XXVIII International Seminar on Urban Form
ISUF2021: URBAN FORM AND THE SUSTAINABLE AND PROSPEROUS CITIES
29th June – 3rd July 2021, Glasgow

Twin-cities over the Messina Strait: a discussion on Reggio Calabria and Messina road-networks linkage.

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Abstract

The idea of permanent connection and territorial integration between mainland Italy and Sicily across the Messina Strait dates to the 19th century. However, it was not until 1970's that the area received the first planning regulations. Since then, proposed linkage projects remained limited to economic-based cost analysis and engineering-design feasibility evaluation. Due to the ever-unstable Italian political scenario, public interest on matter decreased in 1990's and, by then, associated to incipient configurational models and data processing tools, it hindered any further analyses regarding urban agglomerates' morphological changes deriving from this connection. Strait debates resurfaced in 2020-2021, as territorial integration is on the agenda of Italian economic recovery plans, an ideal scenario to revisit and study existent proposals, drawing from exploratory evaluations on urban morphology and twin-cities dynamics. This paper contributes to this discussion, through the analysis of different proposals for the Messina Strait linkage, using Space Syntax' Integration measures to assess configurational changes connections between the urban agglomerates of Messina and Reggio-Calabria; depicting tendencies for their urban dynamics transformation. Results and discussion contribute towards planning policies, while appointing the potentials to enhance a shared functional centrality for twin-cities.

Keyword: *Messina Strait, Twin-cities, Urban Morphology, Regional Integration.*

Introduction

Messina and *Reggio-Calabria* possess unique twin-cities dynamics that can be potentially changed through the establishment of a permanent connection between their road-circulation networks across the *Messina Strait* (Musolino, 2018; Musolino and Pelegrino, 2020). Comparative studies, based on existent proposals for connection (Brancaleoni *et al.*,2010) are essential to, assess how potential urban morphology changes affect cities' functional centralities spatial configuration. As morphological processes are context dependent (Kropf, 2011), interventions that transcend geographical barriers may lead to transformations in territorial and socioeconomic dynamics, therefore, a shared infrastructure can overcome systemic issues caused by spatial discontinuities. However, changes in the configuration may also affect the twin-cities urban agglomerates accessibility hierarchy at local and micro-regional scales. Considering these aspects, the paper objective is to describe, model and compare the effects on configuration of different traverses across the *Messina Strait*, addressing a) morphological characteristics of independent and connected road-circulation networks', and changes in spatial configuration for each proposal; b) functional centralities' hierarchical changes if present. Then, it is discussed if morphological and configurational changes that result from the connections reiterate expected public policies' objectives present in the *Piano Nazionale di Ripresa e Resilienza* (PNRR) (2021).

Background

Messina Strait and the discussion about a permanent connection

In its current state, the *Messina Strait* is a geographical border that comprise a contradiction as, even though it structures together the cities of *Messina* and *Regio-Calabria* through the sea, it also establishes a "barrier" that differentiate their socioeconomic phenomena, and create a divide amongst urban areas that have, otherwise, a natural inclination to integrate (Musolino, 2018). *Messina* and *Reggio-Calabria* twin-cities share several potentialities as interdependent productive, exchange and logistics hubs (Musolino and Pellegrino, 2020), hindered by their seafaring-based transportation and by inherent contrasts in road-infrastructure. Both cities are located along the boundaries of peripheral regions, yet possess fundamental urban-regional network organization differences: *Messina* pertain an isolated, albeit continuous road-network system of smaller dimensions (the Sicily Island) that encompass a commute-functional area amongst important cities, such as *Palermo* and *Catania*; *Reggio-Calabria* even though being one of Sothern Italy principal nodes, is one of outermost nodes in the Italian mainland road-circulation network, thus, placed in a relatively segregated position (ESPON, 2014). Pondering such differences, a connection between these two hierarchically distinct urban networks tends to modify the borderline and change movement patterns in both urban agglomerates (Kolossov and Scott, 2013), a process that may reorganize their socioeconomic functions (Musolino and Pellegrino, 2020). Hence, different configurations that emerge from their integration, can either enhance the twin-cities spatial interdependencies minoring their functional disparities, promoting economic development and improving regional competitiveness (Musolino and Pellegrino, 2020), or lead to a condition where one of the cities surpass and supress the other in functional importance, as well as reinforce "tunnel effects" that redirect movement away from one of the consolidated functional centres (Sohn and Whalter, 2009).

