



Coastal congestion: Simulating port expansion and land use change under zero-sum conditions



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ABSTRACT

This paper examines the displacement effects associated with new land use development in a congested coastal area. A land use micro-simulation model (UrbanSim) and statistical estimation are used to identify the expected future land use impacts arising from the proposed expansion of the Port of Haifa. Maximum and minimum development scenarios are simulated and compared to baseline (business-as-usual) conditions. Simulation outputs refer to future population, employment, residential and non-residential construction for the city of Haifa and its metropolitan area until the year 2038. A key finding relates to the spatial substitution effects of additional non-residential floor space on residential development throughout the Haifa region. This highlights the zero sum effects of land use change under conditions of congestion. The challenge of efficiently using limited land use resources and balancing development across many competing uses and stakeholders, is stressed.

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1. Introduction

Coastal development highlights the challenges of interfacing marine and terrestrial environments. Nowhere is this more acute than in the case of port expansion. Ports are inherently anthropogenic creations that extend mainland functions into the oceans. Coastal zones are intensely developed areas housing potentially conflicting land uses. Port land use competes with residential, industrial and recreational uses for access to finite shoreline space. The port is both endogenous and exogenous to this competitive process. On the one hand, it is invariably the cause of the demand for coastal land, spawning space-intensive economic development in its hinterland. On the other hand, its growth rate is influenced by the physical and socio-economic environment in which it develops.

Port expansion is an especially contentious land use issue in coastal areas. Port facilities are large scale infrastructural projects with clear economic and environmental consequences. The expansion of port facilities is also locationally inelastic. It inevitably incurs zero-sum costs on the one hand and is inherently limited in terms of alternatives, on the other. However, very little is known about the various ripple-through effects of this infrastructure growth on the urban fabric in its immediate hinterland. This forms a major motivation for this paper. Port hinterlands have been

examined in relation to their role in the terminalization of ports (Wan et al., 2013) and their regionalization (Notteboom and Rodrigue, 2005). Surprisingly, rather less attention has been paid to the urban hinterland that invariably sustains the port. Port development therefore cannot be analyzed in isolation of urban development.

We use an integrated land use-transportation model (UrbanSim) to forecast coastal land use change under two alternative expansion programs for the Israeli port of Haifa for the year 2038. The interactions between multiple agents of land use change (households, workers, developers, government) are simulated and the feedback loops between their behavior and land use are explicitly modeled. Conventionally, we assume that agent behavior is motivated by standard principles of utility maximization and risk aversion. We are particularly interested in observing how a disturbance in coastal land use (port expansion) displaces other land uses such as residential development within the wider port hinterland and the region. This spatial spillover effect can be captured by the simulation model where location choices (agent behavior) and land use dynamics (amount of construction, value of units to be built etc) are captured simultaneously and adjusted dynamically.

Due to the intense competition for land along the crowded Israeli shoreline and the strategic importance of port facilities for international trade in a small, open but geo-politically land-locked economy, optimal use of limited coastal land resources is of primary importance. In terms of coastal zone management, this study

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highlights the challenge of efficiently using limited resources and balancing development across many competing uses and many stakeholders. Adding the congestion along the Israeli coastline to this goal results in an inevitable zero-sum effect whereby any development is at the expense of some other development. There is no low-cost or costless route to coastal land use change.

The paper proceeds as follows. We review the literature relating to the land use implications of port expansion in Section 2. Particular attention is paid to the changing role of seaports and their implications for coastal management. Section 3 provides the context of the study. The physical setting and socio-economic composition of the area are described. Additionally the institutional context of port expansion in the Haifa region is charted as coastal development cannot be treated in oblivion of the political processes operating in the area. The fourth section provides a transparent description of the analytic model used in this study. This highlights the efficacy of using UrbanSim for simulating coastal land use change. Section 5 presents the scenarios and the motivation for their formulation. Simulation outputs are presented in Section 6 where two development scenarios are compared with a baseline (business as usual scenario). These results underscore the displacement effects associated with port development. We show that non-residential development has an inevitable substitution impact on residential development given the crowded zero sum conditions along the coast. Finally, we conclude with some implications for coastal zone management arising from the analysis.

2. Literature review

Seaports are more than just trans-shipment points. Historically, ports have been the nuclei around which urban development has taken place and despite their changing functions, they have retained that catalytic role to this very day. However, while in the past ports served as a bridge between the seaward foreland and the landward hinterland, today ports are conceived as nodes in global logistics networks or junctions in international commodity supply chains (Robinson, 2002; Rodrigue and Notteboom, 2010). The hinterland dynamics related to ports, of which land use change is a component, have been coined 'port regionalization' (Notteboom and Rodrigue, 2005). This concept expresses the new functions and morphology of ports brought about by containerization, inland terminals and supply chain management. According to this view, port regionalization is exposed to two forces. The first is globalization that relates to the role of the port in relation to other (port) nodes with which it is connected. This gives rise to competition, increasing mechanization and internal scale economies. The second force is that of local constraints. These relate directly to land use and negative externalities such as noise, pollution and road congestion. When these constraints are severe, the port loses its role as a coastal gateway and activities such as freight, handling and storage that used to be coastal land uses transfer to the port hinterland.

This change in function, operation and ultimately location, has generated a call for a re-evaluation of the role of ports as purely coastal land uses (Oliviere and Slack, 2006). It is argued that ports are no longer just 'spaces'. They are not simply forms of transportation infrastructure that happen to be coastal and with some unique characteristics derived from the land–sea interface. Thus, according to this view, the spatial analysis of port development (which includes land use simulation) does not go far enough. Ports, so the argument goes, are also 'places' and should be investigated as such. This means looking at the governance and institutional contexts in which they operate and the various interests involved in their expansion. The problem with this argument is that while it

might offer insights into the way ports currently operate, it has very little to offer in terms of the future dynamics of port development and the way they impact on land use change. Additionally, it points to a potential problem of identification. If political and institutional factors are most acute in those port contexts where expansion is intense in the first place, the causal effect of governance factors on port expansion will not be identified. When the current political-institutional constellation changes and yet the port continues to expand, a new (ad hoc) explanation will need to be found that is independent of the outcome.

This is closely related to the theoretical interest in the question of why do port cities succeed way after their initial port-related advantages such as accessibility and low bridging points, become redundant? The answer clearly seems to be in the self-reinforcing agglomerative tendencies that they generate. Using the principles of the New Economic Geography (NEG), Fujita and Mori (1996) illustrate how the neo-classical port city model grounded in constant returns and comparative advantage is insufficient for explaining port city growth after the port function ceases to be important. Instead they offer an explanation in which urban port growth emerges endogenously through the agglomeration forces generated by increasing returns and transportation costs. This growth generates a lock-in effect that continues after the disappearance of the initial port-based advantages (access to water etc).

A further important insight grounded in the port-as-agglomeration view, is that while ports, like cities, are part of a network and ports link countries together just as cities do, there is also a synergetic relationship between port activity and local/regional growth. The agglomeration tendencies around ports can result in polarized urban/regional development. Ports are an inherent part of the trade (transportation) costs that lie at the heart of the NEG. High transportation costs create spatial equity by allowing economic activity to disperse. Low transportation costs generate core-periphery inequalities and agglomeration. Ports lower transportation costs and historically have been 'natural' centers of economic activity, often at the expense of other nearby centers. Port development would therefore seem to be a zero sum game in terms of economic activity.

The same may also be true in terms of land use. Huang et al. (2011) have noted that while the multiple interests involved in port development (communications, infrastructure, storage, power, engineering etc) all look to maximize the internal benefits of port expansion, the public interest calls for maximizing external benefits. This includes minimizing traffic bottlenecks and congestion around ports (Wan et al., 2013), reducing negative externalities such as pollution, visual blight and the by-products of land reclamation (Saz-Salazar and García-Menéndez, 2007; Luo and Yip, 2013) and regulating land use (Hansen, 2007, 2011). The hinterland effects of a seaport can be quite considerable. Notteboom (2004) notes that that inland logistics account for 40–80% of all container shipping costs. Wan et al. (2013) have estimated that increasing road congestion around a port by 1% can lead to a reduction in port throughput and hinterland activity by 0.9–2.48%. Thus ports and their hinterlands are heavily inter-connected.

