Interactive Learning through Gaming Simulation in an Integrated Land Use-Transportation Planning Course

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ABSTRACT

The paper describes the use of gaming simulation in the teaching of integrated land use-transportation planning as a part of an undergraduate civil engineering course. A key innovation of the UPTown game developed at the University of Pretoria, South Africa, is the way in which the actions of both public sector planners and private sector real estate developers are simulated by students. This allows students to explore the problems of conflicting objectives and to discover the value of cooperative planning in the land use and transportation development process. The paper describes the background to and rationale for an integrated planning course, and it explains the game and simulation aspects in detail. Assessment of student performance showed that the game significantly enhanced the achievement of learning outcomes. Students who faced more complex and open-ended tasks performed better, reaching higher levels of competence earlier on in the game. The paper should be of value to educators who wish to develop new approaches, such as gaming simulation, to respond to contemporary engineering students' preferences for more active and social learning styles.

Subject headings: Transportation engineering; Engineering education; Simulation

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Introduction

The need to integrate the practice of land use development and transportation planning, as a means of achieving more sustainable, livable, and inclusive communities, has been argued by many scholars (Levinson and Krizek 2008; Handy et al. 2002). Civil engineering curriculums increasingly reflect this integration by including modules on land use and urban and regional planning (Lyles 1987; Khisty 1987; Krizek and Levinson 2005) in order to, as Khisty (1987: 58) puts it, “contribute to the development of analytical, synthetical, and creative abilities of engineers.”

Yet there still seems to be some confusion on what the nature and content of a typical integrated planning module should be, in what is regarded as an already overloaded engineering curriculum. Too often planning courses are presented to engineering students either by engineers who have too limited knowledge of planning, or by planners who have too limited experience of engineering. This results in planning modules with an inadequate scope, for instance a focus on land use only. The integration of urban and regional planning within the engineering curriculum is further hindered by epistemological differences between the disciplines: various authors have argued that civil engineers and planners are fundamentally different in terms of their preferred approach to knowledge, their personality traits, and even their values (Lyles 1981). Planning modules within the civil engineering curriculum thus need to be (1) appropriately structured to elucidate the conceptual linkages between the engineering and planning disciplines; and (2) delivered using appropriate and innovative teaching methods that help bridge the epistemological gap between “social” planning and “technical” engineering.

This paper reports on the use of gaming simulation to help bridge the planning-engineering gap during the teaching of an integrated transportation and land use planning course for undergraduate civil engineering students. Computer-based simulation is considered a promising tool to enhance classroom instruction (Zhu et al. 2011) and to respond to the changing learning styles of contemporary students, including a greater preference for social and active learning methods. Yet simulation has not been widely adopted due to (1) difficulties in developing suitable simulation games, and (2) inadequate demonstration of its effectiveness in education practice (Zhu et al. 2011). We contribute to this area by, firstly, describing the game and its use of technology, and, secondly, assessing the effectiveness of key aspects of the game as a teaching tool.

The UPTown simulation game is designed to help students explore the linkages between infrastructure investment, land development, and city efficiency and equity outcomes, by guiding the development of a hypothetical city over time. Its innovation lies in the way it asks students to simulate the decisions of *both* public sector planners and profit-seeking developers, and the interactions between them, thereby allowing them to discover the value of collaboration and integration not only across professional disciplines but also between the public and private sectors.

The paper starts by describing the pedagogical rationale behind the teaching of land use and transportation planning in an integrated course – with an emphasis on the South African realities – and the need for new teaching methods in this field. This is followed by an in-depth description of the simulation game, and its application within the integrated planning curriculum. Finally, we assess the outcomes of the game and offer conclusions and recommendations on its refinement and potential application elsewhere.

Background

Redefining the role of urban planning in engineering practice

Planning and engineering have not always been detached from each other. During the first half of the nineteen hundreds, when the so-called rational or modernist urban planning system was predominantly a physical, technical and scientific discipline and recognised for its 'professional scientific status' (see Muller 1994; Cuthbert 1985; and Coetzee 2005), it was probably easier for engineers (who in many cases practised certain components of planning such as township design), to associate and integrate with the urban planning profession. However since the mid-1990s the planning profession has transformed internationally, from a predominantly technical profession to one that is more concerned with policy, people and social rationality. Planners increasingly started engaging with community participation and community building processes, conflict resolution and policy making. Various assessments of the transformation of planning indicated that it was (initially) difficult for planners (and even more so for engineers) to adapt to these new 'social processes' and community engagement processes, mainly because these technical professions (and specifically the engineers) were so entrenched in the more physical, technical and scientific domains (Coetzee 2005). This new shift of emphasis gradually started to divorce urban planning from the engineering profession. This could be one of the reasons why such limited attention was given to teaching planning in the engineering curricula.

