6. || APM TERMINALS MEDPORT TANGIER & SEAPORTOPX - Wind Resilience Tool

the challenge

Wind-blown containers are becoming typical hazard in large container yards at some locations, and there are countless operation disruptions owing to uncertain wind forecasts and lack of yard stacking wind resilience, causing hundreds of wind related containers toppling events yearly basis. Recovery mode require extra deployment of resources, special handling and exposing people to different risk profiles as non-routine tasks.

While operating in one of the most technologically advanced, safest and efficient terminals, wind forces was and still a significant safety challenge. Things that created the burning need to look after innovative and unprecedented solutions, taking advantage of Terminal stacking knowledge and learnings, Weather advanced science, Artificial Intelligence, and some basic laws of physics.

Challenges to solve:

- Difficulty to identify containers in weak position, with elevated risk of toppling
- Wind sensors failures, lagging to detect real potential of wind gusts, which increased risk of containers toppling, with sometimes extreme consequences
- Wind sensors false alerts, causing unnecessary yard housekeeping and multiple operations disruptions.

the innovation

Wind Resilience Tool is a wind decision support tool powered by a smart AI engine which provides much more accurate predictions of wind speed and direction at the terminal and automatically alerts users when pre-set wind speed criteria are forecast to be exceeded. And includes local real-time wind measurements within the terminal domain for full visibility of live conditions and model performance. The tool provides an eagle eye on a live 3D yard refined stacking, with a clear visual management system to detect specific containers that are unable to resist upcoming wind gusts. This tool is powered by a complex AI engine that provides high-resolution wind behaviour predictions as well as real-time advice on safe container stacking strategy. The tool considers multiple parameters in the model e.g. wind

speed, direction, wind tunnelling, container position, tier, weight and size to determine the safety margins for each container on yard.

Main outcomes:

- Provide terminal with timely and accurate information to shape micro decisions on live operations to reduce risk, protect assets and enable operations.
- Preventing proactively falling unit events, by performing prompt and targeted yard housekeeping moves only when needed and for specific containers. Reduce operations wind related downtime, caused by false wind alerts coming from nearby stations.
- Reduce latency to act when needed when nearby stations fail to predict potential threats.

how it was implemented

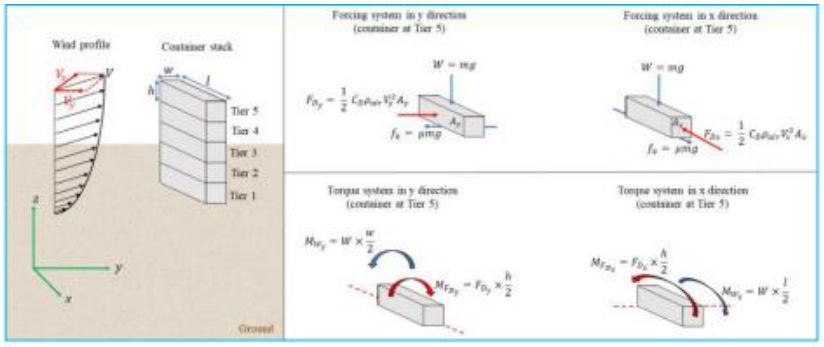
Designed, built and tailored based on APM Terminals MedPort Tangier 'TM2' terminal specifications and learnings, in partnership with field experts 'SeaportOPX'. Ground Study and Tool Development took six months, followed by a thorough quality and testing phase to measure effectiveness. It is now ready and deployed LIVE in TM2 Terminal enabling Safer Yard Operations.

Wind Resilience Tool Interface

Configuration of the Status thresholds is based on the TM2 Environmental Baseline Study and local wind procedures considering multiple parameters, e.g. gust speed, taking into account sensitivity to winds from a certain direction when the wind hits the container sides making the impact heavier, for example / other parameter considered are the container position, tier, weight and size.

The variation in wind status triggers over time and space can be visualized through the map interface. The map interface captures the location of forecast high wind events to support proactive measures to avoid incidents.

In addition, the system followed quality assurance procedures including running automatic quality assurance checks to ensure the model results are constantly benchmarked against measured data. Wind Resilience Tool logic works based on the static balance of force and torque system in both x and y directions (in the horizontal plan) of containers at and above each tier. This logic is briefly described in the following figure for those interested to know more about AI engine physics.