While the land use implications of port expansion have not been directly addressed in the literature, there have been some attempts at simulating the effect of exogenous change (invariably climate-induced) on coastal land use. Hansen (2007, 2010) for example, examines the impact of two coastal flooding scenarios using a cellular automata (CA) driven simulation model. In this model, decision rules govern the mechanical movement of the cell occupants and the probability transitions between different states. The model distinguishes between active land uses such as residential and industrial uses, passive uses such as open space and static land use in which he clusters seaports, airports, waste purification sites

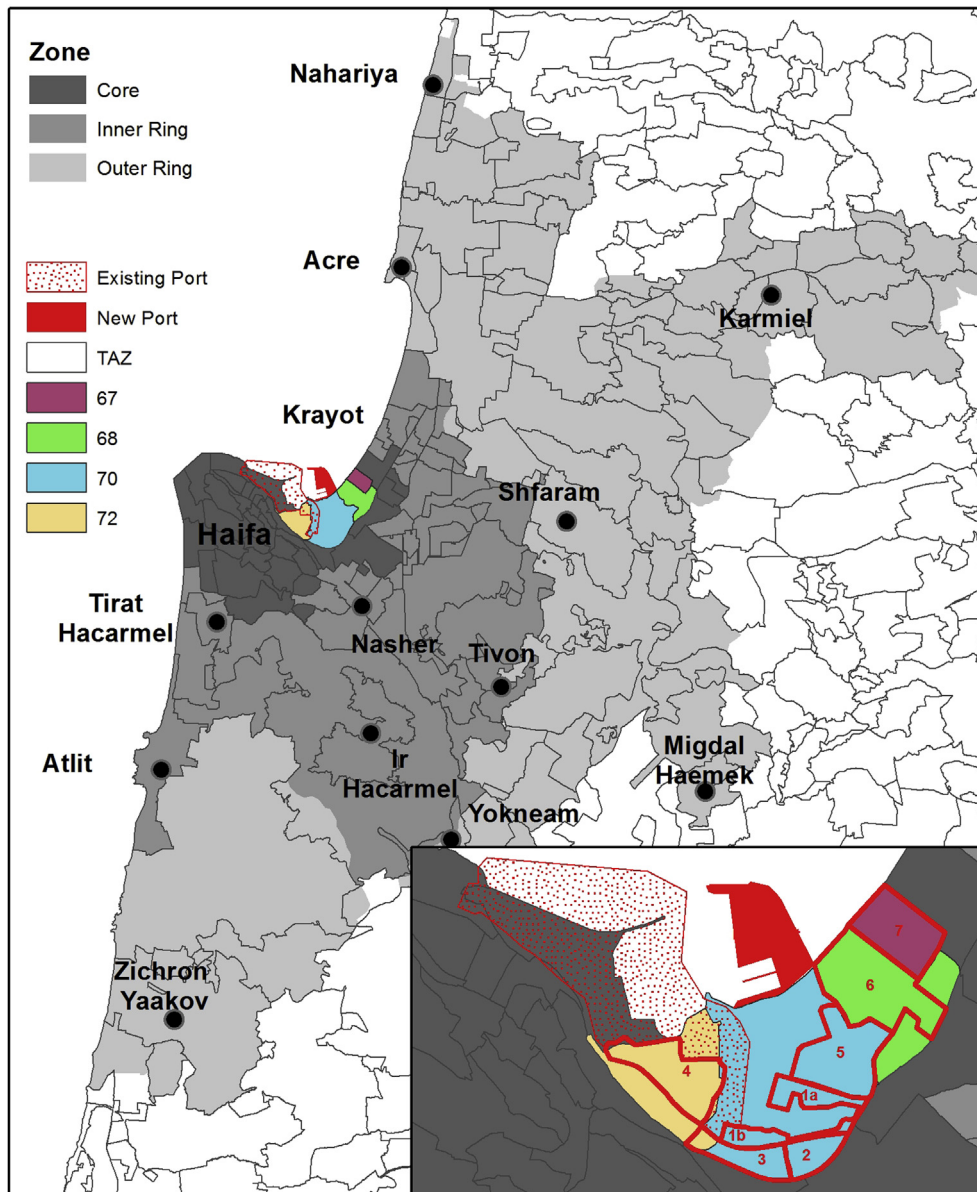


Fig. 1. The Haifa metropolitan area: Core, Inner and Outer Rings and TAZ's; planned Expansion of Haifa Port.

etc. The rationale behind this third classification is that airports and sea-ports generate externalities and therefore affect land uses but cannot be actively transformed into one of the other uses. This is true only as long as land reclamation is not considered. However, in the case of port development this is hardly a realistic assumption. The de Kok et al. (2001) constrained CA model is also used to simulate the long term impacts of land use change in coastal zones. This has served as the prototype for many other CA-type simulations (Sante et al., 2010). Other types of simulation frameworks such as agent-based, econometric and behavioral modeling do not seem to have been used for testing land use scenarios in coastal areas.

3. The study area

Israel's Mediterranean coastline is 197 km in length and highly congested. Seventy eight percent of the coast (153 km) is currently occupied by a variety of land uses. Residential development

incorporates 41 km, defense installations take up a further 31 km, rural residential development occupies 16 km and infrastructure development which principally comprises the ports of Haifa and Ashdod and also various marinas and desalination plants, accounts for a further 19 km. Of this latter figure the Haifa port accounts for 5 km. Planned land uses are expected to colonize a further 46 km: 40 km for planned urban residential expansion and 6 km for planned rural expansion.

This congestion is further exacerbated by trends in maritime transportation, While 90 percent of world trade is conducted via seaports, in Israel, 99 percent of international trade flows through seaports. As a small, open but geo-politically land-locked country, the strategic importance of port facilities for Israel cannot be overstated. Potentially Israel has a role as a transshipment location bridging the Middle East with both Africa and Europe. The growth potential of international trade is estimated as 5–8% pa (MOF, 2012). This means doubling the container capacity over a decade. The prospects for realizing this potential however are constrained.

There is very limited land for expansion along the coast and yet, upward trends in container vessel size mean increasing pressure on increasing port capacity. Modern ports need to accommodate vessels over 300 m long, 50 m wide and with over 120 000 tons of container volume. This imposes very serious land use implications.

Israel's coastal morphology is characterized by aeolianite ridges and dunes. With the exception of the Haifa Bay, the coast has a straight shoreline with relatively narrow beaches 20–100 m wide and up to 300 m in width in the vicinity of river mouths. The coastal plain is the most populated area in the country. It is populated by two of the major metropolitan areas (Tel Aviv and Haifa) and the vast majority of the country's economic and industrial activities.

The city of Haifa is located in the northern Israeli coastal plain. It is Israel's third largest city with population of 264 700 and an additional 762 400 in the metropolitan area (Fig. 1). The metropolitan area of Haifa includes suburbs and satellite towns in the low-lying Zevulun Valley to the north and additional settlements on the Carmel Mountain and along the Carmel Coast to the south. The city is characterized by diverse topography. Parts of the city are located on the Carmel Mountain range (max elevation of 546 m), which protrudes from the coastline forming Cape Carmel. North of Cape Carmel lies Haifa Bay and the Zevulun Valley. The Kishon River, the main river in the metropolitan area, drains into the Mediterranean in the Zevulun Valley north of the city of Haifa. Haifa Bay stretches along a curved 18 km long coastline; bordered by Cape Carmel to the south, the Zevulun Valley to the east, and the city of Acre and its promontory to the north (Zviely et al., 2009). The southernmost section of the bay is a 5 km artificial shoreline comprising the different Haifa Port facilities. The remaining 13 km are natural, sandy beaches (Zviely et al., 2007). The land area east of the bay houses a series of contiguous coastal suburbs collectively labeled the 'Krayot' but consisting of four separate municipalities of different social complexions (total population 160 000). Haifa has a diverse but declining economic base, aside from the port and oil refineries, it has both one of the largest industrial zones in the country north of the city and a vibrant high tech cluster in the south. The Haifa regional share¹ in national GDP has declined over the last decade dropping from 12.9% to 10.5% over the period 2000–2010 (Rubin and Felsenstein, 2013).

Haifa bay is a natural choice for a major seaport. It is a naturally protected bay with Cape Carmel acting as a shield from strong south-westerly storms. The port was opened in 1933 by the British Mandate in Palestine and generated immediate population growth in the city reaching 100 000 inhabitants by 1936. Haifa Port competes with the newer Ashdod port that opened in 1965 and does not suffer from the expansion constraints operating in Haifa. The port is operated by the Haifa Port Corporation (HPC) a subsidiary of the Israel Port Company (IPC) and serves maritime transportation for all types of cargo and docking facilities for large passenger liners. The port is protected by two breakwaters: a main 2 826 m long breakwater to the north-west and a lee, 765 m long breakwater to the east. The entrance width is 183 m. The port's channel is 13.8 m deep and the port can accommodate vessels with a draft of up to 13 m. The main basin has an area of 2 million m² and the land area of the main port covers ~700 000 m². Cargo types in 2012, include local containers (3%), transshipment containers (67%), oil (11%), bulk grain (12%), bulk in grabs (2%) and liquid chemicals (5%) (Haifa Port, 2014). Over the period 2005–9, the IPC initiated construction of a new container dock in the Haifa port, investing one billion New Israeli Shekels (NIS)² in the project. This involved

reclaiming an area of 250 000 m² to build a 700 m long, 15.5 m deep dock. The new facility is operated by the HPC.

Given the growth in international container traffic, the ever-increasing capacities of tankers and the need to compete with neighboring international ports, the IPC is currently promoting large scale port infrastructure investment involving the further expansion of the Haifa and Ashdod ports. In 2007, the Israeli government approved the first stage development of a fifty year strategic development master plan developed by IPC. This provides a vision for the short and long development of Haifa and Ashdod ports in a phased approach based on increasing demand and promoting competition in the local port industry through the participation of the private sector.

