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Assessing the Effects of a War on a Container Terminal: Lessons from Al Hudaydah, Yemen

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ABSTRACT: This paper is focused on the case of the container terminal of Al Hudaydah port (Yemen) and on its situation on the battlefront in a country struggling with a civil war since 2014, despite the military intervention of a Saudi-led coalition since 2015. The goal is to propose a comprehensive OSINT methodology to evaluate the case of this terminal which is the first container terminal hardly impacted by a modern conflict. This study belongs to the field of port geography studies and aims to contribute to a better comprehension of transport and security/development nexus, build on an easy-to-use GIS methodology based on open access data. Lessons learnt from Al Hudaydah container terminal are a step in the description of the relations and dynamics between war and terminals/ports. The main results show that war and battle have two different effects: war leads to long-term effects probably linked to hinterland attrition and change in port hierarchy; battle lead to short/medium-term effects linked to battlefront distance and road blockade. Finally, the port is a valuable asset for both sides involved in the Yemeni Civil War, but it is difficult to evaluate further the importance of the terminal than a sign of the port dynamics.

1 INTRODUCTION

In recent conflicts, the main examples of major ports subject to armed conflict are all exclusively located within countries affected by civil wars resulting from the collapse of regimes following the Arab Springs (2011): Syria (Lattakia, Tartus), Libya (Benghazi, Misrata, Al Khums, Tripoli) and Yemen (Aden, Al Hudaydah, Al Mukalla). Among them, only Al Hudaydah is directly located on a front line since 2018. This is as a result of the intervention in Yemen by an Arab coalition led by Saudi Arabia (2015—…). As far as we know, this is also the first container terminal—i.e., specifically dedicated to their handling—to experience this intriguing situation. This leads us to wonder about the spatial evolution generated at the scale of the container terminal in times of conflict and with the means available at first sight: easily or open access data and literature mostly from the internet.

Studying a port (or a terminal) is an interdisciplinary opportunity according to the last paragraphs pointed by Ng et al. in the article Port geography at the crossroads with human geography: between flows and spaces (Ng, Ducruet, Jacobs, Monios, Notteboom, Rodrigue, Slack, Tam, Wilmsmeier, 2014). Authors say: “They are locally embedded within a particular region, and will always be affected by the local socio-cultural environment; but simultaneously they are the major outlet for external connections, and so will always be affected by global spatial development. They are the intersection and interaction points between people, cargo flows and markets. They are the arenas which attract substantial research interests from many disciplines, which facilitate intra- and interdisciplinary" (Ng, Ducruet, Jacobs, Monios, Notteboom, Rodrigue, Slack, Tam, Wilmsmeier, 2014, 94–95). Therefore, ports, as crossroads and complex objects, could be a new frame of reference to study security and development nexus. Al Hudaydah port fulfills all the characteristics because of its status of interface between the container global system and Yemen Civil War complexity at local, regional and international scales. That is also a borderline case: Al Hudaydah port and container terminal are on the battlefront since June 2018 and the political situation seems deadlocked.

While this work is largely exploratory due to the absence of other comparable situations, two questions/objectives underlie it: (1) One concerns the dynamics and evaluation of the container terminal during the Yemeni conflict. It is then possible to question the role of a terminal as an indicator of this conflict; (2) The other raises the question of the feasibility of an analysis of port geography using the process and methods of open-source intelligence (OSINT). It means understanding the effects on the terminal from open access sources but also to develop a GIS methodology to overcome the lack of reliable data in times of war or in ports outside the main global maritime system.

This paper focuses on the following sources, the vast majority of which come directly from the internet and are open access: shipping data from the United Nations Conference on Trade and Development (UNCTAD); data from The Armed Conflict Location & Event Data Project (ACLED; Raleigh, 2010); public port authority data from Aden Port Authority; Google Earth Pro satellite images (2004–2020); National Geospatial Agency gazetteer; and a thick amount of grey literature was processed (peer reviewed and non-peer reviewed scientific articles, press articles, reports and UN documentation, websites, photographs, etc.). For the development of methodology in Section 5, the QGIS 3.16.7 software (qgis.org) and the mmqgis addon (michaelminn.com/linux/mmqgis/) were used. SRTM and WorldPop data were also useful to assess Yemeni context. A particular attention was paid to the quality of the data used and the metadata.

The rest of the paper is structured as follows: Section 2 draws the context of the Yemeni conflict which led to the battle of Al Hudaydah; Section 3 is dedicated to a critical analysis of Yemeni ports dynamics according to UNCTAD data; creation of new spatialized data at the scale of the container terminal is treated in Section 4 and the analysis is proposed in Section 5; finally, Section 6 serves as an assessment.

2 THE YEMENI CIVIL WAR (2014— …) AND THE BATTLE OF AL HUDAYDAH (2018)

2.1 *The context*

The difficulty in analyzing the Yemeni conflict lies in the multiplicity of local, regional and international actors, but also opportunistic and predatory local actors that result from a socially and economically fragile national context. The following two points are a brief reminder of this situation and of the conflictual dynamics.

Yemen (pop. 27 million) does not have the same stability as its neighbors, Saudi Arabia and the Sultanate of Oman. Its strategic location is ideal: it borders the Red Sea, the Gulf of Aden and the Bab el-Mandeb international strait. Yet it does not benefit from the global shipping routes because of the lack of a large transshipment port that can compete with, for example, the ports of Jeddah (Saudi Arabia) or Salalah (Oman). The constitution of a unified state (1990) led to a political and economic modernization attempt by President Ali Abdullah Saleh's regime. This modernization did not prevent a cycle of conflicts gradually stratifying over the past three decades: nepotism, old divide between South and North, tribalism and sectarianism, economic difficulties, water tensions, etc. (Burgat, 2006; Bonnefoy and Al Rubaidi, 2018; Clausen, 2019, 1–5).