During the 1970s, the emergence of environmental management signalled a new connection between planners and civil and transportation engineers, and the need for a mutual understanding of development. The major developmental turn in planning came in the mid-1970s (partly as a result of the neo-liberal notion of New Public Management (NPM) that emerged in the Thatcher era in the UK) (Harrison 2002; Coetzee 2005). As a result of this movement, planning became more developmental and performance oriented and also more entrenched in municipal management (Taylor 1998). During the 1970s and 1980s, partly as a result of the influence of neo-liberalism and the increasing global and local challenges facing cities and urban regions, the rigid and limited old style city plans, structure plans and development plans started incorporating the principles of strategic planning with its strong focus on visioning, longer term planning, integrated planning, strategic direction, and performance (Coetzee 2005). Major city regions and cities all over the world started drafting strategic plans for their regions, to provide direction for the future growth and development of their cities.

It was the composite effect of these planning trends – the integrated, people-oriented, developmental character, and the strategic planning approach – that eventually spurred the need for an integrated urban planning and management system and a closer relationship between urban planning, development, and urban management (including civil, municipal, and transportation engineering). A new integrated, multi/inter-disciplinary and cross-sectoral approach to planning was needed.

In South Africa this transformation of planning coincided with the political transformation of the 1990s, which introduced entirely new developmental objectives into governance. Prior to the 1990s, the old apartheid planning system in South Africa was widely criticised for its contribution to the creation of fragmented spatial patterns; racial, socio-economic and land use segregation; unsustainable human settlements far from the workplace; and poor quality places and environments (Oranje et al 2000; Republic of South Africa 1999; Coetzee 2005). Apart from ideological drivers, these problems were also fuelled by (1) fragmentation in planning organisations and processes; (2) poor communication and consultation; and (3) a lack of integrated and inter-disciplinary planning. The emerging planning system in South Africa, which was largely spurred by the international trends discussed above (Harrison 2000), was increasingly seen as an important tool to address the enormous challenges of spatial and social reconstruction in urban areas; the enhancement of service delivery; spatial integration; and the development of previously disadvantaged areas. A slew of new policies and laws appeared to entrench the new role of planning.

Of particular importance is the Municipal Systems Act of 2000, which requires each planning authority to prepare an Integrated Development Plan (IDP). The IDP, as the highest order strategic plan in an area, comprises (and integrates) the development needs and priorities from all sector departments, and forms the basis for the administration's financial planning and budgeting for a five year cycle. A key component of the IDP is the Spatial Development Framework (SDF), which presents a spatial vision for the area and includes priority development interventions, bulk infrastructure development, and transportation planning. By its nature the SDF has to involve the engineering professions intensively in all the phases of planning and ongoing implementation.

In view of the inter-disciplinary nature (as well as the new social focus) of planning, it has become increasingly important for planners and engineers not only to cooperate more closely, but also for engineers to be trained in the basic aspects of contemporary urban planning and specifically the aspects related to strategic planning, spatial planning, environmental planning, Integrated Development Planning, and planning policy. If, as Khisty (1987) argues, engineers carry a distinct societal responsibility, and this responsibility is increasing, it seems critical that civil engineers should also obtain further training in the principles of social planning and community engagement processes, and also to develop skills in community based planning, negotiation, community facilitation, conflict resolution and working with politicians.

The need for new teaching methods in transportation planning

Educators are faced with changing abilities and preferences amongst students, requiring them to adapt the teaching methods they employ. Brown and Adler (2008) describe contemporary students as *social learners*, based on the premise that their "*understanding* of content is socially constructed through conversations about that content and through grounded interactions, especially with others, around problems or actions. The focus is not so much on *what* we are learning but on *how* we are learning." (Brown and Adler 2008:3). This is in contrast to the traditional Cartesian perspective on knowledge and learning as the mere transfer of knowledge from teacher to learner in the most efficient way possible.

Brown and Adler further identify the need for students not only to learn *about* subject matter but also to *learn to be* a full participant in the field. This involves acquiring the practices and the norms of established practitioners in that field, or acculturating into a community of practice. Learning to *be* an engineer or planner – that is, acquiring the tacit knowledge required to operate successfully in multidisciplinary, complex environments – is arguably as important as gaining the technical knowledge of science and engineering.

A number of teaching approaches have emerged in response to the changing needs of students. Among the most prominent is *active learning* – a generic approach seeking to engage students more actively in the classroom, through activities such as reading, writing, discussion, or problem solving (Bonwell and Eison 1991). These approaches work best when students are engaged in such high-order thinking tasks as analysis, synthesis, and evaluation. Studies have shown that active learning approaches are generally preferred by students (Nirmalakhandan et al. 2007; Carpenter 2006), and tend to lead to improved student learning and achievement (Nirmalakhandan et al. 2007; Light, und.).

