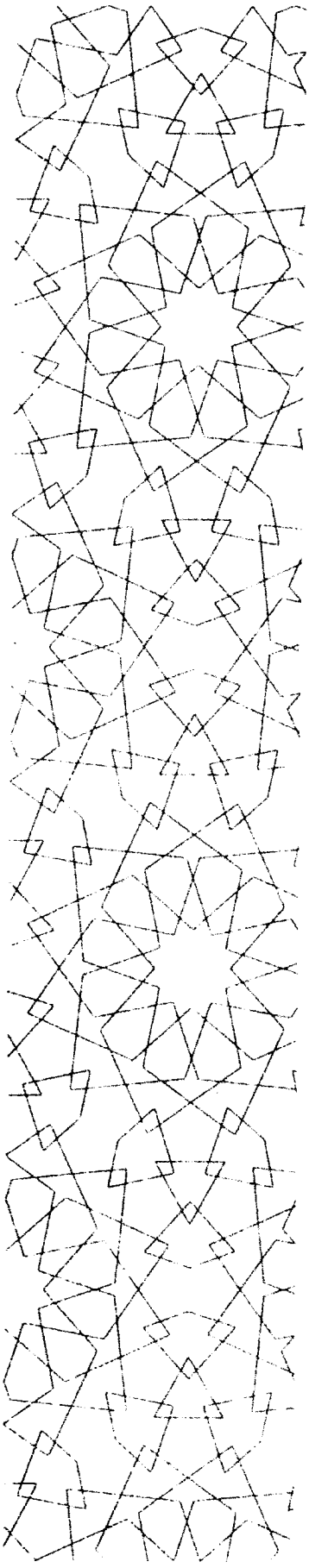

Ph.D. Thesis

TRANSPORTATION NETWORK STRUCTURE AND SPATIAL ACCESSIBILITY

DYNAMIC GRAPH APPROACH

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ABSTRACT

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Changes in transportation network resulting from planned improvements, internal processes (congestion, accidents) and random events like natural disasters, bring about changes for society. The main objective of this thesis is to evaluate the effectiveness of spatial accessibility as a tool for the assessment of network dynamics.

Positive accessibility changes due to infrastructure projects have been often reported. Previous work was mostly confined to case studies or simulations of unique scenarios, related to speed improvements on certain group of links. Graph theory was used no more then to compute shortest paths and o-d (origin-destination) pairs travel times. Few attempts have been made to derive more sound theoretical conclusions. On the other hand, negative effects have been studied under network vulnerability framework. Notwithstanding case studies, more substantial theoretical developments were made, based on risk analysis concepts, leading to dual node- and link-oriented mode of analysis.

Proposed "dynamic graph approach" is unified modelling of positive and negative effects of network changes, with stronger support from graph theory. The network dynamics is viewed in two ways: firstly, as a changing pattern of paths resulting from network modification, secondly – as a stimulus-response pair, where change in link speed brings Hansen-type potential accessibility effect. These two perspectives (qualitative and quantitative) are later merged.

The body of the thesis consists of:

14. the review of evolution of **gravity and potential models** and emergence of accessibility concept;
15. analysis of **subject scope** and time horizon of accessibility research;
16. review of accessibility **components** within 3-sphere partition, with focus on behavioural factors;
17. explanation of **axiomatic** framework of accessibility;
18. discussion on **ethical and political** issues of mobility and accessibility;
19. introduction to **path load** concept and its practical application to road network in Poland;
20. presentation of **base model** used for accessibility computations and author's own software (OGAM, OGAMLab);
21. introduction of **link service fan** concept – a new qualitative tool for topological analysis of network dynamics – with formal properties and algorithms;
22. review of service fan applications to:
    - algorithm improvement,
    - finding accessibility- and interactions-closure areas of transportation network,
    - analysis of link-link relations and network regionalization;
23. review of theoretical grounds of risk analysis and developments on **network vulnerability**;
24. introduction of **link accessibility profile** – a new tool for quantitative analysis of network dynamics;;

25. development of link- and node-oriented **vulnerability indicators** derived from profile;
26. **empirical study** of road network vulnerability of Poland with 13 maps.

Empirical workload was based on IGSO road network database with 2321 transportation zones and 14402 links. Author's OGAMLab software created over 33 mln accessibility profiles for each link and each zone of reference. Profiles were synthesized into few important parameters. Finally, parameters were combined into two mirror indicator sets – named respectively link influence and zone vulnerability set. Each set consisted of 1) magnitude, 2) dispersion and 3) spatial range indicators of influence/vulnerability.

Main theoretical achievement of the thesis was to prove that positive and negative impacts of transportation network dynamics can be observed and explained in unified framework, consisting of three concepts:

- **link service fan** – a subgraph of transportation graph related to single link and closed for interactions and accessibility,
- **link accessibility profile** – a function of accessibility response of the system to link change,
- service fan **event profile** – a data structure for creation of service fan given arbitrary state of related link.