These serious problems are worsened by the strategies of neighboring regional actors as Saudi Arabia, United Arab Emirates and Iran, that regard Yemen as a security issue and by the war on terror policy led by the United States against Al Qaeda in the Arabian Peninsula (AQAP) and Islamic State (province of Yemen). The fall of President Saleh (2012) did not fundamentally change the regime and the rise of the long-suppressed rebel forces of Ansar Allah (also called Houthis) from the Sa'dah region in the north of the country reached a critical level. In 2014, Houthis succeeded in taking control of the capital Sana'a from the new president Abdrabbuh Mansur Hadi's forces. The offensive of the Houthis and their allies undermined the presidential forces and threatened the major cities of southern Yemen, Taiz and Aden. At the end of March 2015, an operation led by an Arab coalition from the Gulf Cooperation Council (except Oman) intervened and quickly federated states from the Arab world and the Middle East (Saudi Arabia, United Arab Emirates, Sudan, Bahrain, Kuwait, Qatar, Egypt, Jordan, Morocco) with a notable Western support (Sharp, 2020, 15).

2.2 *Internationalization of Yemeni Civil War*

Due to the absolute air superiority of the Saudi-led coalition (SLC), in the days following March 25, 2015, most of the major military targets, including ballistic missile sites, Houthis bases, and airports, were hit hard, and continuously bombed until April 21, 2015. This operation was then replaced by Restoring Hope, supposed to aim at restoring security for all Yemenis. Among the targets of the coalition forces were numerous civilian facilities and infrastructures (bridges, electrical equipment, pumps and dams). In response to the strikes, the Houthis engaged in a missile war, targeting Saudi territory and the Yemeni maritime approaches (anti-ship missiles but also underwater mines). The missiles and drones used by the Houthis and supplied by the Iranians arrived mainly in spare parts from Iran (Williams and Shaikh, 2020; 29). These deliveries justified the blockade of Yemeni ports, and then, progressively, the taking of Aden, Mocha and all the islands in the southern Red Sea (Williams and Shaikh, 2020; 29–31).

On the ground, in addition to the Yemeni forces supported by the coalition forces, which make up the majority of the forces facing the Houthis, the SLC deployed heavy equipment (tanks, howitzers, anti-missiles batteries), as well as troops, mainly made up of African auxiliaries. The front line of the border areas between Saudi Arabia and Yemen, Ma'rib and Aden stabilized in 2016 and the south front line runs from Al Bayda in the east to the port of Mocha. In June 2018, this line is changed significantly with the recapture by government and coalition forces of a narrow strip of territory from the small port of Mocha to the large port of Al Hudaydah. In December 2018, the situation was frozen on land at Al Hudaydah and at sea with the SLC blockade.

At a regional level, the SLC operation confirms: (1) the will of Saudi Arabia to impose itself as the regional leader capable of guaranteeing peace in the peninsula, the maritime spaces and the flows bordering it (Guzanski and Shavit, 2017); (2) the great firmness of countering Iranian influence at the Kingdom's doorstep. This influence takes the form of Iranian support to Houthis, a Shiite movement that occupies the region bordering Saudi Arabia but a limited scale compared to Lebanon or Syria (Guzansky, 2015). Iran is seizing the opportunities provided by the Shiite movements in the Arab world to increase its regional influence (Kam, 2016; Guzansky, 2012). The conflict in Yemen is, at the same time, a Yemeni civil war, a Saudi-Iranian proxy war and a point of interest for the US and the international community (antiterrorism). It has entered its seventh year with no military outcome in sight. With each passing day, the failure to re-establish the internationally recognized government legitimizes the Supreme Council of the Houthis and their allies.

The SLC has been weakening since the summer of 2019: (1) almost all Emirati forces are withdrawing from the South in order to be redeployed to their territory and turned directly towards Iran and the Strait of Hormuz; (2) the American election of 2020, won by the Democrat Joe Biden, calls into question the support and the very nature of the relationship of trust with the Saudi regime (Sharp, 2020, 20–21). This results in a blocked configuration and in a humanitarian crisis: a large part of the civilian population issubjected to the investors of war (Clausen, 2019, 3) and to a disastrous situation between health crises (cholera, dysentery and other waterborne diseases to which we can now add SARS-COV2), hunger and lack of everything (Varisco, 2019, 325; 17; Mousavi and Anjomska, 2020, 1–2).

2.3 *The last major battle: Al Hudaydah (June 2018-december 2018)*

Al Hudaydah (pop. 400,000), Yemen's major Red Sea port, is of vital importance as the gateway of a transport corridor running to Sana'a and northern Yemen. Before 1994 and the reunification, the People's Democratic Republic of Yemen, a socialist regime in the south, and the Yemen Arab Republic, supported by Saudi Arabia, in the north, had each a port for the two former capitals: Aden, for Taiz (pop. 620,000) and Al Hudaydah for Sana'a (pop. 2.5 million). This political and commercial divide, which has never been erased since, has created two de facto corridors. It should be noted, however, that Aden has a less exclusive position due to its more diversified hinterland with all the governorates of South Yemen and up to Sana'a. The port of Al Hudaydah has a huge dependence on Sana'a, which is less reciprocal. However, determining the boundaries of the hinterlands is a challenge (De Langen, 2007; Rodrigues, 2020).