Within the ambit of active learning, a set of approaches that can be described as *interactive* allow students to collaborate and cooperate while working together in teams to accomplish a common goal (Johnson et al. 1991). The focus is on student interactions rather than on learning as a solitary activity. Common forms of collaborative learning include small-group discussions, group problem solving, and peer-questioning. The explicitly social nature of collaborative learning is seen as a benefit especially in large classes, where it helps to reduce the emotional constraint of anonymity that is often experienced in a large class setting (Greyling and Wentzel 2007).

The simulation game described here has cooperative elements, as it organizes students into groups simulating agents with different objectives that – as students discover while playing the game – are best met when aligned with those of other groups in a collaborative rather than a competitive fashion.

Gaming simulation as a learning tool

The use of role-playing simulations to teach students to engage with complex systems is not new. During the 1960s various “social simulation” experiments were developed as a means of both investigating social theory and improving education (Starr 1994). Role-playing and games were employed in the exploration and teaching of inner-city dynamics, school reform, and urban economics under conditions of resource constraints (Starr 1994), and often used in the instruction of students who did not respond well to traditional modes of learning. Two games in the urban planning realm included the Community Land Use Game (CLUG), which simulated land use and urban growth from a socio-geographic perspective (Feldt 1972), and METROPOLIS, which focused more on the political and long-range planning roles of urban government (Duke 2000).

Computers played an increasingly important role in computing simulations and displaying results graphically, and ultimately facilitated the cross-over of simulations from the classroom to the realm of entertainment. In 1989 Maxis released SimCity, a highly popular computer simulation package that challenged players to guide the economic and social development of a hypothetical city over time by choosing various fiscal, spatial, and infrastructure investment strategies (Starr 1994). A player acts as the mayor of the town, and does not need to interact with other players during the course of the game.

In recent years simulation has been incorporated into some undergraduate civil engineering curricula as an active teaching method (Nirmalakhandan et al. 2007). In transportation engineering, researchers at the University of Minnesota developed simulation models combining contemporary technologies in transportation modeling, such as agent-based simulations, and web-based technology, to teach transportation planning and traffic engineering to civil engineering students (Chen and Levinson 2006; Liao et al. 2009). Importantly, the evidence shows that simulation-based approaches benefit especially students who prefer visual and active learning (Zhu et al. 2011).

The land use-transportation simulation game described in this paper, named UPTown, has some features in common with the SimCity approach – notably its objective of making a game out of a complex social system; its simulation of the evolution of spatial and economic systems over time, taking real estate markets, population dynamics, transport, and travel demand into account; the ability of players to influence (but not entirely control) the trajectory of the game through simulated interventions; and the use of attractive graphics and visuals for displaying output. Where it differs is in its structuring of the game as an explicitly social encounter between different types of actors, namely the public sector planner acting in pursuit of the general wellbeing of the city and its inhabitants, and the profit-seeking, private sector real estate developer making decisions about investment in building stock. A further difference is that UPTown employs more sophisticated modeling of traffic and travel demand, using discrete choice travel demand estimation and user equilibrium assignment, to enhance its usefulness as a technical teaching tool.

Embedding Gaming Simulation within an Integrated Land Use-Transportation Planning Curriculum

Overview of curriculum

The UPTown game is included in the curriculum of a final year (senior) course in Infrastructure Planning for civil engineering students at the University of Pretoria, South Africa. Placement in the final study year allows the course to build on prior learning of technical topics such as traffic engineering, engineering economics, and numerical methods, while drawing on a more mature, complex understanding of societal issues.

The course is presented as a mixture of lecture, discussion, and practical, with 6 contact hours a week spread over 13 weeks. Lectures and discussions introduce theoretical concepts and start to explore their implications for planning practice in South Africa. In-depth exploration of issues is left for the practical, of which the UPTown simulation game is a major component. Lectures are co-taught by lecturers from the Departments of Civil Engineering and of Town and Regional Planning.

Major topics covered in the curriculum include:

- Planning theory: Principles and aims of land use/ spatial planning, strategic planning and integrated development planning; the role of the engineer in this process; spatial dynamics; relationship between infrastructure planning, transportation planning and spatial planning
- Planning context: Urban, regional and global challenges facing the development of urban regions; developmental role of government (and specifically local government) in developing countries
- Planning tools: Principles of urban (re)structuring and the tools and approaches used to structure and restructure urban regions; spatial planning processes, frameworks, and the hierarchy of plans (from the metropolitan plan at the top of the hierarchy, down to the more detailed precinct plans); urban management and rezoning; township layout and settlement planning.

- Supply and demand analysis: Infrastructure supply and demand concepts, equilibrium, pricing and demand management; characterizing and measuring travel demand, demand forecasting; and economic evaluation of infrastructure projects.

While it is not our purpose here to present a detailed curriculum for a land use-transportation course, we suggest that this set of modules might form a useful basis for future integrated curricula in this field, especially in developing countries.