Italian territorial planning emphasises an urban-regional development and also considers its relative position within the European context (Dematteis, 2008). In that aspect, the connection across the *Messina Strait*, beyond a proposal oriented to local, regional, and national development, is inserted in the scope of a Trans-European Network (TEN-T) (European Commission, 2013). According to Di Ludovico *et al.* 2021 p.7, most of Southern Italy remains excluded from the European Territorial Frames (ETFs), that define Europe's Main Urban and Productive Agglomerations (MEGAs) (ESPON, 2005). The absence of a permanent connection between Sicily and the Calabrian Peninsula restricts the significative vehicular traffic that exists among the independent extents of *Messina – Catania – Palermo*, and *Reggio-Calabria – Napoli*, this last urban area, considered as a potential MEGA. Hence, the project conclusion – that considers a suspended bridge between Sicily and Calabria – is a crucial step for the establishment of a Scandinavian-Mediterranean Transport Corridor (CORR5) and to assure connectivity and accessibility to all European regions (European Commission, 2021). Although the suspended bridge connection is the most endorsed proposal – to the point of being considered in the TEN-T – other traverse approaches, such as an undersea suspended gallery, foresee a closer connection in-between *Messina* and *Reggio Calabria* urban centres (Brancaleoni *et al.*,2010), and could provide different morphological results, and a distinct movement dynamic, given its positioning.

Space Syntax as a method to assess large-scale regional road-circulation networks

Recently, several investigations used Space Syntax models (Hillier, 2000) to address regional interactions and assess local-regional movement-dynamics. This prospect was introduced by Turner (2009) and derive from changes in the road-infrastructure representation, that shifted from Axial Line graphs towards Road-Centre Line (RCL) graphs (Turner, 2007), which are made available through datasets of public or open-collaborative sources. This methodological development allowed the use of pre-constructed urban-regional road-graphs for configurational modelling, as well as their integration to GIS-based platforms (Jiang *et al.*, 2000). Although theoretically feasible since the late 2000's, computational limitations hindered the widespread development of local-regional analyses using Space Syntax, as processing time-lapses tend to increase exponentially with network size. Notwithstanding these deterrents, several 2010's studies were able to model large extents of regional and supra-regional territories, albeit through use of generalized road-graphs with lower levels of detail (Hanna *et al.* 2013; Braga *et al*., 2017; Serra and Hillier, 2019). Improvements in processing power, allied to novel methods for territorial differentiation and generalization, allowed the construction of detailed regional maps, preserving road-geometries and their morphologies across scales, thus, precise modelling of local and regional road-circulation networks (Altafini and Cutini, 2020). The research problem evaluation is possible due to advancements made in the last two decades as, despite the average sizes of *Messina* and *Reggio-Calabria* independent graphs, these constitute a regional road-network system when interconnected. Its relevance also resides on the fact that it addresses a novel territorial context – urban agglomerates regionally connected across an extensive geographical barrier – an issue contemplated in other Space Syntax studies on the subject, but restricted to urban scales (Braga and Campos, 2019).

Methods, procedures, measures and modelling tools

Morphological changes that result from different connection solutions between Calabrian and Sicilian road-circulation networks are evaluated through the assessment of the systems' configurational properties, what requires the processing of several Road-Centre Line (RCL) graphs. To ensure compatibility among the models, graphs derive from a same database, the OpenStreetMap (2021) – an open-source collaborative map project – obtained through an integrated QGIS plugin – the OSM downloader. This plugin is unable to extract, due to their extents, the entire road-infrastructure data, hence, partial maps of Calabria and Sicily were produced, and further joined in QGIS (2020) to construct regional maps. Road-graphs were generalised to exclude road-elements unsuited for configurational analyses (parking lots, cycleways, waterways, mountain trails, etc.); not representative of vehicular-based movement that distort the overall results. Regional maps were then sectioned to comprise the road-infrastructures of the municipalities mentioned within the plans depicted in Brancaleoni *et al.* (2010): *Reggio Calabria, Villa San Giovanni* and *Scilla (Calabria – province of Reggio-Calabria)*; and *Messina (Sicily – province of Messina).* Saccà (2019) described and amended those proposals that envisioned further road-infrastructure changes, with planned expansions for the Calabrian and Sicilian highway systems. The configurational analysis does not incorporate these transit-oriented modifications,