The development plan for the Haifa port includes a proposed expansion of port operations and the development of a port hinterland (Fig. 1). The expansion of port operations essentially involves building a new port to the east of the current facility and reclaiming 700 000 m² from the sea. The new facility is expected to add 0.8 TEU³ of container capacity to the current 1.8 million TEU in the existing Haifa port. Additionally, the new port will add 0.8 km of dock to the current 2.08 km at a total cost of 5.8 billion NIS (BOI, 2014). This project is expected to be completed by 2020 and employ 400–500 direct employees. The port hinterland development relates not just to direct port operations (customs, container storage and haulage areas) but also involves designating areas for ancillary operations such as warehousing, logistics parks and business service areas. All told, the port hinterland development entails land reconversion of 4 million m².

The statutory planning status of the area is especially challenging. The IPC development plan is largely the result of market failure in the area. This has resulted in a largely neglected and under-utilized landscape suffering from land ownership fragmentation, large concentrations of brown field land uses and many years of abandonment. Statutory planning has not kept abreast with land use change and the area is covered by various overlapping and conflicting statutory plans at different spatial levels. The most pertinent plan is NOP13/1/B which is the part of the National Outline Plan for port development covering the Haifa coastline. The area is also covered by the Haifa district plan (TAMAM 6) which basically cedes all planning authority to NOP13/1/B. National Outline Plan (NOP) 30 which covers Israel's coast is generally directed at limiting all port expansion. In addition, over the last 10 years local (city) plans have started to cover various parts of the proposed port development area, attempting to close a planning gap that in some areas amounts to 50 years of neglect. A recent government report cites the land use implications of port expansion as one of the hardest to quantify impacts of any proposed development along the Haifa coast (BOI, 2014). It is precisely to this challenge that we now turn.

4. Methodology

4.1. The UrbanSim land use simulation system

In order to simulate the effect of port expansion on coastal land use, we use the UrbanSim4 land use simulation model applied to the whole of Israel (see UrbanSim, 2011 for details of model setup and calibration). UrbanSim is an open source, micro-simulation integrated land use-transportation forecasting system (Waddell et al., 2003; Waddell, 2011). It is grounded in random utility in which broadly defined 'agents' (workers, households, developers,

¹ Haifa District GDP (core plus inner ring of the metropolitan area).

² 1 USD = 3.468 NIS (30/05/2014).

³ TEU = twenty foot equivalent unit: a container capacity measure.

land markets and institutions) attempt to maximize utility and avoid risk. Agents are represented by interlinked sub-models that are dynamically linked. The UrbanSim system is characterized by the resolution of the input and output. It can utilize a wide range of spatial units, including statistical areas, zones, land parcels and grid cells. In addition, it seamlessly integrates with GIS allowing analysis and visualization of spatial data.

The system comprises a series of internal sub-models and two external sub-models (Fig. 2). The latter comprise a macroeconomic and a transportation model. The macroeconomic model is used to predict the changes in the annual number of households, according to size, race etc. Additionally, it predicts the annual change in employment according to economic sectors. These outputs are imported into UrbanSim and are used as a benchmark (control total) for the different model components. The transportation model is used to input accessibility measures which control all movement of households, jobs etc and drive many of the internal sub-models.

The internal sub-models interact through the model coordinator which imports and exports data to each of the model components after each sub-model run. The sub models can be divided into three groups according to the three central land use components that they simulate: households, jobs, developer\real-estate behavior. Both households and jobs follow a similar three-step process within each simulation year. At the beginning of each simulation year, the transition sub-model compares the amount of jobs\households of a certain type or sector to the benchmark created by the macroeconomic model. The model then adds or removes the relevant households\jobs from the current model run. The entities added to the current simulation year are placed in a pool of unplaced households\jobs. In the second stage, the relocation sub-model analyzes the current households and jobs and adds those relocating within the current simulation year to the pool of unplaced entities populated by the transition model. In the final

stage, the location choice sub-model simulates the location decision taken by the unplaced households and jobs.

The developer\real-estate entity is simulated by two separate sub-models. The development project transition model compares the current (simulated) vacancy rate for each building type to the target vacancy rate and generates new buildings when the current vacancy rate falls below the long term structural vacancy rate. Following the generation of the new buildings, the non-residential\residential development project location choice model predicts the location choices of developers to build new buildings. Finally, the real estate price model predicts the price per unit of each building. For non-residential buildings this is per m² and for residential buildings this is per unit.

In addition to the models detailed above, UrbanSim includes three central “agents” (buildings, households and jobs) whose actions are simulated dynamically. ‘Buildings’ in the UrbanSim zones version, form the basic spatial representation of the various land uses in each zone. Each building is composed of a number of attributes which form an aggregated representation of the specific land use within that zone. Changes to a buildings’ physical attributes (landuse\floor space development) are modeled by the development project transition and location choice models. The effects of the real estate market on the value of the various units (residential units \ nonresidential m²) allocated to the buildings is performed by the real estate price model.

‘Households’ are represented as separate entities each receiving a unique identification code and a variety of attributes (age of head, building id, cars, children etc.). The simulation of the households’ actions is performed by the household transition, relocation and location choice models detailed above. ‘Jobs’ are depicted as individual entities located in the actual zone of employment. Each job is allocated to a predefined economic sector and its home-based status is defined. The simulation of jobs’ actions is performed by the employment transition, relocation and location choice models.

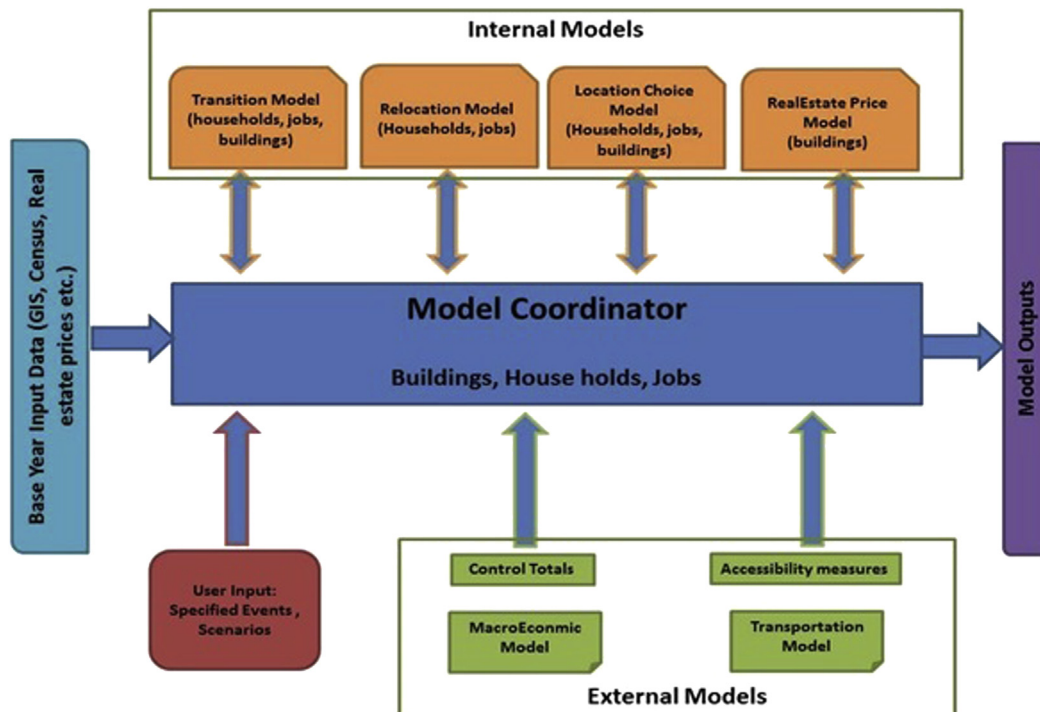


Fig. 2. Components of the UrbanSim model.

4.2. Operationalizing UrbanSim

UrbanSim4 (UrbanSim, 2011) includes grid cell, parcel-based and zone-based versions. In the current application we use the zone version. Our basic spatial building bloc is the travel area zone (TAZ) defined in Israel's National Transportation Model. This model serves as the external transportation model in the UrbanSim system (Fig. 2) and as the source for accessibility measures. The case study area is defined as the Haifa metropolitan area which comprises 3 broad zones (core, inner ring and outer ring) and 122 TAZ's (Fig. 1). This area encompasses 131 municipal entities with a population of 1.07 million people, 64% Jewish and 36% Arabs and Druze. Population density is 1 083 persons per m², roughly half of that of the Tel Aviv metropolitan area. However in the core zone, this rises to 4 283 (half of the Tel Aviv counterpart zone) and declines to 1 090 and 722 in the inner and outer zones respectively. These broad zones subdivide into TAZ's. Nationally, Israel is divided into 651 such areas. The proposed port expansion covers four TAZ's (67, 68, 70 and 72, Fig. 1).

The household control totals (see Section 4.1 above and Fig. 1) are based on future population projections at 5 years intervals and by race (CBS, 2012). We use a linear trend projection for the intervening years. The number of persons per households according to the National Census 2008 (3.07 for Jews and 3.72 for non-Jews) is used to calculate future number of households by race. Employment control totals are based on predictions of change in employment by sectors for 2020, taken from the Israel 2020 master plan (Technion, 1997). These trends are extrapolated to 2050 using national employment forecasts by sector for 2020, 2030 and 2040 outlined in National Outline Plan 42 for land transportation (MOI, 2013).