Objectives of the game

The game is designed to help students engage with the practical implications of many of the topics discussed in class. In terms of outcomes, the game is intended to train students to be able to:

- Understand the nature of the relationships between land development, travel demand, and transport system performance;
- Critically examine the implications of various land use-transportation strategies (such as compact city, sprawl, or corridor development strategies) on city performance and quality of life criteria;
- Explain, based on own experience, the role of different role-players (private and public) in the spatial development process, and the nature of the relationships between them; and
- Communicate effectively with other role-players via formal planning documents and informal discussion.

A key characteristic of the game is its orientation towards discovery. None of the outcomes listed above are spelled out in advance. Students are merely given the overall objectives of the game – namely to facilitate the spatial and economic growth of a town over time – within the constraints of the "action space" at their disposal (as public or private sector actors), and left to explore various strategies and relationships on their own. Feedback is provided to help students identify the positive and negative outcomes of their actions, in order to develop their own understanding of these matters.

The UPTown Game

Context

The hypothetical setting chosen for the game is one typical of the South African development landscape, namely that of a mining town faced with high population growth due to the expansion of a nearby mine. (Variations on this theme have been added in recent years). The game starts with the town already housing 60,000 people, with a rudimentary street network, and with a large rural hinterland where future expansion may occur. Growth is constrained here and there by geographic barriers such as mining land, a mountain range and a river. Travel modes initially include walking, automobile, and informal (minibus-taxi) paratransit, with the option of adding formal fixed-route transit in later stages of the game. Both walking and taxi modes are used extensively, typical of travel patterns in developing countries.

Playing the game

Each game is structured as an encounter between public sector planners, exercising control over both land use management and investment in the transportation network, and private sector real estate developers. Planners and Developers both pursue the ultimate aim of accommodating as much growth as possible (in terms of population and employment, but not necessarily spatial footprint), as high growth levels are directly linked to the town's success as a vibrant and attractive community. An equity dimension is added by the fact that players have to attend to the needs (in terms of housing, jobs, and transport) of both lower-income and higher-income segments of the population.

Planners and Developers have different objectives and different means of pursuing them. For Planners, success is measured by a number of objectives reflecting the general health of the city, such as:

- Sufficient land being available to accommodate housing and business growth;
- Improving accessibility of low-income workers to jobs (to reflect progressive social goals);
- Facilitating the efficient movement of people by striking a balance between sufficient investment in transport capacity (by highway and/or transit modes), and cost-effectiveness (thus avoiding over investment) of the transport network; and
- Reducing the cost of living and vehicle emissions by containing growth in average trip distances.

The game proceeds in three rounds, each representing a 10-year period, and each building on the previous round. Actions Planners may take in any round of the game include:

- Selecting the *location* and *type* of future development to be allowed, by specifying the type of land uses to be allowed by the zoning code for each zone;
- Selecting the maximum *density* of development to be allowed by adjusting the Floor-Area Ratio (FAR) allowed by land use type and zone;
- Investing in additional *road capacity*; or
- Investing in *new transit modes* with superior capacity and speed characteristics.

Planners are thus forced to consider land use development and transport demand together. They are encouraged to start the game by developing a spatial development strategy for managing the growth of the town for the coming decade, to ensure coordination of zoning and investment decisions.

Developers have the ultimate objective of maximizing the profits derived from developing and selling or renting out building stock. The program simulates land values and construction costs based on the size, type and location of new development, and then calculates the Developers' profits based on the amount of floor space that is actually occupied. Developers thus have to find a balance between developing sufficient floor space to accommodate all potential growth in households and businesses (so as not to constrain overall growth by a shortage of building stock), and keeping vacancies low (as vacant buildings reduce profits). There is no explicit budget constraint but the last point acts as a penalty for over-development. In pursuit of these objectives, Developers can:

- Select the *location* of new building stock to be developed, for each of four types of developments; and
- Specify the *amount* of new building stock to be developed (in square meters of floor space).

The actions of Planners and Developers affect each other in current and subsequent rounds of the game. The amount of floor space of any given type that Developers can construct in a zone is constrained by zoning and maximum density specifications chosen by Planners. Location decisions of Developers affect the distribution and density of travel demand, and the need for Planners to expand transport capacity in subsequent periods. Developers are also forced to integrate land use and transport considerations, as low accessibility resulting from high congestion or excessive sprawl reduces building rents and thus profits. Developers thus have an incentive to match development location and density with (current and future) excess capacity in the road and transit network.

Cooperation and competition

It is this linkage between public sector planning and private sector investment decisions that gives the game its cooperative nature. Neither Planners nor Developers can control each others' actions. The actions of a third group of role-players – private households and businesses – are not controlled directly by either group, but simulated externally. But a key feature of the game is that it takes the performance of *both* Planners and Developers into account when determining the overall performance score for the town. Thus each group benefits from the other group reaching its objectives. Objectives are structured so as not to be perfectly aligned – for instance, excessively sprawling development might reduce development costs (favoring Developers), but decrease cost-effectiveness of road investments (penalizing Planners).