being restricted to the addition of access roads towards the traverse structures, maintaining current grid morphologies unaltered. Considering this, the plans depicted in Brancaleoni et al (2010), and Saccà (2019) are used solely to locate the reference positions where the bridges and the undersea gallery are set to be built. Models comprise five road-graphs: the *Messina Area* (municipality of *Messina*), and the *Reggio-Calabria Area* (municipalities of *Reggio-Calabria, Villa San Giovanni and Scilla*) independent road-circulation networks; and the systems connected through two distinctly placed suspended bridges (P1 and P2 – that represents the 2013 cancelled project insertion), and through the undersea gallery.

Space Syntax Angular Analysis (Turner, 2007) assess the road-infrastructure configurational properties and depict movement potentials in RCL-based networks through dataset conversion into *angular segment maps* in *DepthmapX 0.8* (2020). In such procedure, modelling weights networks' *j-graphs* according to the angle (*angular coefficient*) between each connected pair of vertices (road-elements), segmenting the continuous polylines in two (*angular segmentation*) and attributing individual values for each road-element depending on angle variations amidst the pairs (t-intersections, crossings); continuity is preserved when no interruptions or direction changes happen. *Angular coefficients* correspond to a weighted *topological step* and allow to depict depth differences between spaces, through considering the shortest angular paths among the origin-destinations pairs of all road-elements. Depth is a component used to calculate *Integration* hierarchies; in Space Syntax, *Angular Integration* is equivalent to mathematical *closeness centrality*, as it calculates average costs of traveling over the shortest paths, from each road-element to all possible destinations in the network. Hence, it depicts a road-element *to-movement* potential, or its *relative accessibility* – how central its position is in relation to all other road-elements depth. Normalising *Angular Integration* results is a fundamental step for comparative studies that assess systems with different depths. Normalized Angular Integration (NAIN) (Hillier, Yang, Turner, 2012) bring *closeness* absolute values to comparable ranges, by weighting them by each system's *Total Depth*, thus, by its size. This allows qualitative and quantitative comparisons regarding the centralities' distribution and value, and permits to identify changes in *Integration Cores*, where functional centralities are often located.

Results and Discussion

Results for the independent networks demonstrate that the *Messina area* possess a higher absolute NAIN value than the *Reggio-Calabria area*, attributable to its greater compactness (Table 1). Still, both systems are similar in that regard, characterized by compact *Integration cores*, given their predominantly orthogonal grid morphologies that define non-hierarchical and pervasive functional centralities (Figures 6.1 and 6.2). Both urban expansions tend to linearity with their urbanizations structured in parallel to the seashore, that results in a rather constant NAIN distribution across their historical and functional centres (Figure 6.1 and 6.2). In that aspect, however, *Reggio-Calabria* possess an important contradistinction to *Messina*, as the Southmost area of its centre is set beyond a natural divide (Figure 6.2) which confines the historical centre *Integration core*. When compared to the *Reggio-Calabria's* historical centre, NAIN values in the area observe a decrease,

due to the presence of few crossing points, that weakens the overall connectivity and which enhances the area spatial segregation. Further differences emerge when *Reggio-Calabria* and *Messina* urban expansions are considered. The Integration core peripheries are defined by the highway systems, through partial ring-roads that surround the functional centres in both cases; still, Reggio-Calabria road-infrastructure distributes centrality in an ampler radius than the Messina area. The inland road-circulation is fragmented alongside the mountain and valley areas, that leads to overall lower NAIN values and a relatively segregated condition in either instance. (Figure 6).

