EU-CIRCLE

A pan-European framework for strengthening Critical Infrastructure resilience to climate change

D7.6 Summary report for tools integration external to EU-CIRCLE

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Statement

The objective of this Deliverable is demonstrating the integration of EU-CIRCLE with other external models/tools for the assessment of climate impact to critical infrastructure and the effectiveness of adaptation measures.

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Executive Summary

The Deliverable presents the integration of EU-CIRCLE with other external models/tools for the assessment of climate impact to critical infrastructure and the effectiveness of adaptation measures. Various external models/tools developed by EU-CIRCLE partners in other research projects or by other institutions were adopted in different analyses within the project. The results were also demonstrated and utilised via the Critical Infrastructure Resilience Platform (CIRP).

Contents

1 Introduction

The objective of this Deliverable is demonstrating the integration of EU-CIRCLE with other external models/tools for the assessment of climate impact to critical infrastructure and the effectiveness of adaptation measures.

The integration included the application of the outcomes from the AMAZON coastal overtopping model, which were used as the boundary condition inputs for the flood simulations in the CADDIES model. The hazard mapping results from CADDIES were combined with building information by the CORFU/PEARL damage assessment tools to estimate the hazard impact to critical infrastructure for current and future climate scenarios. All the outputs were integrated and demonstrated in the EU-CIRCLE's CIRP for effective risk communications with the stakeholders for adaptation strategic planning.

2 Integration with external tools

2.1 AMAZON coastal overtopping model

For coastal flooding case study in Torbay, the overtopping discharge along the sea defences were used as the boundary inflow condition for flood modelling. The discharge rate were produced by the AMAZON model (Hu 2000, Haskoningdhv UK Ltd 2017), which simulates the random waves travelling as bores. The discharges for the current and the future climate change scenarios with various probabilities were generated by the AMAZON model as a set of time series inflow hydrographs for different sections along the coastlines in Torquay, Paignton and Brixham.

Figure 1 shows the simulated overtopping discharges for a 1 in 200 year event under current climate scenario for various sections along Paignton with a duration of 100 hours. The discharge hydrographs for their corresponding locations were therefore used as the boundary inflow conditions in CADDIES flood modelling.

In Paignton, an adaptation measure to install a secondary flood defence was proposed for flood mitigation. The reductions of overtopping discharge for different crest heights of the secondary flood defence were also analysed using the AMAZON model.

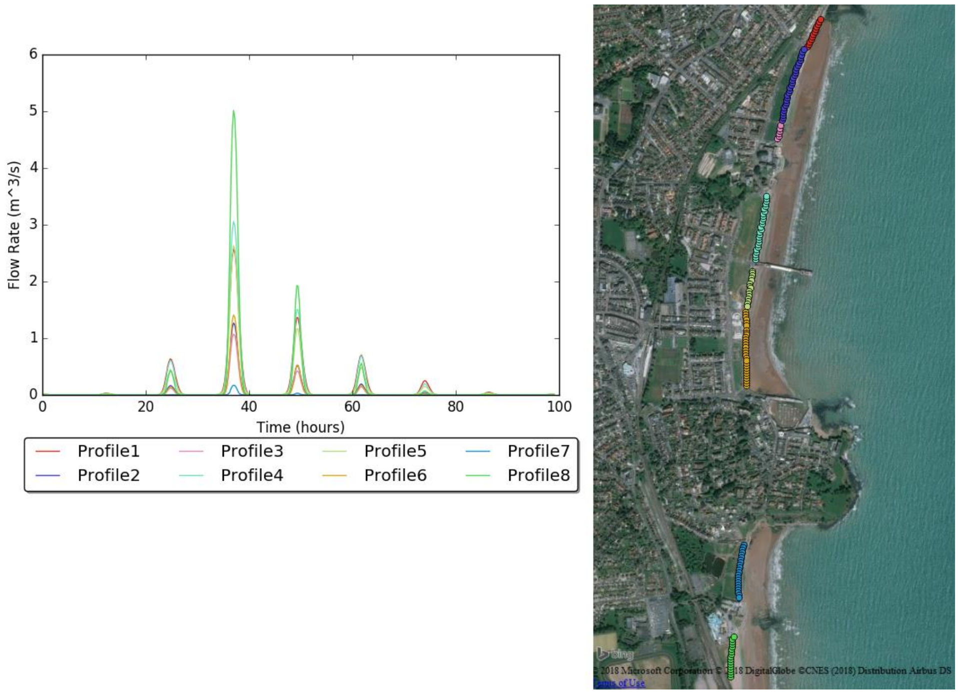


Figure 1 The discharge profiles for 1 in 200 year overtopping event (left) for various coastal sections (right)