This creates an incentive for groups to compromise and to coordinate their actions around a common vision for the area.

Each game is played by six students divided into two groups: two students work together as Developers and four as Planners. The experience is competitive to the extent that students in different games compete against one other to emerge with the highest cumulative growth over three rounds of the game.

Treatment of transportation

Both the transportation network and travel behavior are treated at a relatively high level of detail, to allow students to quantitatively explore and apply concepts such as capacities, saturation, and travel demand estimation. Thus six types of road links are available, ranging from rural gravel roads, to urban arterials and freeways – each with its own traffic flow and capacity characteristics known to the students. Planners can in any round of the game change road supply, by adding new road links, upgrading streets to higher order roads or freeways, adding lanes to existing links, or implementing traffic management schemes such as one-way couplets. The costs of upgrading or providing new facilities rise progressively with the order of the facility.

Alternatively, additional transport capacity can be created in the form of fixed-route transit. In the current implementation of the game only one additional transit mode is allowed, namely Bus Rapid Transit (BRT) operating in exclusive lanes (and thus requiring additional infrastructure investment by the public sector). Students can add BRT to any part of the network, but the number of passengers using it is determined by the competitiveness of its level of service against other modes.

Use of visual aids for analysis and communication

A number of visual aids were developed to assist students in visualizing the problem, developing potential solutions, and communicating their actions. The first is a simple Geographic Information System (GIS) viewer designed to display zonal and network attributes. Figure 1 shows an example of the GIS viewer screen.

In every round each group submits their decisions on zoning changes (in the case of Planners) and building stock development (for Developers) in a tabular spreadsheet format, for incorporation into the off-line simulation engine.

Together with zoning and network data, each group of Planners and Developers also submits a report in which they communicate their approach with each other, and with the lecturer. The report represents a brief Strategic Plan or Investment Plan, in which the group presents an overall strategy for the area in the