Significative configurational changes occur when there is a connection between *Messina* and *Reggio-Calabria areas*' road-circulation networks. Both bridge proposals (P1 and P2) impose an extensive redistribution and reorganization that tends to weaken the area road-network *Integration*. NAIN absolute values shift towards intermediate ranges, with values lower than the *Messina* independent network, yet higher than the *Reggio-Calabria's* independent system (Table 1). Although this suggests that the *relative accessibility* is reinforced in *Reggio-Calabria* area, the spatialized models describe, instead, that its functional centre suffers an overall decrease in *Integration*, with lower NAIN values when compared to its independent network, above all in its southernmost area, as anticipated (Figures 6.4 and 6.6). Hence, P1 and P2 proposals analysis point towards a displacement of the *Integration core* towards the Sicilian side of the *Messina Strait*, following the suspended bridges insertion points. Comparisons between P1 and P2 demonstrate that the Integration reduction within *Reggio-Calabria's* functional centre is more accentuated in P2 – the proposal in execution until 2013 – which can be associated to its greater metric distance from the Calabrian urban centre (Figures 6.4 and 6.6). In this context, and perhaps reinforced by potential "tunnel effects", the emergent centre in the *Messina area* tends to surpass and suppress the *Reggio-Calabria's area* consolidated functional centrality. Such urban-regional transformations patterns might compromise the vitality of both functional centralities – with substantial consequences, above all, for *Reggio-Calabria* – and tends to jeopardize the development a shared Functional Urban Area (FUA), aspect that characterizes the twin-cities dynamics.

Table 1. Values for Normalized Angular Integration (NAIN) measures

Measured System – Municipalities	System Characteristics	NAIN – Min. Max. Values
Messina	Independent Network	0.076 - 0.379
Reggio-Calabria, Villa San Giovani, Scilla	Independent Network	0.041 - 0.243
P1 - Suspended Bridge Proposal	Linked Network	0.046 - 0.297
P2 – Suspended Bridge Proposal	Linked Network	0.045 - 0.295
Suspended Undersea Gallery Proposal	Linked Network	0.047 - 0.327

Compared to P1 and P2, the undersea gallery is the alternative that tends best to preserve NAIN values, with those being closer to those found for the *Messina* area independent network (Table 1) (Figure 6; 6.7; 6.8).