2.2 CADDIES flood model

CADDIES is a high performance flood model developed by UNEXE in a previous research project funded by the Engineering Physical Science Research Council (EPSRC). The model adopts the cellular automata (CA) based approach that utilises a set of transition rules (Ghimire *et al.* 2012, Guidolin *et al.* 2016), instead of solving complex hydraulic equations, to simulate the flood propagation on the surface. It also implements parallel computing technologies to maximise the performance of available computing resources to accelerate the simulations (Guidolin *et al.* 2012). CADDIES has been proven to provide flood predictions comparable to the ones obtained from hydraulic models with a fraction of computing time (Gibson *et al.* 2016, Guidolin *et al.* 2016).

To accurately analyse the flood impact to critical infrastructure, the best available resolution of terrain data were applied to flood modelling. In Torbay case study, 1m LiDAR from the Environment Agency were used for simulations. It allowing more precise inspection of the influence of flooding to the critical infrastructures, as shown in Figure 2 and 3, leading better assessment of the cascading effects. The demand of multiple high-resolution flood simulations in EU-CIRCLE to provide accurate evaluations of flood impact to critical infrastructure would require extraordinary computing time, if the tradition hydraulic modelling approach was adopted. To fulfil the objective within limited time, CADDIES was applied to deliver the results efficiently. It was also integrated in the Critical Infrastructure Resilience Platform (CIRP) that allows for stakeholders running flood simulations on-demand, where the results are further visualised and analysed in the CIRP.

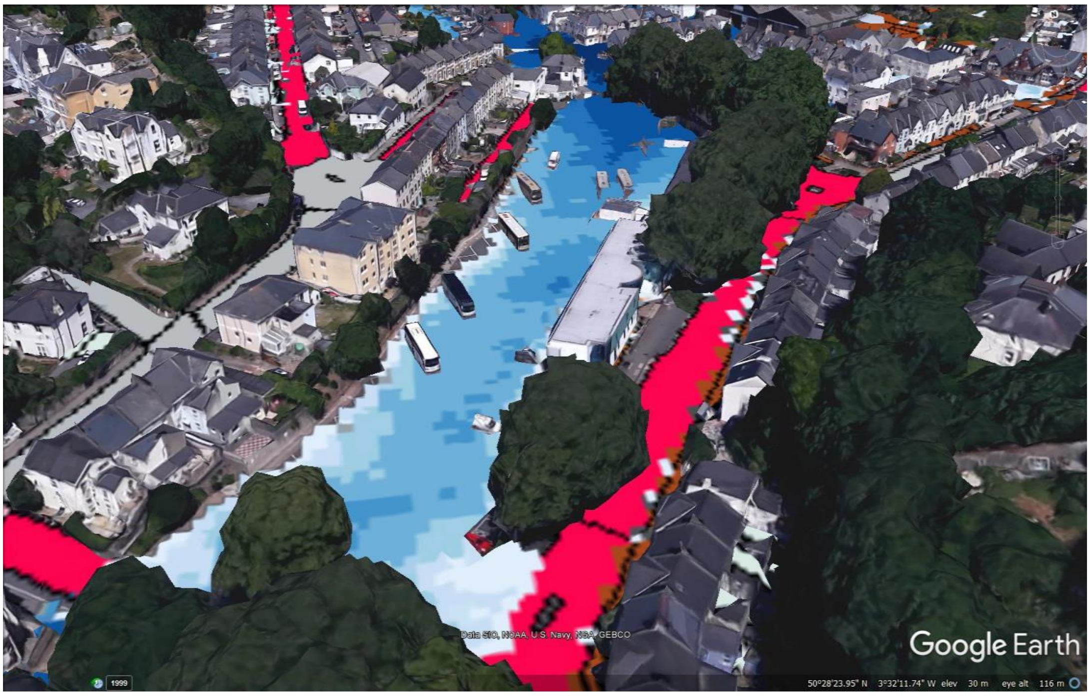


Figure 2 *High resolution flood modelling result from CADDIES for analysing flood impact to the coach station and transportation network in Torquay*

