voice Recorder
FMS	Flight Management System
FO	First Officer
PIC	Pilot in Command
VHF	Very High Frequency
VOR	VHF Omnidirectional Radio Range

9.2. References

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