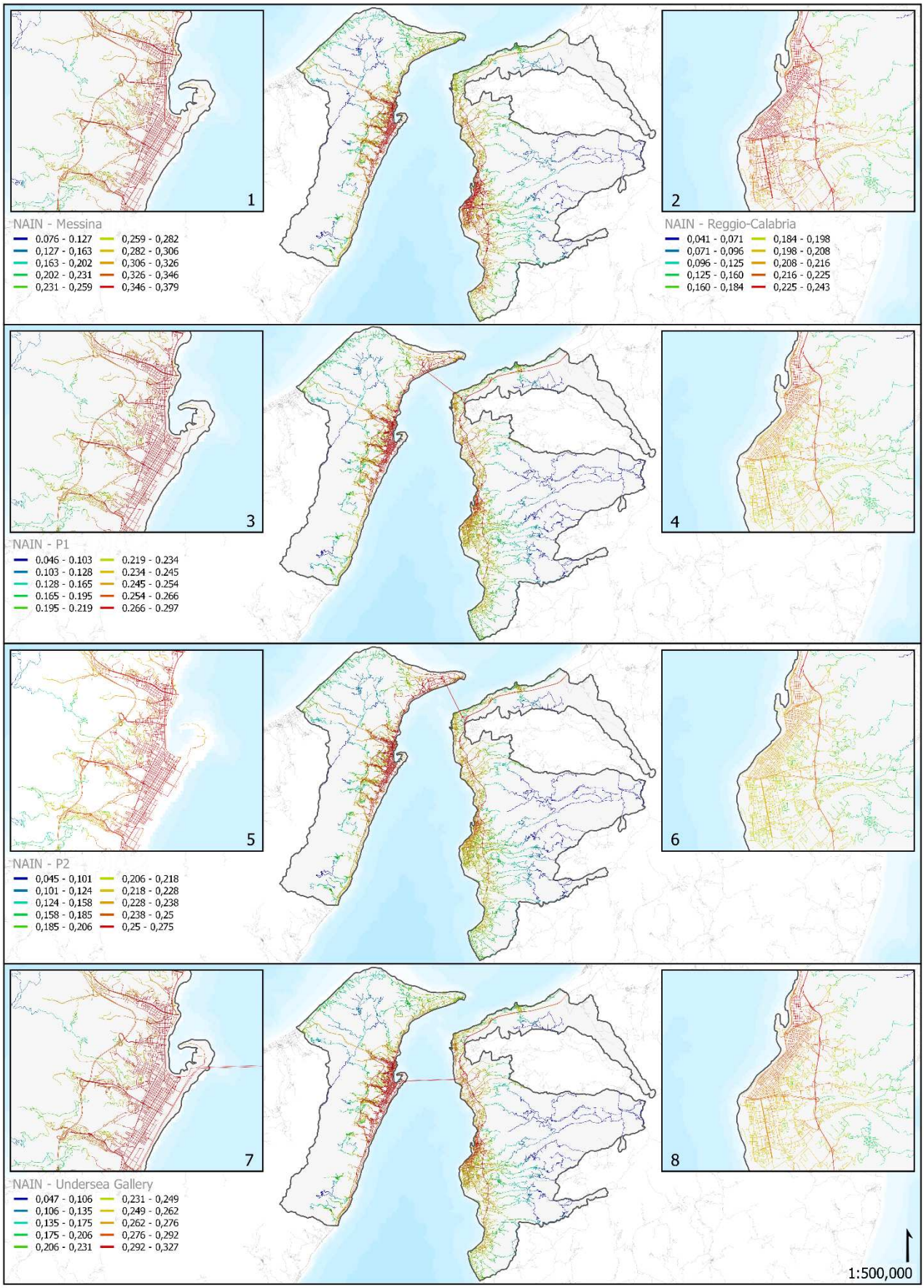

Figure 5. *Normalized Angular Integration (NAIN) analysis for the independent Messina and Calabria road-circulation network, for P1 and P2 suspended bridge proposals, and for the undersea gallery proposal road-circulation networks.*

The undersea gallery modelling demonstrates that *Integration* hierarchies' distribution across the connected systems tend to be more even, preserving existent functional centralities. While negative effects still exist – *Integration* decreases in *Reggio-Calabria's* southmost part –, those are diminished in comparison to those observed in the bridge proposals. From the configurational perspective, this provides a greater potential for the emergence of a shared functional centrality, as no centre surpass or supress the other in importance, preserving the morphological characteristics form *Messina* and *Reggio-Calabria*. Hence, from this standpoint, it is the alternative that best contemplates the Italian planning goals for the region (PNRR, 2021).

Conclusions

Messina and *Reggio-Calabria* twin-cities share unique dynamics, with potential to be an important functional space in a peculiar geographical environment – the Messina Strait. Nevertheless, while the strait defines the area, it also configures itself as a barrier, that hinders local-regional development. In this context, minoring the area – and Southern Italy's – disparities, depends on a robust integration between *Messina* and *Reggio-Calabria* as shared functional centralities, in which a permanent connection ought to be seriously considered. Evaluating the morphological dimensions of such linkage is crucial to assess if changes in spatial configuration enhance the areas' *Integration* and attend the objective sought in the Italian – and European – planning goals. Although all the alternatives tend to change the spatial configuration at regional scale, both bridge proposals tend to jeopardize the *Integration* within *Reggio-Calabria's* area road circulation network, with the *Messina area* surpassing and supressing Calabrian functional centralities. Losses in the *relative accessibility* of *Reggio-Calabria* might threat the vitality of both urban areas, since the functional interdependence already exists in-between the twin-cities, with partial interaction through seafaring transport, might be weakened if one of the urban centres decrease in functional importance. However, the undersea gallery minors these negative effects of a connection, as it promotes a more even redistribution of the *Integration,* which tends to promote the emergence of a more interdependent Functional Urban Area (FUA), that characterize twin-cities.

Integration analyses allowed to address some of the traverse proposals potentialities and negative effects, still, further studies ought to consider other configurational parameters such as *betweenness centralities* – to assess "tunnel effects" –*, land use*, functional attractors, and a larger territorial setting, in order to perform a multidimensional and multiscale evaluation of the effects of a traverse across the *Messina Strait*.

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