To adapt UrbanSim to the case of Haifa port expansion we estimate the various sub models (see section 4.1) and create base year data. This involves allocating data to the zones table (representing the spatial attributes) and the various 'agents' dynamically represented within the model. Each of the 651 zones is allocated a variety of spatial attributes which are used by the different UrbanSim sub models. The attributes of each zone include a variety of distance measures such as distance to highways and major roads, distance to Tel Aviv and to the nearest central business district. The distance attributes are calculated by extracting the centroid point of each zone and calculating its distance to roads and to Tel Aviv and the nearest central business district using the "Near" geoprocessing tool in ArcGIS. In addition to the distance attributes, travel time variables such as average travel time to the four central business districts and travel time to the nearest central business district (CBD), are allocated to each zone based on accessibility measures from the National Transportation Model.

The buildings in the current application are allocated to one of four types (residential, governmental, industrial and commercial). As a result, the aggregation of buildings by type for every zone creates a maximum of four synthetic aggregated buildings per zone, representing the actual land \ floor space use within that area. Each building includes a variety of attributes (annual growth, average value per unit, building type, land area, nonresidential m², residential units, m² per unit and zone id). This allows for a more detailed representation of the building stock. The data used to populate the table comes from a national buildings GIS layer that was populated with attributes such as land use, floor space, land area, value and the number of households per building. By overlaying the zones layer with the national building layer, each building is assigned to a zone and the properties of each building type in a zone are aggregated.

Households within the UrbanSim model are represented as separate entities each receiving a unique identity and a variety of

attributes (age of head, building allocation, number of cars, children, income, persons, race, and workers). The demographic data allocated to each household is based on aggregated Statistical Area (SA)⁴ data which has been disaggregated by floor space and then re-aggregated to residential buildings and zones maintaining the SA total. The allocation process is done using SQL to disaggregate the number of households in each SA. Each household entity and its' socio-economic properties are allocated to a building. Full details of this process are described elsewhere (Lichter and Felsenstein, 2012). The age of the household head is taken as 50 years representing the national average. The number of household inhabitants (persons) is calculated by dividing the total population per SA by the number of households in the area. Annual household income is calculated by multiplying average SA monthly household income by 12 (months in a year). The race variable relates to Jewish and non-Jewish populations. The number of Jewish and non-Jewish households in a SA is calculated according to their proportion in the total number of inhabitants in the SA. The number of workers per household is calculated by deducting the number of persons under the age of 15 from the total population and multiplying by the percentage of participants in the work force during 2008 in the relevant SA. The number of households per SA where children are present is calculated by multiplying the number of households by the percentage of households having children under 18 years old. Households are classified as with children (1) or without children (0). Similarly, car availability has three categories: 0 cars, 1 car or 2+ cars. The number of households in a SA belonging to each of the three groups is calculated by multiplying the number of households in the SA by the percentage of households belonging to each category.

Jobs within UrbanSim are located within the zone of employment and are represented as separate entities able to freely locate, move and relocate. Each job within the model is identified by three variables; location, economic sector and home-based status. Jobs are allocated to specific building types with economic sector acting as the bridge. Thus every job is located within an industrial, commercial, governmental or residential (in the case of home-based employment) building. The building identifier then ties economic activity and home based employment to land use.

4.3. Port development scenarios

In order to simulate the land use changes arising from port expansion we articulate three scenarios. These are all derived from IPC development plans for the Haifa port, coastal area and hinterland grounded in the guidelines and estimates appearing in NOP13/B/1, the planning document pertinent to the area. This development plan divides the relevant area into 9 separate expansion areas (Fig. 1, Table 1). All scenarios cover the forecasting period 2008–2038. Under the 'business-as-usual'(BAU) scenario the model is left to run with no external intervention. This generates baseline conditions against which development scenarios are compared. The development scenarios posit two alternative futures. In the 'minimal development' scenario, we adopt lower bound figures from NOP13/B/1 for port expansion. In the 'maximum development' scenario, we inject a disturbance equivalent to the anticipated upper bound for development. For the latter two development scenarios we 'disturb' the model by injecting an exogenous change to commercial land area in three discrete stages for the years 2024, 2027 and 2030. This is in line with the expected incremental growth in commercial and

⁴ The SA is the smallest administrative unit for which socio-economic data is available. It represents spatial areas of roughly 3 000 inhabitants.

Table 1
Development scenarios.

Expansion area	UrbanSim zone (TAZ)	Built area expansion: minimum development scenario (m ²)	Built area expansion: maximum development scenario (m ²)	Additional employment: minimum development scenario	Additional employment: maximum development scenario
7	67	–	426 000	296	1 135
6	68	111 000	840 000	–	2 239
1a	70	138 600	138 600	19 634	25 450
1b	70	138 600	138 600		
2	70	150 000	150 000		
3	70	210 000	210 000		
5	70	–	402 000		
New port	70	720 000	720 000		
4	72	69 000	366 000	998	5 295

industrial floor space over the period of development and makes for a more realistic simulation. We then observe the cumulative impact at five year intervals starting from 2025 onwards. The maximum and minimum development scenarios are based on the likelihood of development given the land ownership issues and environmental constraints on IPC expansion plans.

To articulate these scenarios within UrbanSim we use the following steps that illustrate how expected areal expansion translates into expected additional employment. Initially, each of the nine expansion areas is categorized according to future economic activity planned to develop therein and assigned to one of the four relevant UrbanSim zones covering the area (TAZ's 67, 68, 70 and 72). The next step involves converting proposed land development (PLD) into floor space development (FSD). This is calculated as: $FSD = PLD * 0.6 * 1.5$. We assume the difference between net and gross land cover (that includes roads and infrastructure) is 40% and that the average number of floors per building is 1.5. We then proceed to subdivide calculated floor space into land use types (Commercial, Industrial and Governmental). This is based on the land-use mix existing in other similar concentrations in Israel. Expansion areas 70 and 72 (Table 1) categorized as port-focused development activity, are assigned land use and employment attributes based on those existing for the Ashdod port. Expansion areas 67 and 68 categorized as logistics-focused development activity, are assigned the land use and employment attributes of the Airport City logistics center that exists proximate to Ben Gurion International airport. Finally, expected additional employment under the two development scenarios is derived comparatively, using the sectoral employment shares existing in the Ashdod port and the Airport City logistics center. Given the distribution of employment and non-residential land consumption per employee in these two projects, we apply these ratios to the expected floor space in Haifa and derive the expected additional employment for the different expansion areas (Table 1).

The following scenarios are simulated:

4.3.1. Business as usual (BAU)

Under this scenario all the agents in the UrbanSim model (households, developers and jobs) are able to freely move around and develop. No limitations to development are implemented and no a-priori development events are simulated. The model allocates workers, jobs, population and land use as dictated by the control totals.

4.3.2. Minimum port development (PDMIN)

This scenario is based on the minimal predicted development and is composed of a variety of stages which include initial land reclamation, private port development and some hinterland development. The proposed development includes an addition of approx. 1.5 million m² of non-residential land use and

approximately 21 000 additional jobs, the vast majority in port-focused development activity (such as container handling, bonded warehousing, trucking and transportation, legal and customs services). Logistics-focused development activity is only marginally represented in this scenario. As noted above, this development is added incrementally to the model at discrete time steps in years 2024, 2027, 2030.

4.3.3. Maximum port development (PDMAX)

This scenario is based on the maximum predicted development and is composed of a variety of stages which include initial land reclamation, private port development and additional development in the port hinterland area. The proposed development includes an addition of approx. 3.4 mil m² of non-residential land use

Table 2
Simulated Impacts on Haifa Metropolitan Zones, by key variables 2038.

	Core	Inner	Outer	Total
Population				
BAU (%)	31.6	29.8	38.6	1 454 560
PDMAX (%)	31.0	29.6	39.5	1 461 078
PDMAX-BAU	-7 055	-2 106	15 679	–
PDMIN (%)	31.3	30.2	38.5	1 450 600
PDMIN-BAU	-5 881	4 171	-2 250	–
Jobs				
BAU (%)	44.0	20.9	35.1	661 320
PDMAX (%)	47.0	19.8	33.3	695 883
PDMAX-BAU ^a	1 996	-473	-960	–
PDMIN (%)	45.9	20.1	33.9	684 151
PDMIN-BAU ^a	2 388	-367	-190	–
Residential units				
BAU (%)	31.6	30.1	38.3	563 476
PDMAX (%)	31.0	29.9	39.1	564 764
PDMAX-BAU	-2 972	-1 013	5 273	–
PDMIN (%)	31.3	30.5	38.2	560 666
PDMIN-BAU	-2 620	1 315	-1 505	–
Total value residential capital stock (Israeli shekels, billion nominal 2008 values)				
BAU (%)	30.4	30.4	39.2	1 248.5
PDMAX (%)	31.2	29.7	39.2	1 275.4
PDMAX-BAU	1 851.1	-97.5	939.6	–
PDMIN (%)	30.2	30.6	39.3	1 234.1
PDMIN-BAU	-659.5	-224.4	-549.7	–
Non-residential floor space (m²)				
BAU (%)	37.6	24.0	38.4	26 315 720
PDMAX (%)	44.1	21.5	34.4	28 985 610
PDMAX-BAU ^a	-499 216	-93 727	-137 167	–
PDMIN (%)	41.0	22.8	36.3	27 224 225
PDMIN-BAU ^a	-231 837	-120 296	-239 362	–

^a For the jobs and residential floor space variables, the differences between scenario and baseline estimates also discounts the initial injection used to generate the shock (jobs and floor space).

and approx. 34 000 additional jobs. Again the majority of expected employment is in port-focussed activity but in terms of built area, the scenario gives much more focus to the development of large scale hinterland logistics activities. These are space intensive (anticipated expansion of 1.15 mil m²) but not labour intensive (an additional 3 300 jobs). Again, this expansion is injected incrementally into the model over three periods so as to create a more realistic development scenario.