Figure 3 *High resolution flood modelling result from CADDIES for analysing flood impact to critical infrastructures in Paignton*

CADDIES is capable of modelling surface flooding from intense rainfall, and coastal flooding caused by overtopping, and the combinations of both. Figure 4 shows the modelling results of the maximum flood depths for a 1 in 100 return pluvial rainfall event (left) and a 1 in 200 year overtopping event (right). The latter adopted the analysing results from the AMAZON model as mentioned in Section 2.1.

Figure 4 Flood extents of 1 in 100 year return period pluvial event (left) and 1 in 200 year return period overtopping event (right) for the present scenario

2.3 CORFU/PEARL damage assessment tool

The flood information obtained from CADDIES modelling were overlapped with the building layouts, together with the building use information and the depth damage relationships from the Multi-Coloured-Manual (Penning-Rowsell *et al.* 2010) to evaluate the direct flood damage of each property. For the Torbay case study, the building layout and use information were obtained from the Ordnance Survey Mastermap (Ordnance Survey 2017), and the National Receptor Dataset (Environment Agency 2017), respectively. The latter includes a specific code associated to the Multi-Coloured Manual that indicates the depth damage functions to be used for each individual building. The hazard information, building locations and vulnerability functions were integrated using the CORFU/PEARL damage assessment tool. The tool was originally developed to evaluate flood impact to properties in six case study cities in the CORFU project (Chen *et al.* 2016, Khan *et al.* 2018). Its functions were further enhanced in the PEARL project (Vojinovic et al. 2017). For other case studies (e.g. Khulna), the tool can also take standard GIS data and custom-defined hazard vulnerability functions to evaluate the damage incurred by hazards.

The CORFU/PEARL damage assessment tool was applied to determine the direct flood impact in the case study areas with EU-CIRCLE, where the results were demonstrated in CIRP and other visualisation tools created within EU-CIRCLE. The tool was also integrated with the cascading effect assessment tool developed within EU-CIRCLE such that the analysis can be completed within single simulations. The modelling results from CADDIES included not only the maximum flood depths but also detailed flood information during the simulated events. Therefore, the outcomes were used to analysed the movement of flood water, the spatiotemporal changes of flood damage and the propagation of indirect flood impact due to the failure of critical infrastructure, as shown in Figure 4.

The snapshots in Figure 5 illustrate the increasing extent and depth of flooding as the time progresses. It is due to the 12 hour interval used for displaying the information in the figure. With a more frequent temporal exporting interval, the flood extent and depth are reducing during two tidal peaks that the urban drainage systems are acting to discharge surface water, as demonstrated in the 3D visualisation video https://youtu.be/gMfZPVGNw_M. However, the assumption that the damage will be only recovering after the event, except the disruption to road accessibility. Therefore, the level of flood damage in the video stays the worst value even the flood depth has receded.