The port and the city were regularly bombarded by the SLC forces, including several buildings in the port and terminal (August 2015). In 2018, this last major port in the hands of the Houthis and their allies became a first-class objective and the target of an offensive launched by Yemeni government forces supported by the SLC and Emirati ground forces from Assab (Eritrea) and South Yemen. Moving up from Mocha in June 2018, the main offensive was launched on June 13, 2018, after an intensive bombing campaign of the main defense lines in the south of the city and the city itself. For 7 months, interspersed with periods of ceasefire, the last battle of the civil war took place in three phases (Fig. 1): (1) June 2018 with the capture of the airport and defensive positions south of the city; (2) September-October 2018 with the capture of road number 3 towards Sana'a at the level of kilometer 16 (Kilo-16); (3) November-December 2018 with the attempt to completely besiege the city.

The fortifications surrounded the city in several lines with the main defense including the container terminal. It became a major stake in the conflict on a national and international scale as well as the first example of a container terminal stuck on a front line.

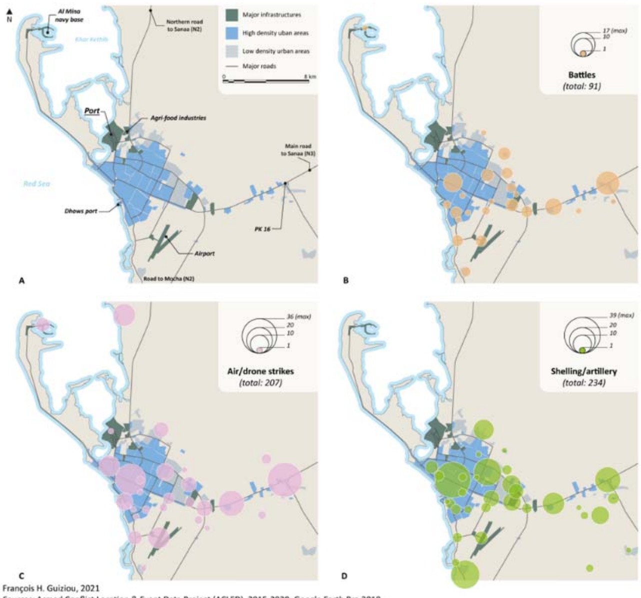


Figure 1. The battle of Al Hudaydah (June-December 2018)

When, in November 2018 SLC backed forces struggled to besiege the city, two political events stopped their offensive: (1) the international community denounced the murder of the Saudi journalist Jamal Ahmad Khashoggi by officials of the Kingdom (October 2018); (2) the Yemeni humanitarian drama put forward by the United Nations and relayed by the international media. The international community pressured the coalition not to cut the last major supply infrastructure for aid delivery. On December 13, 2018, the Stockholm Agreement (including the Agreement on the City of Hodeidah) ended the battle. According to the ACLED database, in the entire battle, only one strike, by the SLC, hit directly the port, which remained largely out of the clashes. The evacuation of the port by Houthi troops (May 2019) validated the application of the Agreement but led to a frozen battlefront where fighting and bombing remain episodic.

3 TRENDS FROM UNCTAD STATISTICS AND PROBLEMS AT SUBNATIONAL/LOCAL SCALE

3.1 *Al Hudaydah in UNCTAD Database*

The dynamics of a port during a war, and even more so during a battle, can be assessed by the evolution of the number of ships using it as well as by the tonnage and quantities handled. However, statistics on the port's use are not easily available in this case, mainly because of the conflict. In addition, the production of data by the major international organizations (United Nations agencies, World Bank, etc.) is often a compilation/aggregation of data produced by private operators (consultancy firms, intelligence contractors, etc.) whose collection methods are based on data produced by port companies and operators as well as on more or less precise evaluations. At the same time, sites dedicated to collect AIS data (MarineTraffic, Vesselfinder, etc.) produce an exceptional amount of information on port traffic and vessel typology, but the acquisition of these studies is most often unaffordable for preparatory work with limited resources. Moreover, these data are declarative and methods exist to distort them (Boudehenn et al., 2021). Thus, assessing a trend at the global or regional scale is possible, but assessing the trajectory of infrastructure at the state, subnational, and local scales is challenging.

This section focuses on maritime data provided by the United Nations Conference on Trade and Development (UNCTAD), one of the most widely used and valuable database in the transportation geography and economics community. The statistics on maritime transport are broken down into 16 tables of temporal data, with annual to quarterly granularity, organized around groups of economies, national economies, at the port and flag levels, on the main types of traffic (dry bulk, liquid bulk, RoRo, containers, etc.), their tonnage (DWT) and port performance. Among these tables, it also proposes the LSCI (Liner shipping connectivity index), LSBCI (Liner shipping bilateral connectivity index) and PLSCI (Port liner shipping connectivity index) which make it possible to establish the trends for the international (LSCI and LSBCI) and national/international (PLSCI) port hierarchy and their integration in the world maritime economy, driven by the container market.

As a work focused on the national and local levels of a container terminal, this paper mostly looks at two tables: the PLSCI (a quarterly index of nearly 900 ports handling containers) and the Container port throughput (annual data). The choice of an index and statistics on containers was made for three reasons: (1) containers are present in large numbers, easily identifiable and sometimes countable through a standardized unit (TEU); (2) they are key elements of maritime globalization and of hinterland structuration (Frémont, 2007, 15; Frémont and Soppé, 2005, 187; Rodrigue, 2013, 66–67, 113–120; Guerrero, 2014, 92; Guerrero and Rodrigue, 2012, 2–7); (3) while it is difficult to know what is contained in a shed, a silo or a container (from the sky), the latter has the advantage of being mobile, small size, multimodal and each unit can be considered as an intermediary storage unit (halfway between the goods in and the stack or ship where it is stored). The large number of observable containers and clusters can be estimated as a sufficient quantity for a study of the evolution of a container terminal (with the limitations presented in Section 5).