5. Empirical results

We now examine the simulated ripple-through effects of port expansion. The scenarios relate to a sequential increase in commercial and industrial floor space between 2024 and 2030 and the results are observed for 2038. The impact of the increase is simulated for 5 key variables: population, jobs, number of residential units, value of residential units and non-residential floor space. Given the absence of virgin land for expansion in the case study area, we are particularly interested in observing the zero-sum and displacement effects generated by a large, point-oriented increase in non-residential floor space. The results are presented at three levels. First, we look at the aggregate metropolitan wide effects distinguishing between core, inner and outer rings. Then we observe these changes at the TAZ level. This spatial zone-based analysis, allows us to identify some of the more subtle variation across the metropolitan area. Finally, we focus on one particular aspect of the zero-sum land-use trade off and analyze the effect of port expansion on residential choice in the Haifa area.

5.1. Aggregate analysis

Table 2 presents summary simulation results for the Haifa metropolitan area in 2038. The percentage share of each of the five key variables across the three broad rings is presented for the BAU, PDMax and PDMIN scenarios. Additionally, the difference between the scenario and the baseline (BAU) is presented in absolute terms.

Under all scenarios, population in the core is expected to double by 2038 and increase in the inner and outer rings by 75% and 43–48% respectively (contingent on the specific scenario). These are gross increases over the initial 2008 population which is roughly 250 000 in both the core and inner rings and 500 000 in the outer ring. Under the maximum scenario, total net population impact (discounting all alternative growth in the absence of the port) is 0.3 percent greater than the baseline with the highest impact expected in the outer ring (Table 2). In the minimum scenario, total population falls short of the baseline with the inner ring gaining relatively but the core and outer rings losing population shares in comparison with the BAU scenario. Port development which includes three injections of new employment and non-residential floor space in years 2024, 2027 and 2030, does not seem to have any dramatic effect on population increase in metropolitan Haifa when compared to the counterfactual situation.

In terms of employment, gross jobs by 2038 are predicted to be between 95 and 110 percent higher than the initial 2008 levels in all rings and under all scenarios. Additionally, the injection of 21 000 port-related jobs in the core under the minimum scenario and 34 000 jobs under the maximum, both register positive gross employment effects in the metropolitan area after discounting for growth that would have occurred alternatively. Under all three scenarios, since the jobs are injected in the core, their footprint is evident through till 2038 with over 40 percent of all employment taking place in this area (Table 2). Under both the PDMax and PDMIN scenarios, the core registers a positive job effect versus the alternative in 2038 while the inner and outer rings do not break even. In the core, this net effect is worth about 550 jobs under the

maximum scenario and approximately 2000 jobs under the minimum scenario. While these are moderate net increases given the scale of the initial shock, the most pertinent finding is that the minimum scenario has a greater impact in the core, than the maximum scenario. This is because the difference between the two scenarios is substantial in terms of additional floor space but less so in terms of additional employment. Most of the additional non residential space under the PDMax scenario (logistics and storage space) does not translate into job-intensive employment.

Given the expected population and job distribution as depicted in Table 2, we now examine where the extra workers and residents are likely to reside. What does a shock to non residential land use do to residential land use? At the outset, it should be noted that this latter variable registers a much lower gross increase from its starting level, than all the other variables. By 2038, the gross number of residential units across all scenarios and metropolitan rings expected to rise by 58–65% from its initial level. This lower level of response within the Haifa metropolitan area, may imply that some of the demand for residential housing triggered off by port development, will be met outside the area. In other words, non-residential development has an effect on residential choice. Second, when discounting the BAU scenario, the net effects found to be most significant under the PDMax scenario, are in the outer ring (net increase of 5 273 units) and in the inner ring under the PDMIN conditions with a net increase of 1 315 units (Table 2). In all other situations, the result (versus the alternative) is negative. This suggests that non residential development has a ripple-through displacement or substitution impact on residential development. Such a result is especially true for the crowded coastal core where any new form of land use development is likely to have zero sum effects.

Taking this observation a step further, we look at the effect of port expansion on the value of residential stock. If the increase in non-residential development associated with the port squeezes residential land use elsewhere, we expect this to be reflected in capital stock values. In places where residential development is expected to expand, we expect the value of capital stock to increase due to increase volume of housing. But we expect a more dramatic rise in areas where the volume of residential units is displaced and demand still remains high. In such places, we expect rising house prices to cause disproportionate upward pressure on house values.

The results in Table 2 reflect these expectations. Under the PDMax scenario, the core is the area where the most residential displacement occurs (Table 2) and consequently it is the area where value of residential stock increases most. In this area, the value of housing by 2038 is anticipated to be 1.85b Israeli shekels more than the alternative. This figure is roughly 60 percent of the difference in total value of housing stock in metropolitan Haifa between the maximum and BAU scenarios. Thus, the pressure for residential units in the core as a result of port expansion is likely to capture nearly two thirds of the appreciation in residential capital stock values in the total metropolitan area by 2038. In the inner ring, the port is expected to constrain the number of residential units by roughly one third of those in the core. However, in terms of value, things are very different. Because of the much lower values of properties, the total capital stock value in this area does not even equalize the value that would have existed under the alternative and falls short by roughly 0.1b Shekels. In the outer ring, where port development acts as a catalyst for residential development, there is an expected increase in the value of residential stock simply due to the increase in volume of residential units. This amounts to about half of that expected in the core.

Under the PDMIN scenario the port constrains the building of residential units in the core and outer ring but not the inner ring. However as port land use expansion is only about 45 percent of that

expected under the maximum scenario, its effects on residential units and value of stock are much less. In all areas it causes a reduction in the value of capital stock less than that likely to occur in the absence of port expansion and this reduction is much less than under the maximum scenario and marginal in the inner ring (a reduction of 0.2b shekels in the value of residential stock). The effect of displacement on residential values is therefore felt most acutely within the core and when the threat of displacement is most acute.

Finally, we look at principle land use trigger for the simulation, the addition of non-residential floor space in the metropolitan core. As to be expected, this changes the relative shares of non residential land use across the metropolitan area and strengthens the core at the expense of both the inner and outer rings (Table 2). Gross floor space addition in 2038 ranges from 79 to 147 percent more than initial levels in 2008, depending on scenario and metropolitan zone. Net floor space shows a somewhat different picture. When discounting for BAU growth alone, the net difference (2.9 mil m²) is roughly the size of the disturbance, i.e. the one-time maximum injection of 3.4 mil m². is equivalent in size to the expected 'natural' growth in commercial/industrial floor space. The 'shock' of port development thus doubles non-residential development beyond what it might have been under BAU conditions. The same is roughly true for the PDMin scenario where an additional 1.5 mil m² are injected into the core. The difference between this scenario and the BAU case is 1.3 mil m². Thus when the injection of a fully developed port is also netted out of the forecast, we get the marginally negative values in Table 2. The main observation here is that the port development not only displaces residential development but also non-residential floor space and mainly in the core.

5.2. Zone level analysis

Given that the spatial building block of our analysis is the TAZ, we now present the simulation results disaggregated to that level. We do this for the same key variables identified in Table 2 and present a series of maps relating to the percentage change over the period 2008–2038.

With respect to jobs, the scenario results for PDMax show a higher increase in the number of jobs relative to BAU occurring in the core area, the inner city neighborhoods and the industrial bay area surrounding the port (Fig. 3). Outside the core area, a higher increase in the number of jobs occurs in the inner ring town of Tirat

Hacarmel south of Haifa. In the outer ring, an increase occurs south of the town of Tivon and in the vicinity of the town of Karmiel. On the other hand, a decrease in the number of jobs (relative to BAU) can be discerned in the northern outer ring area, east and north of the city of Acre. In the PDMin scenario, differences from BAU are less pronounced. Most of the increase in the number of jobs occurs in the bay area, in the vicinity of the port.

In terms of the effect of port development on residential units and the number of inhabitants, we can see that both the number of units and inhabitants experience a higher increase in certain parts of the Haifa city core under the BAU scenario than under both port development scenarios (Figs. 4 and 5). Under PDMax, both the number of residential units and the number of inhabitants are slightly higher in certain zones in the city core, however in neither one of these scenarios do these increases exceed those of the BAU scenario. The spatial patterns of population increase closely follow the patterns of increases in residential units as expected. An increase in the number of residential units in the PDMax scenario, relative to the BAU scenario occurs in the southern part of the outer ring. An increase in residential units under this scenario occur in the outer ring especially around established growth poles such as Karmiel and Yokneam.