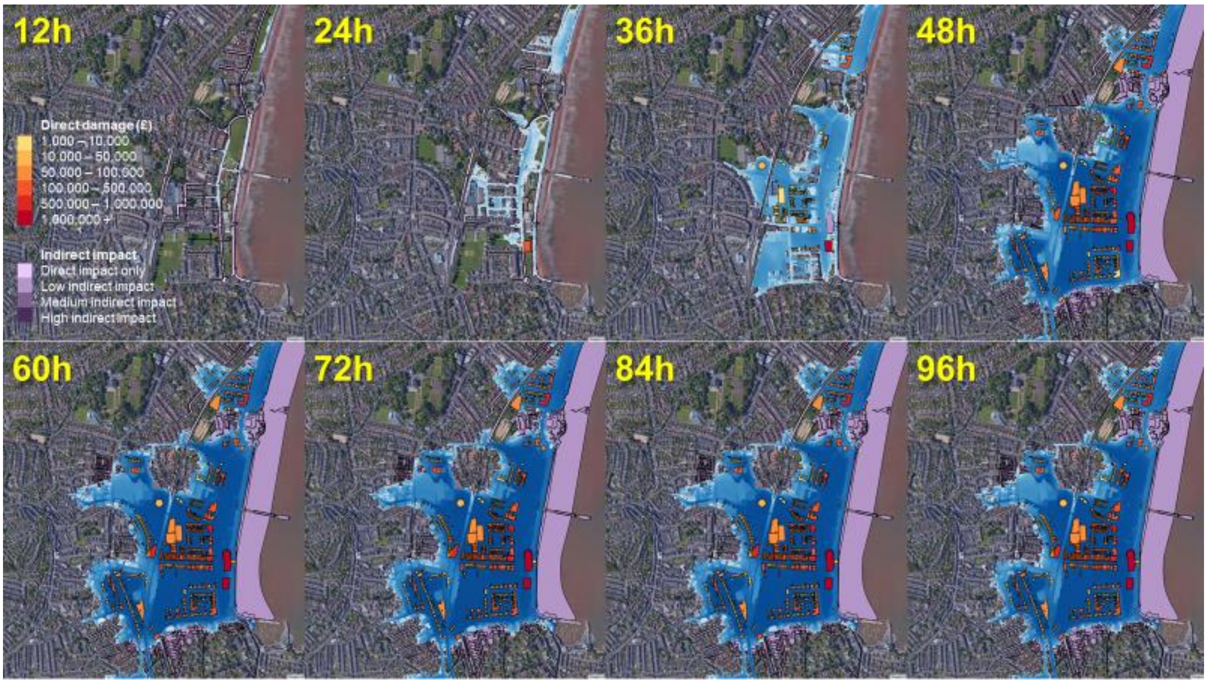


Figure 5 The changes of flood damage and indirect impact due to critical infrastructure failure during a 1 in 200 year return period overtopping event in Paignton

2.4 Fire simulator

The G-FMIS (Geographical Fire Management Information System) a proprietary toolbox which runs in as Desktop Application embedded in ARCGIS environment and as set of web-Services. G-FMIS/ web-service for wildland Fire Behaviour estimation and Spread Simulation (G-FMIS Wildland Fire Simulator) has been used for EU-Circle purposes, as an external tool for running simulations for the Virtual City and Cyprus case studies, as shown in Figure6. For more information: http://g-fmis.gr/en