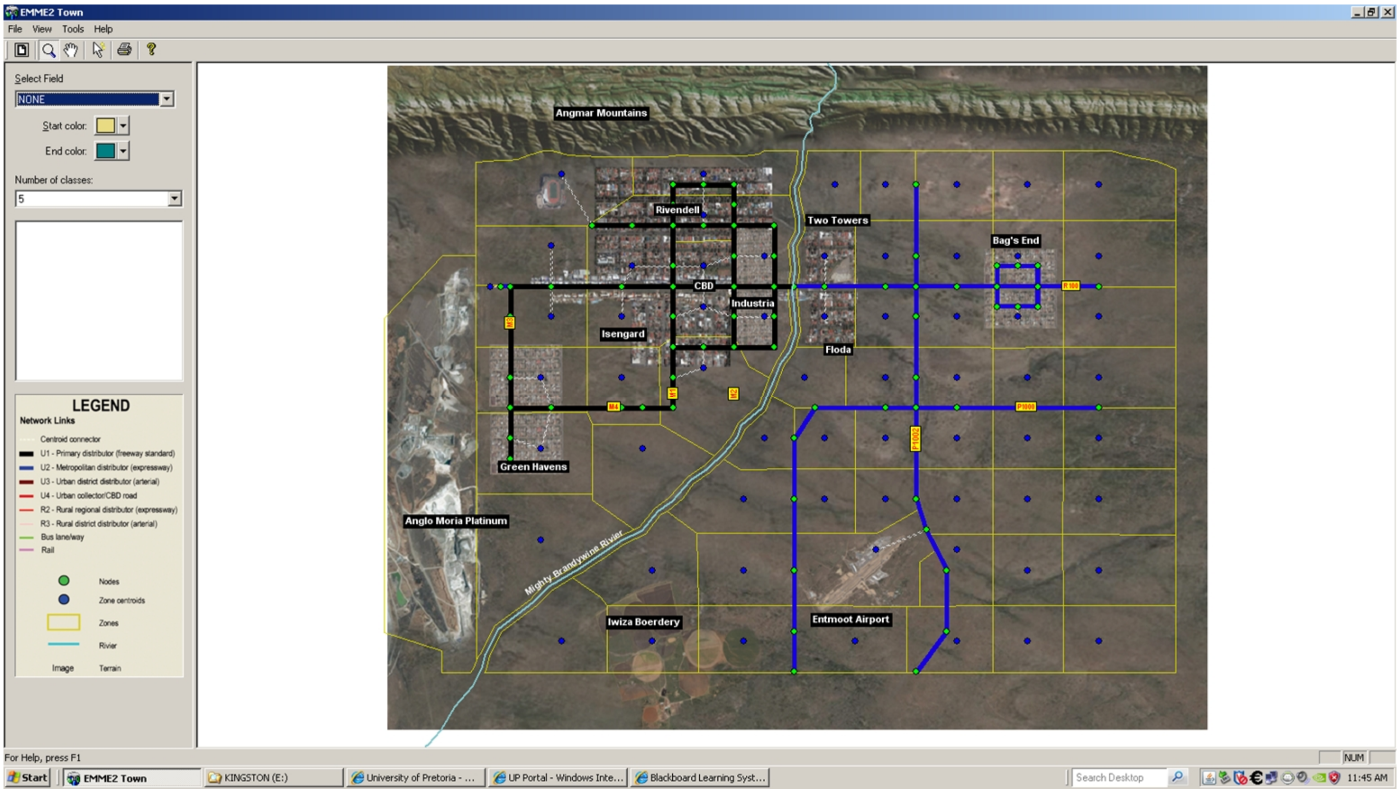

Figure 1. Screenshot of GIS Viewer developed to explore spatial and transport data

coming decade, an analysis of the problems identified, and a rationale for and description of specific

actions or projects to be undertaken. Together with any informal meetings between Developers and Planners in a game that students choose to organize, the reports play a key role in facilitating cooperative learning and formalized communication between parties.

Simulation engine

The behavior of private role-players – households and businesses – and their impact on land use and travel is simulated off-line through a two-step simulation package developed specifically for this purpose. The main tasks of the simulator are shown in Figure 2. In each round, a land allocation module first calculates the total amount of new floor space to be occupied in each of the four land use categories (low density residential, high density residential, commercial, and mining/industrial). The calculation of *occupied* floor space is driven by (a) the total amount of *developed* (i.e. available) floor space submitted by Developers, (b) constant ratios assumed for the amount of floor space consumed per job or per

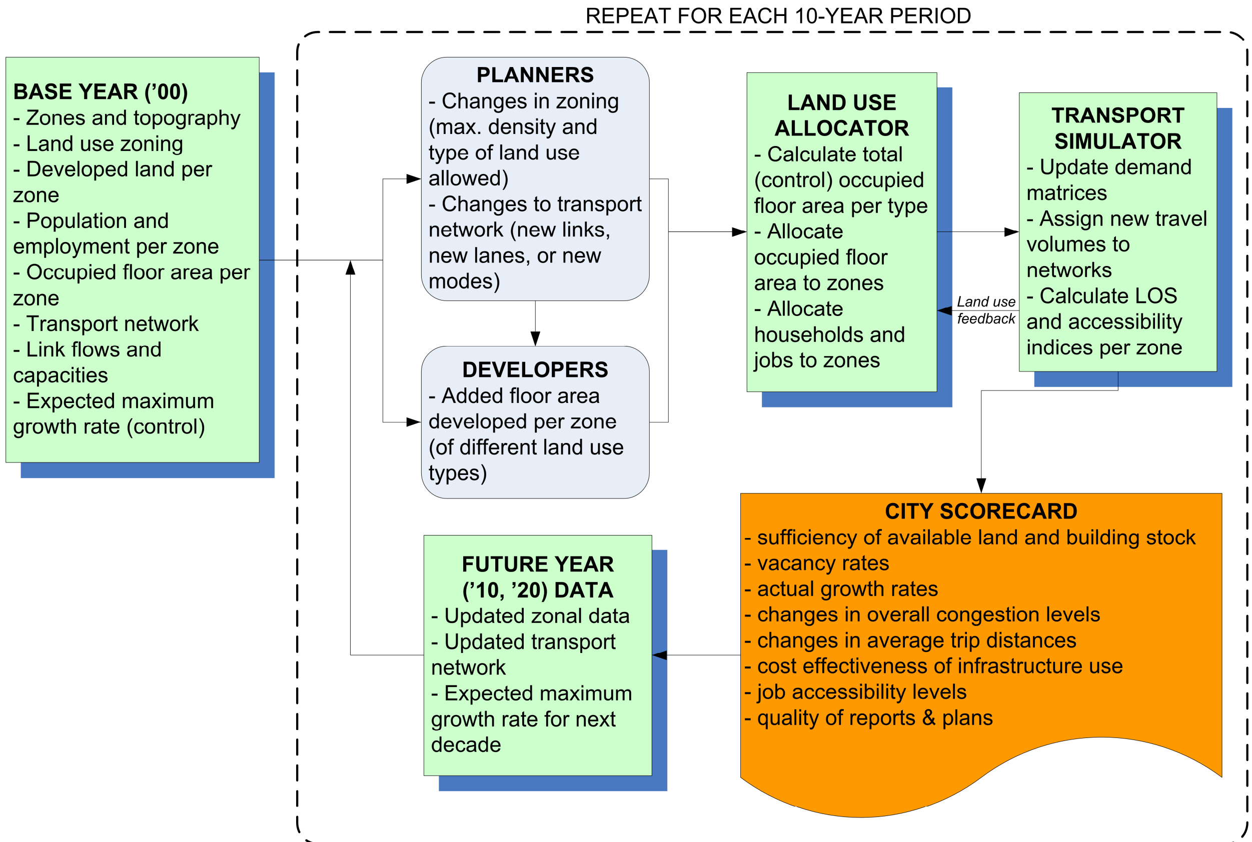

Figure 2. Process diagram for UPTown land use-transportation simulation game

household (by type), and (c) the maximum potential growth rate calculated for the city in this round (which depends on the city performance in the previous round).