Both development scenarios will cause a decrease in the value of residential real-estate in the outer ring of the metropolitan area relative to the BAU scenario. This trend prevails in the BAU scenario as well but is much less pronounced. As noted above this is probably the result of the effect of port development on residential buildings, however it may also be a secular trend regardless of port development. Increasing the supply in the outer ring growth poles will pull down prices in these places. In the city core, the residential areas adjacent to the port are likely to lower increase in value (compared with the alternative) due to obvious negative externalities. The situation is different however for select zones that form a ring of locations where positive value changes can be expected (light blue colored TAZ's at the edge of the core, Fig. 6). City neighborhoods south of the port will experience reduced real-estate values relative to BAU. But those zones at the edge of the city core are probably sheltered from the disutilities of the port and are likely to experience a rise in unit values or a reduced decrease.

Finally, both development scenarios lead to a spatial concentration of non-residential floor space (Fig. 7). Non residential development tends to cluster in select locations. In contrast, under the BAU scenario, non-residential floor space is distributed more

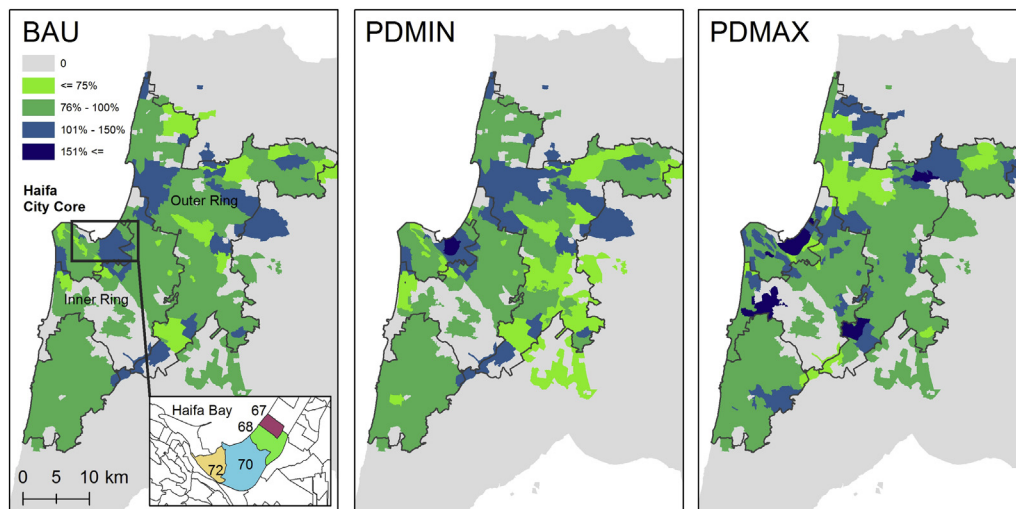


Fig. 3. Jobs (change in % years 2008–2038).

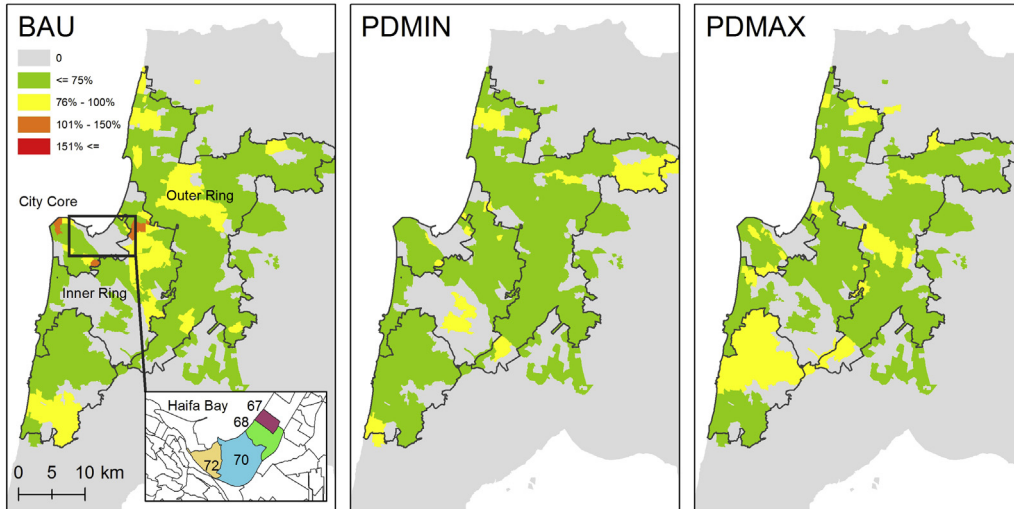


Fig. 4. Residential Units (change in % years 2008–2038).

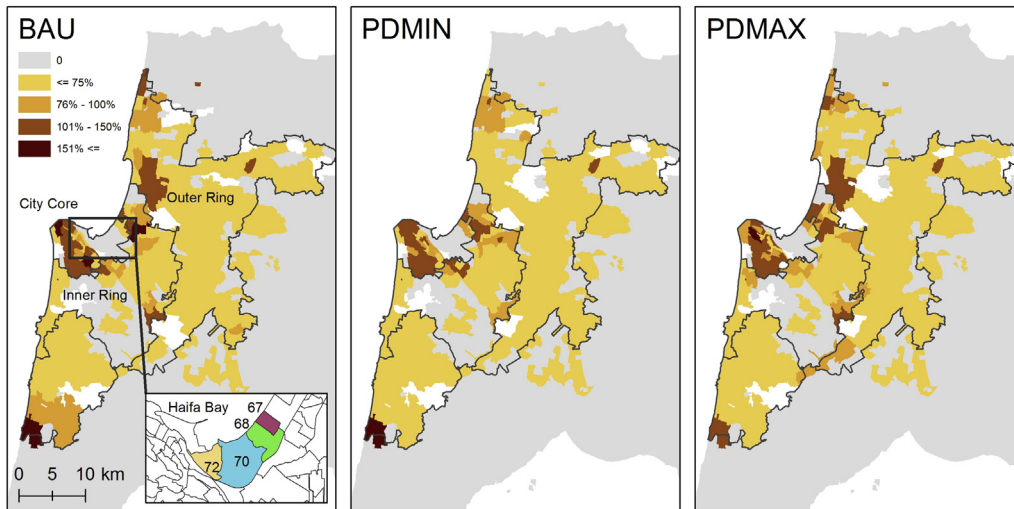


Fig. 5. Population (change in % years 2008–2038).

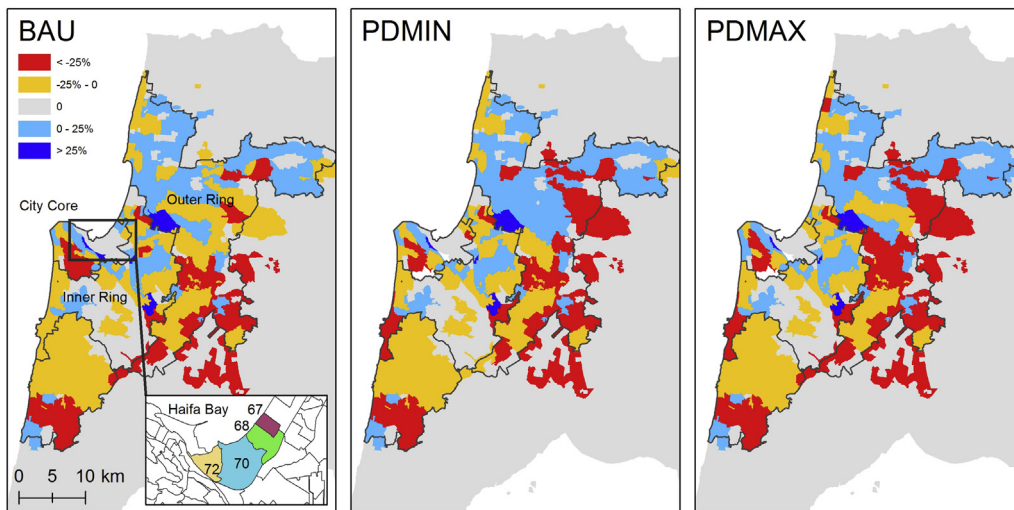


Fig. 6. Residential units value (change in % years 2008–2038).

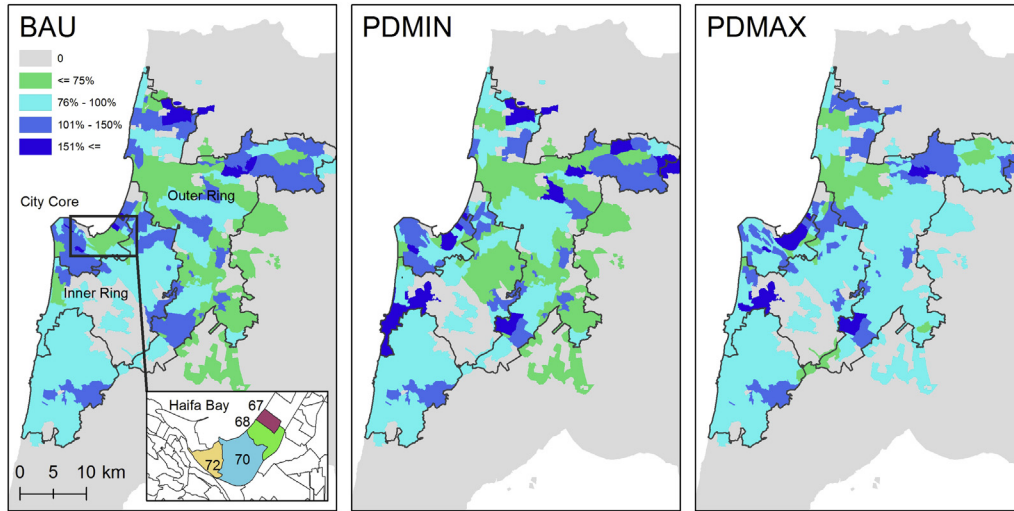


Fig. 7. Non-residential floor space (change in % years 2008–2038).

equally across the metropolitan area. An increase of non-residential floor space occurs in the bay area (in the vicinity of the port) in both development scenarios. In the PDMIN scenario, and even more profoundly under PDMAX, non-residential floor space is reduced in the inner city neighborhoods. In selected areas in the inner and outer rings, port development scenarios lead to an increase in non-residential floorspace, specifically in the southern portions of the metropolitan area.