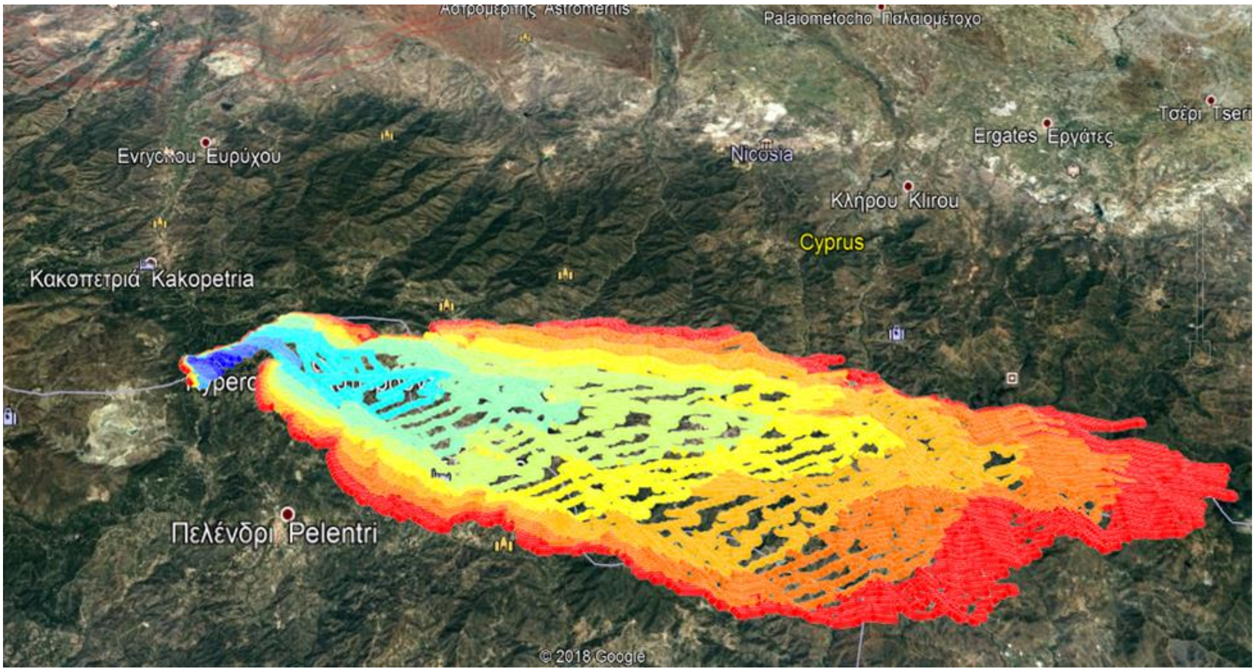


Figure 6 Examples of wildland fire simulations for the Cyprus Workshops (March 2017) resulting from G-FMIS Wildland Fire Simulator

2.5 Transportation Modelling Tool Aimsun

For the purposes of EU-CIRCLE an interaction and communication channel has been established with the Department of Transportation Planning and Engineering of the National Technical University of Athens. This collaboration has focused on the analysis and resilience of road transport networks, taking as case study a model of Athens road transport network. More specifically, there were discussion and collaboration on how to implement the Aimsun software in SimICI

Aimsun has the capacity of fusing travel demand modeling, static and dynamic traffic assignment with macroscopic, mesoscopic, microscopic and hybrid simulation, with both Dynamic user equilibrium (DUE) techniques and stochastic/discrete route choice models. It is capable of determining network flows, paths and vehicle routes that are optimal with respect to both cost and energy efficiency, and introduce pricing models which provably optimize the allocation of energy and environmental 'cost' among vehicles

NTUA has implemented the software for simulating the road network of Attica Region, as shown in Figure 7, through 15567 sections with a total section length of 5419km and total lane length of 7591km and 6257 intersections. It has an integrated control plan for traffic lights, reserved lanes for buses, centroids, O/D matrices and traffic demand.

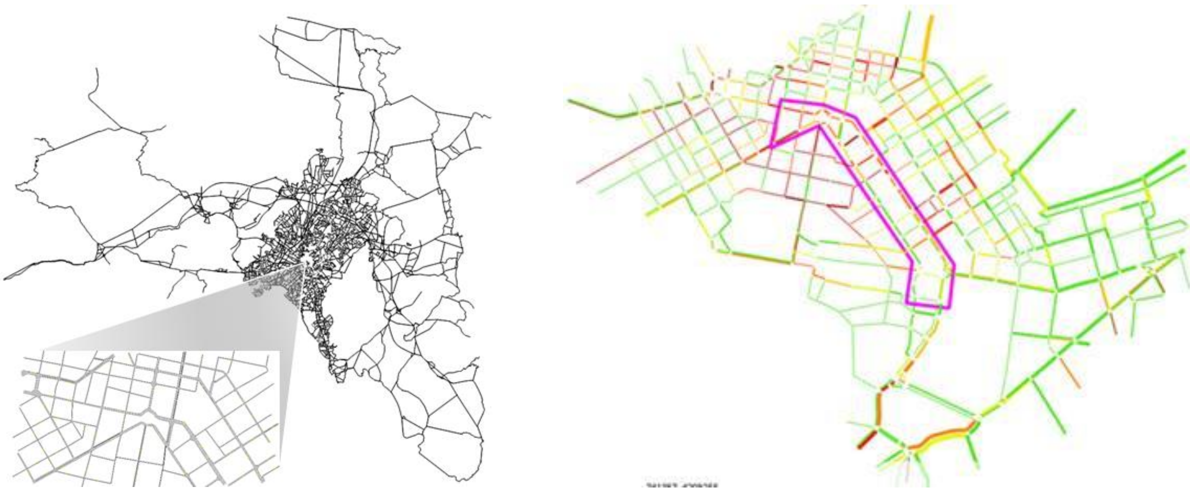


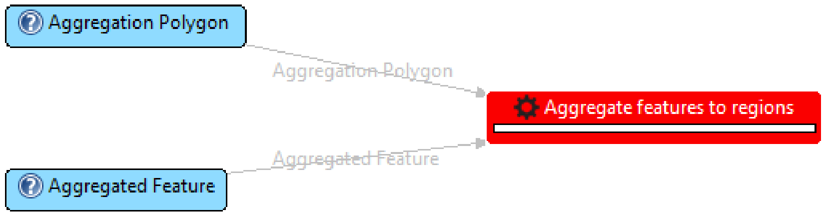
Figure 7 Road network in Attica Region and transportation modelling outcome from Aimsun