3.2 *PLSCI and Container port throughput*

It is therefore possible to compare the trajectories of the three main Yemeni ports (Fig. 2): (1) for Al Hudaydah, the PLSCI indicates a significant downward trend over the period 2006–2020 in terms of its maritime integration into the global containerized system. This is no longer calculable as of 2018. The establishment of the front line next to the port that same year is undoubtedly the cause: the terminal is emptying; regular lines are disappearing and container ships no longer take the risk to use the port. The terminal where all container traffic is concentrated is losing its function as the head of the Sana'a corridor. This downward trend could also be linked to competition with Aden, whose port facilities are more developed, efficient and less impacted by the war. (2) For Aden, there is no visible trend over the same period. This is probably due to Aden's less exclusive hinterland and its strong dependence on the security context. This is verified in recent history with the inability of Aden to become a transshipment platform and the strong subsequent unrest of the Arab Spring such as the multiplying number of political actors and groups in Yemeni politics. The great variation in traffic also depends on the terrorism threats on a longer time (Guiziou, 2014, 208–209). (3) Al Mukalla, a general-purpose port away from the main fronts and dedicated to the eastern region of Yemen (Hadramawt) cannot compete with the two others. The PLSCI thus reflects trends which seem possible for Yemeni ports trajectories when compared to the hinterlands and the security context.

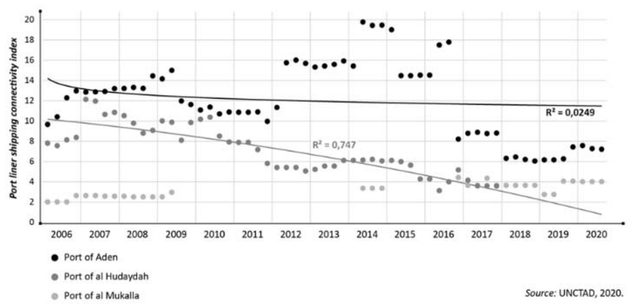
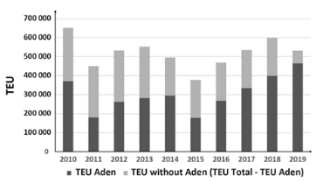


Figure 2. Port liner shipping connectivity index (PLSCI) for the three major ports in Yemen

The Container port throughput analysis, a compilation of data from port authorities and data providers (Lloyd's List Intelligence in particular), is more critical because its limitations are more easily identifiable (Fig. 3). Subtracting the Aden Port Authority (APA) data from the Container port throughput, we see that over the period 2015–2018, the data for ports other than Aden are exactly 200,000 TEU annually. Most of the container traffic of these ports is handled by Al Hudaydah which, along with Aden, is the only one equipped with cranes and adequate equipment for the massification of container traffic. Thus, there are at least 4 years where the activity of the AHCT is a virtual estimation. In addition to the bias that this implies, the distribution between Al Hudaydah and other small ports (including Al Mukalla where the imagery shows a modest container activity) remains problematic: the main assumption is the arbitrary allocation for the period of 2015–2018 for figures in the continuity of the year 2014 (200,003 containers). For the year 2018, for example, the imagery shows the AHCT empty. Therefore, the assessment of 200,000 containers outside Aden is obviously not realistic as Al Mukalla can in no way absorb several hundred thousand containers due to lack of equipment, storage capacity and sufficient hinterland depth. However, the figures for 2019 seem more realistic with the return of small numbers of containers to Al Hudaydah and a visible development of traffic in Al Mukalla.



	TEU Total Yemen (UNCTAD)	TEU Aden (APA)	TEU without Aden	
2010	651 798	370 382	281 416	
2011	450 149	180 183	269 966	
2012	532 323	262 624	269 699	
2013	552 307	282 283	270 024	
2014	495 368	295 365	200 003	
2015	378 098	178 098	200 000	Estimation
2016	468 208	268 208	200 000	
2017	534 693	334 693	200 000	
2018	598 999	398 999	200 000	
2019	531 097	464 923	66 174	

Sources : UNCTAD ; Aden Port Authority.

Figure 3. UNCTAD Statistics TEU handled in Yemeni ports (2010–2019) compared to APA statistics

Having made these observations, the question is how to get around the obstacle of the lack of data for the period 2015–2018 in order to have, if not precise data, at least an idea of the trends in container traffic within the port. The answer may lie in the following methodology, which does not count TEUs but focuses on space occupation by TEUs.

4 ASSESSING THE TRENDS OF A CONTAINER TERMINAL: STACK OCCUPATION METHODOLOGY

4.1 *Introduction to the methodology*

Assessing the evolution of the number of containers handled could be challenging, even with a broad approach and that is the case in this example. Remote satellite imagery, now more and more available, may help because the container is a standard unit which is countable and a metric for logistic performances at local and global scale. A lorry is generally carrying one or two TEUs, a ship can carry hundreds up to several thousands and a terminal can store up to hundreds of thousands on its stacks.

This standardization should help to evaluate the number of TEU a terminal handle/store, but the reality of a classic container terminal everyday life is much more complex (Dekker, 2006):

1. Containers could be stacked on one level to several levels. Evaluate from a picture the size of a pile is a complex operation, because of the quality of photos, shadows, huge variation of levels from one tier to another, etc.;
2. Containers could be loaded or empty which is not seeable from remote sensors/photos because of the nature of the totally closed box. Administrative files, precise localization on the stack and the number of each container are barely available outside companies and terminal authorities and even then, it is virtually impossible to have a precise idea of the tonnage and the value;
3. Containers are logistic objects which move but could also be stored for a long time at the same place. The best example of this mobility is articulated in the terminal, where the connection between ship and lorries is particularly visible before and after the port of call and loading/unloading operations. Even in the terminal, a container may move several times between stacks (stacking management) or stay stored for a long time.