5.3. Port expansion and residential choice

The section deals with the question: what does port expansion do to residential choice in the metropolitan area? This is a highly pertinent question because the change in residential values, triggered off by port expansion identified above, is likely to have further implications on residential choice. For the individual, the decision to choose the Haifa metropolitan area over other alternatives or the decision where to live within the Haifa metropolitan area, is likely to hinge, ceteris paribus, on the relative cost of residential units.

In contrast to the foregoing dynamic simulation, the analysis here is statistical and cross sectional. The empirics are suggestive rather than exhaustive. Statistical testing is presented to add further weight to the identification of the ripple-through process that we argue, underpins port expansion. To proceed, we first establish the causality in the residential value-residential choice relationship. While we imply that the former influences the latter, we need to be able to discount any potential endogeneity. To do this, we estimate the simultaneous relationship between residential land values (as a proxy for the value of residential capital stock variable analyzed above) and residential choice. This is formulated initially as a binary choice of Haifa metropolitan area versus elsewhere. Given the fact that our value variable is continuous and our choice variable is dichotomous, the appropriate estimation procedure is probit two-stage least squares (P2SLS) regression. The details of this procedure are described in the Appendix. Having established the direction of causality, we then proceed one step further and estimate a second multinomial logit (MNL) regression in which residential choice is either the core, inner or outer ring of Haifa versus the alternative of location elsewhere in the country.

The P2SLS results confirm that land values are inversely related to residential choice in metropolitan Haifa but not the other way around (Table 3) This choice is also inversely related to the number

Table 3

Probit 2SLS (P2SLS) estimation of land values and residential choice.

In land value		Residential choice (Haifa metropolitan area; other)	
Constant	8.787	Constant	-2.664
Haifa Met	-0.432	In land Value	-0.687*
In HH Inc	0.014*	In HH Inc	0.053
In distance TA	0.908	In distance TA	1.037*
In avg time CBD	-1.307	In jobs	-0.117*
In vacant land	0.095*		
In number units	-0.388		
Adj. R ²	0.599	Pesudo. R ²	0.277
		LRχ ²	156.03
		Log likelihood	-202.877

N = 563.

All continuous variables in ln.

*significant coefficient, p < 0.01.

of jobs (agglomeration effect) of Haifa with respect to the alternative, i.e. location elsewhere in the country. Land values themselves are directly related to income and the amount of vacant land. As this regression is in logarithms, the coefficients are directly interpretable as elasticities. A rise of 1 percent in the average TAZ income will translate into a rise of 1.4 percent in land values.

The MNL estimation reconfirms the inverse relationship between land values and residential choice within each of the main zones of the metropolitan area (Table 4). As land values rise, the probability of choosing Haifa as a residential location (core, inner or

Table 4

Probability of residential location, Haifa metropolitan area: MNL regression.

	Residential location choice: Haifa		
	Core	Inner ring	Outer ring
Constant	-2.553	-14.628	-20.702
In land value	-1.442*	-1.613*	-0.765*
In HH inc	0.006	1.421*	0.558
In distance TA	1.623*	1.736*	2.185*
In jobs	0.165	-0.038*	-0.270*
Pseudo R ²	0.227		
LRχ ²	192.21		
Log likelihood	-309.71		

N = 563.

Baseline category – outside Haifa Metropolitan area.

All continuous variables in logs.

*significant coefficient, p < 0.05.

outer ring) versus the alternative, falls. The outer ring seems to compete best with the alternative and has the smallest coefficient, but this is still negative and significant. Higher income groups tend to choose the inner ring over the alternative but not the core perhaps because it is too close to the port and its negative externalities. Neither do they choose the outer ring which is probably too peripheral in relation to the alternatives. Distance to Tel Aviv has a positive effect on residential choice within the Haifa metropolitan area and this affects increases with the move from the core to the inner and outer rings. The impact of distance is the least for the core probably because the proximity to Haifa substitutes for Tel Aviv making it relatively less attractive. Distance has the largest impact on the probability of choosing the outer ring probably because the alternatives are less attractive. This may be interpreted as evidence of a 'cushioning' or 'lock-in' effect of distance: more distant locations such as the outer metropolitan ring are beyond the wide residential shadow cast by Tel Aviv.

The implication of these results for port development are clear. The anticipated ripple-through effects identified above (Sections 5.1 and 5.2) generated by a shock to commercial/industrial coastal land use on the value of residential units, have implications for the ability of the Haifa metropolitan rings to compete as a residential location. The interpretation of the robust negative coefficient on land value (Tables 3 and 4) is that increasing port development may squeeze the residential market in Haifa causing it to become high priced (high value of residential capital stock or land values). In a congested coastal urban environment such as Haifa, this is an exemplar of zero-sum development. Thus, there is a residential cost to be paid for port expansion.

6. Conclusions and coastal management implications

We have shown above that port expansion in the Haifa core is likely to generate longer-run spatial impulses throughout the metropolitan. Because of the congested conditions along the Israeli coast, a short-term, place-oriented shock can have longer term land use effects due to the displacement effect that it triggers. We have highlighted the effect of the non-residential development associated with port expansion on residential development and similar processes can be identified in non-coastal locations and with respect to other land uses (Felsenstein et al., 2013). Port expansion is a land-intensive activity. However, as we have shown, the employment differences between the maximum and minimum expansion scenarios are small as increasing port-related land use does not proportionately increase employment. The anticipated extra employment resulting from port expansion, squeezes residential development in the vicinity of the port and creates development opportunities in the outer ring (maximum scenario) and more limited development in the inner ring (minimum scenario).

Underlying the dynamic processes outlined in this paper is the fundamental observation that coastal land is a resource with inelastic supply. In a congested environment, port expansion is zero-sum, coming at the expense of other land uses. The challenge would seem to be efficiently using available limited land use resources and balancing development across many competing uses and stakeholders. This would avoid the market failure that leads to the under-developed, low density landscape of dereliction and abandonment that characterizes current land use utilization in the Haifa port hinterland. Ostensibly, the praxis of integrated coastal zone management (ICZM) offers a whole suite of procedures for dealing with this kind of situation. These include mechanisms for improving coastal governance, introducing regulatory commissions, streamlining the planning system and the like (Christie et al., 2005; EEA, 2006). However cumulative international experience suggests that the efficacy of these ICZM tools is rather limited

(Portman et al., 2012). They often suffer from a time lag with respect to implementation and enforcement that dilutes their effectiveness and has them chasing rather than regulating development.

Our results suggest that due to the crowded nature of coastal development, over time the intensification of land use is inevitable (and desirable). While the nature of port hinterland activities such as warehouses and logistics centers, dictate relatively low density development, current under-utilization of land use could be the principle bottleneck to future development. This calls for a concerted effort in the areas of both brown-field restoration and land re-parcelization in order to reduce the problem of ownership fragmentation. While these would seem to point to tools out of the standard ICZM arsenal that includes regulation, planning coordination etc, our message is that the ripple-through impacts of port development generate spatially dispersed outcomes. While we have sketched the outline, future work needs to articulate these in a more direct fashion. This would include not just observing how and where port expansion impacts the wider region but the more spatially textured issue of whether port expansion causes neighboring zones to compete with or complement each other and who wins or loses in this process.

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Appendix. Regression analysis

1. Estimation

We use probit two-stage least squares (P2SLS) regression to estimate simultaneous equations for land values and residential choice. Formulating a joint sub-system incorporating these variables presents an estimation challenge as the former is an observed continuous variable while the latter is dichotomous. The standard 2SLS approach where both endogenous variables are continuous is therefore not appropriate. We use the approach suggested by Maddala (1983) which involves creating instruments for the endogenous variables in the first stage and substituting them into the structural equations in the second stage. This is applied using the CDSIMEQ 2-stage routine programmed in STATA (Keshk, 2003).

In stage 1 (estimated by OLS and probit), models are fitted using all exogenous variables and the predicted values obtained. From these reduced-form estimates, predicted values from each model are obtained for use in Stage 2. In this stage the original endogenous variables from the first stage are replaced by their fitted values. Finally, we correct for standard errors (adjustment of the variance-covariance matrices) as the models are based on predicted values and not on the appropriate observed values.