2.6 GIS Analyses

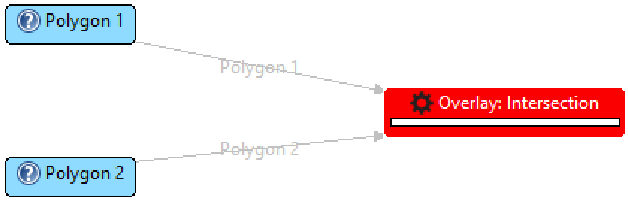
A series of GIS analyses have been incorporated into CIRP from the open source ERGO-CORE platform:

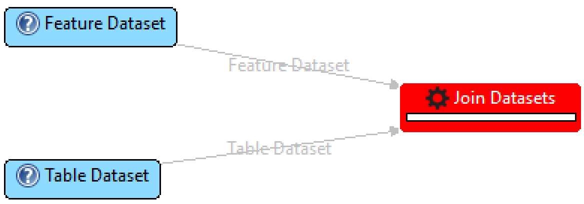
- Aggregate Features
- DEM Slope Map
- Intersect Features
- Join Datasets

The following tables describe the associated usage, inputs and outputs. For a complete list of CIRP analysis see D5.5.

Analysis	Aggregate Features Analysis		
Description	Aggregates (ave, sum, min, max) features in line or point dataset to polygon dataset		
Graph			
Input Dataset	Aggregation Polygon (Type: Polygon or MultiPolygon)	File Type: Shapefile	Cardinality: Single
Input Dataset	Aggregated Feature (Type: Point or Polygon or Multipolygon)	File Type: Shapefile	Cardinality: Single
Input Parameter	Fields to aggregate	Value: string (selection from sum, avg, min, max)	Cardinality: Single
Output Dataset	Type: anonymousPolygon	File Type: Shapefile	Cardinality: Single
Plugin Provider	ERGO Consortium		

Analysis	DEM Slope Map Analysis		
Description	Computes the slope of a Digital Elevation Model		
Graph			
Input Dataset	Type: Elevation Map	File Type: raster (ASCII Grid)	Cardinality: Single
Input Parameter	Slope Method	Value: string (selection from ZevenbergenThorne1987 or Horn1981)	Cardinality: Single
Output Dataset	Type: demSlopeRaster	File Type: raster (ASCII Grid)	Cardinality: Single
Plugin Provider	ERGO Consortium		

Analysis	Intersect Features Analysis		
Description	Computes the intersection of two polygon layers (feature datasets)		
Graph			
Input Dataset	Type: Polygon or Multipolygon	File Type: shapefile	Cardinality: Single
Input Dataset	Type: Polygon or Multipolygon	File Type: shapefile	Cardinality: Single
Output Dataset	Type: Polygon or Multipolygon	File Type: shapefile	Cardinality: Single
Plugin Provider	ERGO Consortium		

Analysis	Join Datasets Analysis		
Description	Joins a table dataset to a feature dataset		
Graph			
Input Dataset	Feature Dataset (Type: Polygon or Multipolygon or Line or Multiline or Point)	File Type: shapefile	Cardinality: Single
Input Parameter	Field to join on	Value: string (field from Feature Dataset)	Cardinality: Single
Input Dataset	Table Dataset	File Type: CSV	Cardinality: Single
Input Parameter	Field to join on	Values: string (field from Table Dataset)	Cardinality: Single
Output Dataset	Joined Dataset	File Type: shapefile	Cardinality: Single
Plugin Provider	ERGO Consortium		

3 Conclusions

Within EU-CIRCLE, several powerful external tools were integrated with the hazard and impact evaluations to deliver a holistic analysis that offers a comprehensive assessment. These methodologies used in these tools are generic that can be implemented in multiple applications. The seamless link among various elements enable a streamlined workflow of climate impact assessment using the EU-CIRCLE framework that can be easily transplanted to other case studies.

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5 Acknowledgment

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