These principal limits are problems for assessing the evolution of number of containers, especially in countries when stacking strategies are based on poor/medium management. The main challenge here is to create data as reliable as possible via a standardized spatial approach of binary occupied/non-occupied grid cells. This stacking occupation methodology is then indirect: the goal is not to account TEU but cells occupied by containers. There is a potential link between TEU number and occupied cells at each date but it is not developed in this paper.

The methodology is based on available Google Earth data from 2004 to 2020 and treatment by GIS trying to show the main dynamics during AHCT experienced war, a difficult situation on the battlefront and an apparently decreasing traffic. This approach is based on following facts and estimations:

1. More than 3 level tiers seem to be rare according to shadows and lack of stacking cranes, and no more 2 level tiers are visible at the start of 2018;
2. Obviously, the AHCT is not a first-class terminal: stacking strategy and management are allegedly, at best, medium. The containers are handled by lorries and with the help of four quay cranes (gantry cranes), at least four reach stackers, and a dozen of straddle carriers. The storage of these machines was bombed in 2016, but most of the equipment seems still operable. Two gantry cranes were also damaged by bombing in 2016 and are no longer usable;
3. Containers are stacked in many places in the port, broader than the only asphalted terminal. This fact probably shows lacks in the logistic chains (taxes, corruption, lack of demand during the war, goods at the destination of occupied territories, difficulty to manage empty containers, etc.).

Note that the main limitation of this method is that it relies on satellite data that is not continuous in time.

The port of calls of container ships are also distributed in a regular way but not necessarily cyclic and obviously not coordinated with the images. Another limit is that containers are black boxes, but their dynamics and spatial distribution (clusters) could be an indication of the activity of the terminal (or the port).

4.2 *Implementation*

The methodology applied here consists in precisely evaluating the occupation rate of each stack in the terminal (10 entities) and informal "stacks" surrounding (5 entities). The three categories [M], [M'] and [m] are applied to describe a comprehensive approach of port dynamics linked with containers handled in a formal managed area or not. These areas were estimated from satellite images without any preconceived notions of their dynamics. We can just estimate that containers in [m] areas are empty, in long transit, or/and less important than the ones in [M] and [M'] areas because of their poor staking conditions. Areas are defined by these factors: (1) container density; (2) geometric disposition; (3) visible use of reach stackers and straddle carriers; (4) asphalted areas/non-asphalted areas and roads/alleys between. In addition, we also defined the two major stacks [M] in the immediate vicinity of the container berths. Finally, we can estimate what are the AHCT limits and the informal areas because of the lack of space. The elements of this classification are presented in the map (Fig. 4) behind.

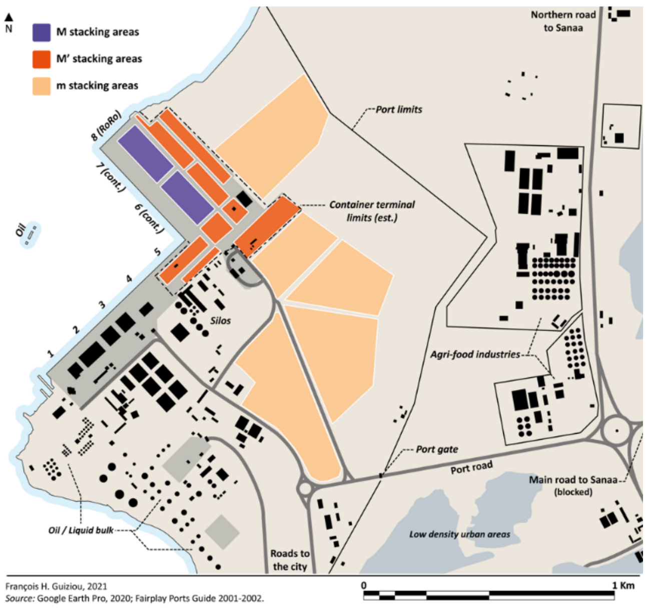


Figure 4. Port of Al Hudaydah (2018) and [M], [M'] and [m] stacking areas

Basically, the accounting methodology applied for [M], [M'] and [m] areas are the same:

1. it needs 2 TEU per 12m×12 m grid cells to be considered as an occupied cell. This choice of 12m×12m is defined by the dimensions of the TEU: 1 TEU = 6.1×2.44 m; 2 TEU (most of the containers) = 12m×2.44m;
2. in theory, each grid cell could contain, on one level, around 10 TEU. In some cases, due to the photographic quality (dust, clouds, shadows) and contestable visual counting, the choice has been made not to validate some occupied grid cells.

Thus, the visual accounting has been made with the rules presented in the following figure (Fig. 5).

The principal goal is to identify, with a standardized methodology, changes in container occupation of each cell and clusters of occupied cells to express these changes as a percentage for each stacking area (percentage expressed with respect to the maximum occupation on the period for the entire terminal: 1,250 cells on 21 September 2014) and the temporal evolution of this occupation rate. This methodology was used to analyze of 120 photos on the 2012–2020 period, by visual classification. This classification has been double-checked. It assumed, despite the limits seen before, that the analysis offers a realistic view or, at least, reliable tendencies. The results are presented in the following paragraphs.