In our case the 2-equation system consists of a land value model (y_1 - continuous variable) estimated by OLS and a residential choice (y_2 - dichotomous variable) estimated by probit, as follows:

$$y_1 = \gamma_1 y_2^* + \beta_1 \mathbf{X}_1 + u_1 \quad (1)$$

$$y_2^* = \gamma_2 y_1 + \beta_2 \mathbf{X}_2 + u_2 \quad (2)$$

Note that while $y_1 = y_1^*$, y_2^* is observed as a dichotomous endogenous variable, i.e. it equals 1 if $y_2^* > 0$ and 0 if otherwise.

As y_2^* is not observed (i.e. only observed as a dichotomous variable), the structural equations (1) and (2) are re-written dividing through by standard errors:

$$y_1 = \gamma_1 \sigma_2 y_2^{**} + \beta_1' \mathbf{X}_1 + u_1 \quad (3)$$

$$y_2^{**} = \frac{\gamma_2}{\sigma_2} y_1 + \frac{\beta_2'}{\sigma_2} + \mathbf{X}_2 \frac{u_2}{\sigma_2} \quad (4)$$

The two-stage estimation then proceeds with the estimation of reduced-form OLS and probit models for land values and residential choice respectively:

$$y_1 = \Pi_1 \mathbf{X}_1 + v_1 \quad (5)$$

$$y_2^{**} = \Pi_2 \mathbf{X}_2 + v_2 \quad (6)$$

where X = matrix of all exogenous variables and Π_1, Π_2 = vectors of parameters to be estimated.

The predicted values from equations (5) and (6), $\hat{y}_1, \hat{y}_2^{**}$, are plugged back into the model for the second stage estimation. Thus the original endogenous variables in (1) and (2) are replaced by their fitted values from (7) and (8).

$$y_1 = \gamma_1 \hat{y}_2^{**} + \beta_1 \mathbf{X}_1 + u_1 \quad (7)$$

$$y_2^{**} = \gamma_2 \hat{y}_1 + \beta_2 \mathbf{X}_2 + u_2 \quad (8)$$

2. Data

The source of data relating to household income, employment, land value, distances and travel times is the 2008 Census and the National Travel model as outlined in Section 4.2 (above). The spatial resolution of much of this data is the SA and it is aggregated to the level of the TAZ for the purpose of UrbanSim processing. Residential choice is UrbanSim data, generated from Monte Carlo sampling for residential choice by TAZ. The sample size is 563 and the coverage is national. This means that residential choice can be either metropolitan Haifa or another location nationally. Additionally, since all the data is TAZ-based, we can disaggregate choice within the Haifa metropolitan area to core, inner or outer zone (versus elsewhere).

In stage 1 of the P2SLS system we use OLS to regress land values on residential choice (Haifa or other), household income, distance to Tel Aviv, average travel time to nearest CBD, vacant land and number of residential units. We use probit to regress residential choice on land value, household income, distance to Tel Aviv and number of jobs. In stage 2 we take the fitted values from Stage 1 and repeat the estimation correcting for standard errors. The results are reported in Table 3. The MNL regression (reported in Table 4) uses the same covariates as the probit regression.

References

- BOI, 2014. Policy towards the Development of Israeli Seaports. Recent Economic Developments #137. Research Department, Bank of Israel, Jerusalem. <http://www.boi.org.il/he/NewsAndPublications/RegularPublications/Pages/develop137.aspx>.
- CBS, 2012. Long Range Population Projections for Israel: 2009–2059. Demography and Census Department, Central Bureau of Statistics, Jerusalem.
- Christie, P., Lowry, K., White, A., Oracion, E.G., Sievanen, L., Pomeroy, R.S., 2005. Key findings from a multidisciplinary examination of integrated coastal management process sustainability. *Ocean. Coast. Manag.* 48, 468–483.
- de Kok, J.L., Engelen, G., White, R., Wind, H.G., 2001. Modeling land-use change in a decision-support system for coastal-zone management. *Environ. Model. Assess.* 6, 123–132.
- EEA, 2006. The Changing Faces of Europe's Coastal Areas. European Environment Agency, Office for Official Publications of the European Community, Luxembourg.
- Felsenstein, D., Lichter, M., Ashbel, E., Grinberger, A.Y., 2013. Land use-land cover dynamics at the urban fringe. In: Malkinson, D., Czamanski, D., Benenson, I. (Eds.), *Modeling Land Use and Ecological Dynamics*. Springer, Heidelberg, pp. 143–165.
- Fujita, M., Mori, T., 1996. The role of ports in the making of major cities: self-agglomeration and hub-effect. *J. Dev. Econ.* 49, 93–120.
- Haifa Port, 2014. <http://www.haifaport.co.il/template/default.aspx?PageId=25> (accessed 01.06.14).
- Hansen, H.S., 2007. An adaptive land-use simulation model for integrated coastal zone planning. In: Fabrikant, S.I., Wachowicz, M. (Eds.), *The European Information Society: Leading the Way with Geo-information*. Springer, Berlin, pp. 35–53.
- Hansen, H.S., 2010. Modelling the future coastal zone urban development as implied by the IPCC SRES and assessing the impact from sea level rise. *Landsc. Urban Plan.* 98, 141–149.
- Huang, W.-C., Chen, C.-H., Kao, S.-K., Chen, K.-Y., 2011. The concept of diverse developments in port cities. *Ocean. Coast. Manag.* 54, 381–390.
- Keshk, O., 2003. CDSIMEQ: a program to implement two-stage probit least squares. *Stata J.* 3 (2), 1–11.
- Lichter, M., Felsenstein, D., 2012. Assessing the costs of sea-level rise and extreme flooding at the local level: a GIS-based approach. *Ocean. Coast. Manag.* 59, 47–62.
- Luo, M., Yip, T.L., 2013. Ports and the environment. *Marit. Policy Manag.* 40 (5), 401–403.
- Maddala, G.S., 1983. *Limited Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, Cambridge, UK.
- MOF, 2012. Annual Report, State Revenue Administration. Ministry of Finance, Jerusalem (Hebrew).
- MOI, 2013. NOP 42: Integrated National Outline Plan for Land Transportation. Ministry of the Interior, Jerusalem (Hebrew).
- Notteboom, T.E., 2004. Container Shipping and Ports: An Overview. *Rev. Netw. Econ.* 3 (2), 86–106.
- Notteboom, T.E., Rodrigue, J.P., 2005. Port regionalization: towards a new phase in port development. *Marit. Policy & Manag.* 32 (3), 297–313.
- Oliviere, D., Slack, B., 2006. Rethinking the port. *Environ. Plan.* 38, 1409–1427.
- Portman, M.E., Esteves, E.L.S., Le, X.Q., Khan, A.Z., 2012. Improving integration for integrated coastal zone management: an eight country study. *Sci. Total Environ.* 439, 194–201.
- Robinson, R., 2002. Ports as elements in value-driven chain systems: the new paradigm. *Marit. Policy Manag.* 29, 241–255.
- Rodrigue, J.P., Notteboom, T.E., 2010. Foreland-based regionalization: integrating intermediate hubs with port hinterlands. *Res. Transp. Econ.* 27, 19–29.
- Rubin, Z., Felsenstein, D., 2013. Regional GDP Estimates for Israel (unpublished) (Hebrew).
- Sante, I., Garcia, A.M., Miranda, D., Crecente, P., 2010. Cellular Automata Models for the simulation of real world urban processes: a review and analysis. *Landsc. Urban Plan.* 96 (2), 108–122.
- Saz-Salazar, S., García-Menéndez, L., 2007. Port Expansion and Negative Externalities: Estimating the Costs Borne by Local Residents. Department of Applied Economics, University of Valencia, Valencia, Spain (unpublished). <http://www.alde.es/encuentros/antiores/xveea/trabajos/s/pdf/46.pdf>.
- Technion, 1997. Israel 2020: Masterplan for Israel in the 21st Century. Neaman Institute, Technion, Haifa.
- UrbanSim, 2011. The Open Platform for Urban Simulation (OPUS) and UrbanSim Version 4.3, Users Guide and Reference Manual. The UrbanSim Project University of California Berkeley, and University of Washington. <http://www.urbansim.org/downloads/manual/latest-stable-release/opus-userguide.pdf>.
- Waddell, P., Borning, A., Noth, M., Freier, N., Becke, M., Ulfarsson, G., 2003. Microsimulation of urban development and location choices: design and implementation of UrbanSim. *Netw. Spat. Econ.* 3 (1), 43–67.
- Waddell, Paul, 2011. Integrated land use and transportation planning and modeling: addressing challenges in research and practice. *Transp. Rev.* 31 (2), 209–229.
- Wan, Y., Zhang, A., Yuen, A.C.L., 2013. Urban road congestion, capacity expansion and port competition: empirical analysis of US container ports. *Marit. Policy Manag.* 40 (5), 417–438.
- Zviely, D., Kit, E., Klein, M., 2007. Longshore sand transport estimates along the Mediterranean coast of Israel in the Holocene. *Marine Geol.* 238 (1–4), 61–73.
- Zviely, D., Kit, E., Rosen, B., Galili, E., Klein, M., 2009. Shoreline migration and beach-nearshore sand balance over the last 200 years in Haifa Bay (SE Mediterranean). *Geo-Marine Lett.* 29 (2), 93–110.