Households are simulated in three income categories, each demanding different amounts of residential floor space. Jobs are simulated as either *basic* (including manufacturing and mining industries) or *retail* (including commercial (shopping), office, and public services). Fixed ratios are maintained between basic and retail jobs, and between households and jobs, to ensure that an overall jobs-housing balance is maintained, and that an undersupply of residential buildings will also constrain job growth, and vice versa.

The next step is to allocate new jobs and households to zones. A rule-based allocation model is used, similar to the model developed for the City of Johannesburg in South Africa and described in Venter et al. (2006). The model uses a set of simplified indicators, including accessibility, prior levels of development, and proximity to job opportunities, to allocate occupied floor space up to the maximum allowed by zoning and building stock availability.

Taking the location of households and jobs into account, a transport simulator then determines travel demand and assigns it to the networks specified by the students. Constant trip rates (per household income and job type category) are used to estimate trip generation, and a doubly constrained gravity model used to update origin-destination matrices. In order to simulate travel behavior in a realistic manner an incremental nested logit model is used to simultaneously model changes in mode use, trip destination, and route choice. (It is also possible to model time-of-day choice but this has not been implemented as we focus the game on the peak periods only). The demand model is described in more detail in Venter and Mokonyama (2009). A key feature of the demand model is that it provides for feedback between the various steps of the four-step model, to obtain a more fully equilibrated demand response to land use or transport interventions. There is also some feedback between the demand simulator and the land use allocation, through the iterative feedback of accessibility indices.

Students do not have access to the simulator when making decisions, and only receive feedback on the success of their actions at the end of every round. That the game is not as interactive as, for instance, SimCity, is intentional. The focus of the course is on allowing students to explore and understand the substantive relationships underlying spatial and transport development, and not on learning to run modeling software. (Nonetheless some motivated students made it their mission to "crack" the simulator to enable them to predict more closely how their strategies would fare).

Output and feedback

At the end of each round participants in each game receive feedback in the form of a city scorecard, on which the performance of the city is scored against the objectives for each group. Typical scorecard indicators include: the sufficiency of land and buildings made available for accommodating growth; profitability of development; cost effectiveness of the road and transit networks; reduction in congestion levels; containing growth in average trip distances; and job accessibility for low-income residents. For every indicator meeting a pre-defined performance threshold the group earns two points on their scorecard (towards a maximum of 10). Scorecard scores contribute about 10% of student grades for the course.

Each group also receives a grade for the quality of the report handed in, in order to provide students with an incentive for honing their skills as communicators. The combined score of both Developers and Planners in a game indicates overall achievement, and is used to calculate the maximum potential growth rate for their city for the coming decade using simple proportionality: a score of 50% in one decade reduces the potential growth in the next by half. There is thus a positive feedback loop between performance and challenge: high performance in one decade leads to higher growth in the next, raising the level of difficulty of the game as the potential problems of congestion and land supply to be dealt with become more severe.

Each group also receives more detailed transport performance information in the form of volume plots on the network, and volume/capacity ratios calculated for each link. Students can use this data to identify and address road or transit capacity issues in the next round.

Assessment of Student Experience

Assessment of member contributions is one of the difficulties of using group work as a teaching strategy. Some educators favor peer assessment as a mechanism (Cheng and Warren 2000). We opted for a combination of objective performance measurement (based on the scores attained by each group on their scorecards), and subjective self-assessment. Self-assessment was approached as an opportunity for formative assessment, where the students were encouraged to reflect on various aspects of the gaming experience, and to link their own experiences with the subject matter of the course.

Attainment of subject matter competence

Since the integrated course was a new course that incorporated the simulation game from the start, the opportunity was not available to test the impact of the simulation game objectively against a no-game control case. We considered two measures to assess the effectiveness of the game in helping students attain subject matter competence, namely scorecard scores and subjective ratings.