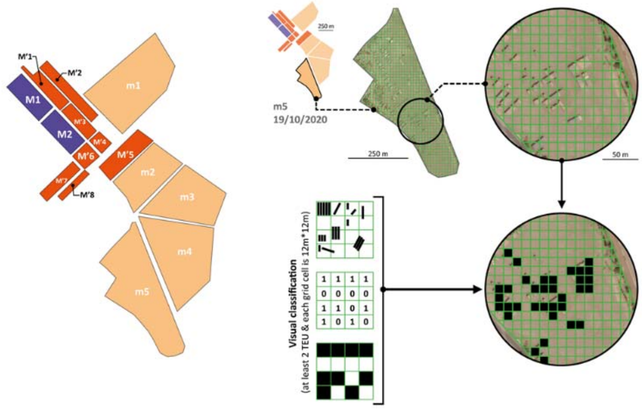


Figure 5. Stacking areas and grid cells visual classifications

5 RESULTS AND ANALYSIS

5.1 *Long-term analysis (2012–2020)*

The main question here is to compare our data with the trends identified with the PLSCI. The general trend ([Total], see Fig. 6) of the strong decline of AHCT seems to be largely confirmed on the period (R^2=0.84): the port seems to be under pressure from the war, especially since 2018 and even more during the battle. We could also observe the existence of a small growth of occupied cells which incarnates the return of a small container activity, confirmed by imagery where we can observe some feeders back. But this general trend needs to be decomposed at the scale of [M], [M'] and [m] areas to establish fine-grained trends. Thus, we can note two spatial dynamics:

1. [M] and [M'] are in a constant decline from 2016 and [M], typically the busiest area on the pre-battle period (and in theory for a good stacking strategy), was totally non-occupied shortly after the start of the last phase of the battle (September 2018). A linear regression between these two areas shows that there is a strong spatial link between them (R^2=0.88): when [M] is occupied, [M'] is generally occupied too. It shows that the limits of the formal terminal are quite well assessed but that, during the battle more than during the war, there is no activity and probably no traffic at all. The closer

the battle is (and the battlefront), the more reduced is the traffic is. Activity was back in mid-2019, which is roughly the date of the application of the Stockholm Agreement. It is then very likely that the pressure of the battle is a key factor;
2. [m] is more difficult to analyze because of its non-formal and messy nature. The link between the terminal ([M]+[M′]) and [m] is less well established (R^2=0.65) and many containers, particularly those in distinct clusters of probably empty ones, can be stacked there for a long time. The year 2018 is a turning point for [m], where the percentage of occupied cells drops drastically from 35% to 15% a few months before the battle and then declines to its lowest level of around 10% until the middle of 2020. This is possibly due to the combined effects of the classic dynamics of empty containers, the urgent need of containers to maintain a trade by lorry and the fossilization of old and damaged containers. The satellite photos of [m] areas show, until the end of 2020, numerous stationary containers and clusters. A hypothesis is to consider that drop not only as a major change in the activity of the terminal but also as a possible announcement of the upcoming battle by well-informed local operators.

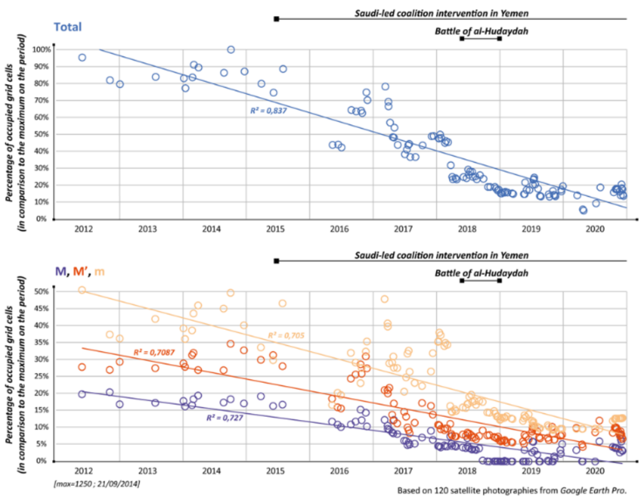


Figure 6. [Total], [M], [M′] and [m] percentages of occupied grid cells in comparison to the maximum, 2012–2020

This long-term analysis has to be completed by a pre/post-battle study, focused on the 2018 year and the surrounding months.

5.2 *Pre- Battle/Post-battle analysis*

Focusing on the following heatmap and maps (Fig. 7) of the coefficient of determination (R^2) from a linear regression (linear function f(x)= ax+b; $R^2 = \text{corr}(x,y)^2$) between occupation rate of stacks on the period 2012–2020 (based on the maximum 100% rate for the terminal on 2021 September 21), it is possible to determine some characteristics of the terminal and its surrounding spaces. These linear regressions could be interpreted as a spatial dependence (R^2 tends to 1) or independence (R^2 tends to 0). This materializes adequation to the model f(x)=ax+b and, therefore, the strength of the link between two stacks on the period. It is not a link between the number of containers and even less container mobility stack to stack, but a spatial indicator based on the occupation by containers in spatially localized stacks (difference between correlation and causality). For instance, the link between [M1] and [M2] (R^2=0.59), explained that the variation of occupied cells by containers of [M2] is linked for 59% of the variation of occupied cells of [M1] according to the linear model. This doesn't describe the full nature of this relation. The following observations, in addition to photo observations, could describe the terminal structuration:

1. Generally, [M] and [M′] are quite well linked, but with a variation of R^2 (67%> R^2=0.5 / 49%> R^2=0.6 / 13%> R^2=0.7). It also seems to have a stronger link between stacks in the northern area of the terminal ([M1], [M′1], [M′2], [M′3]) and, on the other, between stacks in the southern area ([M2], [M′4], [M′6], [M′7], [M′8]);
2. Generally, [m] stacks are poorly linked both with [M] stacks and other [m] stacks which shows the random and non-formal nature of [m] stacks;
3. [M1] and [M2] (R^2= 0.59) are moderately linked because there are two distinct berths, and could also reinforce the observation (a1);
4. [M′5] (generally R^2 around 0.4 with [M] and [M′], around 0.1-0.2 with [m]) has an interesting position and seems to be largely independent and could be a specific/private stack;
5. [M′7] and [M′8] (R^2=0.78) are strongly linked probably because these stacks are dedicated to reefers (fridge containers) and need electricity connections to be operable;
6. [m2] and [m5] (R^2=0.80) are strongly linked probably because of the vicinity of the exit road of the terminal;
7. Note that in all cases we observe that a (slope) is positive (so the models show a positive relation between stacks) and b is often close to 0.