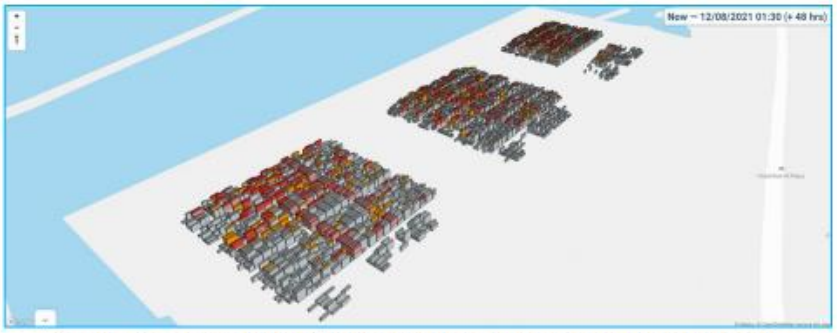


In the figure above, parameters are defined as follows

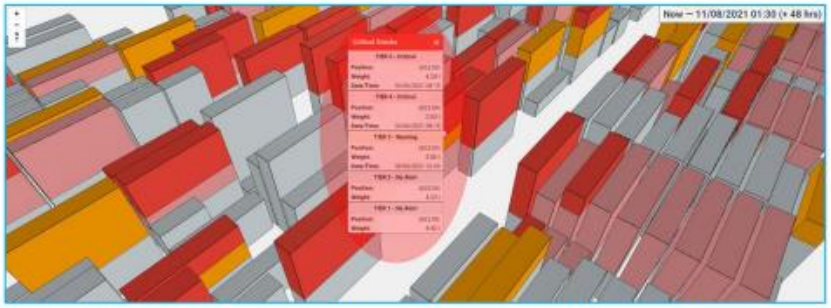
V	Wind speed
V_x	Wind speed component in x direction
V_y	Wind speed component in y direction
h	Container height
w	Container width
l	Container length
m	Container mass

g	Gravity acceleration
C_D	Drag coefficient (=1.2)
ρ_{air}	Air density (=1.2 kg/m3)
μ	Steel-Steel friction coefficient (=0.5)
A_y	Frontal area of orthogonal to y direction
A_x	Frontal area orthogonal to x direction
F_{D_y}	Wind force in y direction

F_{D_x}	Wind force in x direction
f_k	Friction force
W	Container weight
$M_{F_{D_y}}$	Torque due to wind force in y direction
$M_{F_{D_x}}$	Torque due to wind force in x direction
M_{W_y}	Torque due to container weight opposite to wind force in y direction
M_{W_x}	Torque due to container weight opposite to wind force in x direction



Containers with high risk of toppling are proactively highlighted



Hovering over each container stack provides further information about containers at each tier

result

After introducing the tool the terminal took positive confidence to go through windy periods safely; deploying cutting edge technology and data science to eliminate the risk of exposure to falling containers, increasing safety capacity. When an upcoming high wind event is forecasted over the next 48 hrs, yard operations automatically receive notifications of any critical and/or warning containers over the yard. Yard operations then takes proactive safety measures accordingly knowing which containers are the most critical at the earliest time to move them around. The convention colouring for containers in alert from now to +48 hrs is orange, red, and faded red when the containers are in warning, critical, or conditional alert modes, respectively.

These alert modes are defined as follows:

- Warning Mode (Orange Colour): A container with 70% risk of toppling due to applied wind force in any directions (x or y directions in horizontal plan).
- Critical Mode (Red Colour): A container with 90% risk of toppling due to applied wind force in any directions (x or y directions in horizontal plan).
- Conditional Mode (Faded Red Colour): A container has 90% risk of toppling due to applied wind force in any directions (x or y directions in horizontal plan), if the container stack in front of it, which itself has 90% risk of toppling due to applied wind force in any directions (x or y directions in horizontal plan), is removed / domino effect.

Sharp positive results, terminal moved from frequent high wind related falling containers in2019 and 2020 to NONE during 2021. Awarded with total absence of toppling containers during one full year of deployment. An absolute success!

conclusion

With every challenge comes the opportunity to improve and discover hidden strengths, solving problems and leading change for better and safer Cargo Handling is key to safety excellence. At TM2 we believe that safety capacity and fail-safe systems based on breakthrough innovative solutions are critically important to keep ahead and boost safety performance.

Wind Resilience Tool was the fruit of a team of expert's hard work, dedication and passion to Lead with care. The idea matured in the lab moving from high-resolution prediction tool to 2D heat-map proposal and ending up exceeding expectations by deploying 3D flyover map with risk margin calculated down to every container. The Tool provided extra understanding and new learnings about the wind behaviours and how gust interact with the stacking containers, these insights fuelled Terminal procedures and stacking strategy to balance loads and figure out the best stacking shape possible, with minimal impact on operations flow and high impact on terminal safety resilience. Cause the only way to discover the limits of possible things is to actually to go beyond them setting the stage for new possible limits. Creativity is thinking up new things. Innovation is doing new things.

Link to demonstration video: https://www.youtube.com/watch?v=DZHUC2C04R8