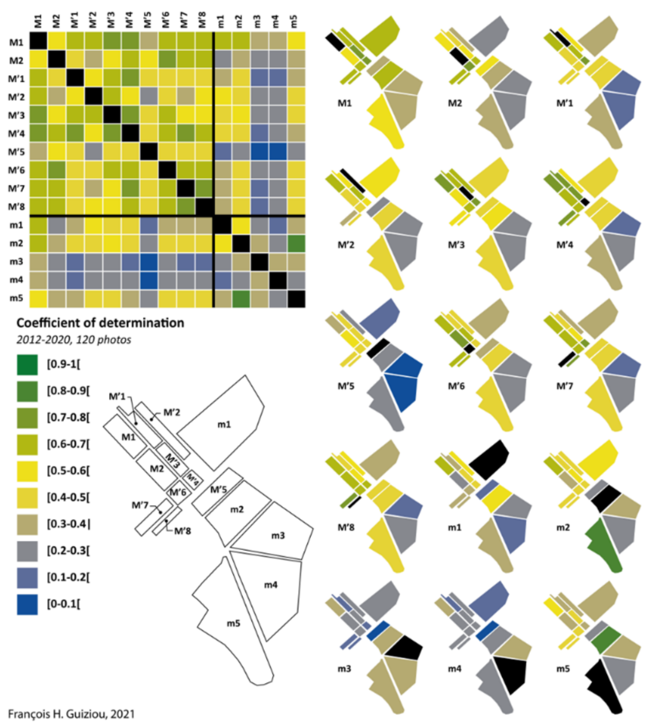


Figure 7. Coefficient of determination heatmap (linear regression) and spatial distribution, 2012–2020

Using these observations, it is possible to advance that there is nothing too different between the AHCT and other container terminals: specialized areas are dedicated to different types of containers (a4, a5), there is probably quite a decent stacking strategy (a1, a5, a6) and the container berths are well identified by their relation with stacks (a1, a3). Moreover (a1) and (a2) confirm that assessed limits of the formal terminal are again well identified, even if (a4) asks the question of the localization and situation of [M'5] as part or not of the real terminal.

We cannot unfortunately go further on the pre-war period because of lack of data (only 11 photos between 2012–2014), but we can focus on the pre-battle and battle/post-battle period. The same work was done with the two periods April 2016-May 2018 (pre-battle) and June 2018-July 2020 (battle/post-battle), as presented in the following heatmaps (Fig. 8):

1. during the pre-battle period, the model described before is efficient in spite of war. The only difference is the high spatial independence between [M&M'] and [m], except for the [m2] and [m5] as seen in (a6). This independence is probably linked to war and lack of container traffic (no need to use the [m] areas);
2. during the battle/post-battle period, a very high independence is now seeable for near all the couples of stacks. [M1] and [m5] (R^2=0.63) are the only exception but it is certainly due to the fossilization of [m5] and the emptiness of [M1].

This change could be related to some factors: (1) strong diminution (and disappearance during the battle) of port calls and container traffic; (2) modifications of the stacking strategy which tends to become more and more daily/messy because of the battle situation and the troubles after the battle (episodic fights and shelling); (3) space in the terminal which can lead to a more permissive staking strategy; (4) use of only one of the two container berths because of the diminution of port calls and the higher security and proximity of berth 6 (Fig. 5) and end of the use of gantry cranes replaced by on-board cranes (Lift-On/Lift-Off or LoLo) for a small container traffic, etc. The battle is a turning point in the history of the AHCT because of the fights around the ports and perturbations linked to them, but also because of the changes in the traffic dynamics at all levels: local with a less effective terminal; national, with the change of port hierarchy; international with the changes of services to the port. These different changes could be problematic if their effects should last in the long run.

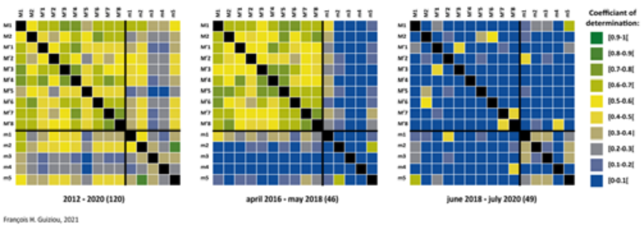


Figure 8. Coefficient of determination heatmaps (linear regression) 2012–2020, April 2016-May 2018, June 2018-July 2020

The two analyses of data proposed in the previous methodology could explain that the decline of the terminal is a two-level phenomenon: the war and the hinterland attrition (Sana'a and Sa'dah) moreover with the SLC maritime blockade, is a long-term effect; the battle and the establishment of the battlefront are a middle to short-term effect, as it is difficult to manage the terminal because of fights in the vicinity and the lack of accessibility to outlets because of the close battlefront. The combination of both is hard to overtake despite some signs of recovery of port calls and return of container traffic.

5.3 *Fortification, port management and strategic value*

These last paragraphs bring some facts (from satellite photos) and a hypothesis to put further the debate and the analysis. A first fact is that the large fortification of the port and the AHCT. As a line of defense of the city, the port fortification started in May 2018, few weeks before the battle. Starting trenches and sand walls, the defenses were fast reinforced during the battle by a lot of containers, both for roadblocks and heavy walls (at least 400 TEU). Containers played a big role in the impossibility for SLC-backed troops to take Al Hudaydah. This atypical function of containers shows, first, the large number of fossilized containers easy to use for defensive purpose and, second, the value of the port and terminal, both in terms of defense and maybe as a strategic object. At the end of 2020, even after the withdrawal of Houthis from the port, fortifications were still standing. Another important fact is the restart of a decent port management just months after the battle. The two damaged gantry cranes were deconstructed between May 2019 and September 2019 and stored closed to the terminal. The two remaining cranes seem to be inoperable, but the LoLo ships are back at berth 6 and a little traffic is going on. Even in poor conditions, with the lack of oil and electricity, as well as the additional difficulty to pay the port staff (due to conflict between the two branches of the Central Bank of Yemen), the terminal and the port had been restarting an activity with feeders and a lorry traffic to Sanaa by the northern road.

This raises questions about the future of AHCT and the strategic value of a container terminal. For the future, the answer will probably depend on four factors: the political solution to the Yemeni Civil War; the changes in the hinterland limits; the concurrence with Aden and the place of AHCT in the container trade hierarchy; the confidence of companies and level of prices to visit the terminal (particularly additional costs as insurances, e.g., risk of war). For the strategic value of a container terminal, the question is delicate and could be seen from several frames of reference or scales. It is impossible to generalize: the absence of comparisons does not allow us to deviate from this case study and will therefore limit us to making assumptions. A port is always a strategic asset. The maritime blockade as well as the take of Yemeni ports by SLC-backed troops illustrate that well. At the terminal level, it is difficult to evaluate this strategic importance. Blockade and hinterland attrition undeniably affect the container traffic in the terminal but, on the other hand, it is difficult to assess the complex local geopolitical and economic situation because of a lack of sources. Moreover, with gantry cranes non-operational and traffic limited to LoLo and RoRo ships, any part of a port could be considered as a container terminal if there is enough space and depth. Another good argument could be the low level of destruction and damages during the battle.

However, we can consider the terminal as part of the port which is a strong political card for both SLC and the Houthis in a process of a political negotiation toward the international community. Houthis exploit the vital importance of the port for the population. SLC says they bring pacification and aid to all the Yemenis by ousting the Houthis and attempting to avoid missile attacks from them. Is this terminal an indicator of the Yemeni Civil War? We think that the answer is a (weak) yes: (1) because of the trends which could show an evaluation of hinterland attrition; (2) because the battlefront established on the terminal marks the last major battle of the war and the blocked situation which continues until today; (3) because it is part of the port from which the attack triggered international intervention to limit the SLC operations. But, in the end and in a strategic frame, it is difficult to separate the terminal from the port and we can only argue that the container terminal activity could be a strong indication of port dynamics.

6 CONCLUSIONS

This paper proposes an unprecedented case of a container terminal struggling with a conflict at national scale (civil war and Saudi-led intervention in Yemen) and at local scale (battlefront). The effects of this high intensity armed conflict are: (1) the constant degradation of the terminal activity which results in a near complete disappearance of container ships port of calls and TEU traffic in the first months of 2019; (2) a change in Yemen port hierarchy and (3) maybe also a change in historical hinterlands. The effects of the war on the terminal are long-term effects (attrition of the hinterland, maritime blockade) but the effects of the battle are stronger (distance to the battlefront, road blockade and fortification of the terminal). This is not a surprise and these two temporalities could drastically change the status of the AHCT. In addition, the fortification of the port and the limited damages during the battle are signs of a strategic interest of both factions confronted to a blocked battlefront and situation. This interest is probably more politic than operational. A light recovery is noticeable both in port management and in traffic since mid-2019 but this trend is difficult to evaluate and the long-term effects are unpredictable.

The paper also points out the interest of an OSINT methodology, basically the multiplication of sources and sub-methodologies, to assess the situation of a port in a lacking data context. The exploitation of open access data from varied actors/producers permits to understand the situation at many levels of a terminal in time-related, geographical and conflictual approach. An effective and diversified OSINT study is a good first step to assess a situation before putting more efforts (e.g., time and money). There is no surprise mainly because of the interdisciplinary nature of ports studies as described by Ng et al. (2014).

The GIS methodology proposed in this paper, based on a grid cell occupation of stacks by containers, is an indirect space and time-related useful process. Obviously, it needs to be refined, reproduced and developed, but it offers, at least in this case, reliable trends, which show the terminal, if the port, dynamics. From totally open access data, this new database allows to complete the ones from public and private data providers.

During a conflict or when data is lacking, assessing the dynamics of a terminal or a port is also a key factor in modern logistic operations, for instance to identify if it could manage the international aid and its ability and capacity to connect with its hinterland. It will also be an advantage for the evaluation of the dynamics of container traffic at the range and hinterland scales as proposed by Rodrigue (2020). This methodology is also a first step for a most sophisticated tool or model. The limits of it are the availability and quality of primary data, and, in this case, mainly the satellite imagery. Moreover, it is not possible to compare at the scale of TEU, but only to see the spatial changes.

Finally, the case of Al Hudaydah container terminal, as a brand-new situation, is hard to describe and to answer more than the facts, interrogations and hypothesis presented before. However, this terminal could be considered as an indicator in the Yemeni Civil War and show the high economic and strategic importance of containers from the global scale (global maritime system) to the local scale (terminal), even in armed conflicts and their local development. Maybe another evidence that containers are a paradigm of globalization even at local scale.

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