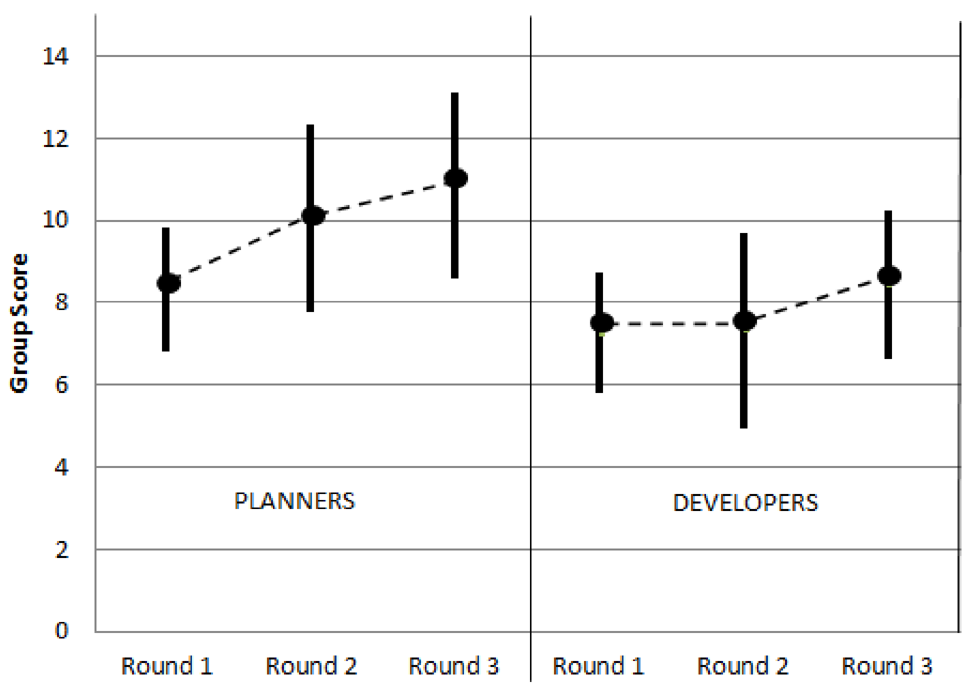

Figure 3. Mean and standard deviation of group scores (out of 15) across three rounds of the UPTown game.

Figure 3 shows the mean and standard deviations of the group scores calculated for each group's performance after every round, for Planners and Developers separately. Out of a maximum score of 15, the median score for Planners was 10 and for Developers 8. The scores reflect the attainment of specific outcomes for city performance, and thus reflect – albeit imperfectly – the extent to which students were able to use the concepts and tools discussed in class for solving real-world problems. The median scores indicate that students were on average successful in doing so.

Perhaps more important than absolute scores is the slope of each graph. Both Planners and Developers increased their scores between the start and the end of the game, indicating progressive mastery of the game and of the tools at their disposal. On average Planners performed better than Developers, which is somewhat surprising given the fact that Planners in this game perform more complex tasks (including land use planning, travel demand estimation, and transport infrastructure investment) than Developers (who only control building stock development). The reason for this might be that the higher complexity of the Planners' task forced them to explore and understand the essential relationships driving the game earlier on, while Developers took longer to achieve this.

Table 1. Student assessment of simulation game (n=94)

Question	Number (%) of responses per category		
To what extent did the UPTown game contribute to your understanding of the infrastructure/development planning process? (Scale: 1=no help, to 9=significant)	Poor contribution (rating = 1-3)	Average contribution (rating = 4-6)	Good contribution (rating = 7-9) 31 (52%)
- Students playing Planners	2 (3%)	27 (45%)	11 (33%)
- Students playing Developers	0 (-)	22 (67%)	
How would you rate the contributions provided by various members of your group?	Everybody contributed equally	Unequal: some did less than others or nothing	One person did all the work
	55 (59%)	38 (41%)	0 (-)

As a subjective measure of the effectiveness of the game as a teaching tool, students were asked to rate the extent to which the game contributed to their understanding of the integrated land use-transportation planning subject matter. Students' answers (summarized in Table 1) were generally positive, with an average score of 6.1 out of 9. Planners were generally more positive than Developers: about half of Planners gave the game a rating of 7 or higher, compared with only a third of Developers. This can once again be related to the higher level of competence reached by Planners earlier on in the game. In general, it seems that students perform better, and develop a better grasp of the material, when faced with more complex analytical tasks and more "degrees of freedom" in terms of the set of actions they can take to reach their objectives.

Assessment of game as socially interactive learning experience

In assessing the students' experience of the game as a social learning activity, two key questions are whether they experienced it as a cooperative exercise (rather than a competitive or individualistic one), and whether students came to appreciate some of the challenges inherent in the practice of planning as a collaborative undertaking.

To assess the level of teamwork achieved, students were asked to report the extent to which group members contributed to their group's efforts. Table 1 shows that about 60% of students felt that everybody contributed equally, while the remainder of students reported that some did more work than others. No students reported that one person did all the work. Teamwork is not necessarily the same as collaboration – the latter implies people engaged in *different* tasks but working towards a commonly formulated goal (Killen 2000). During contact sessions the lecturers did observe that most groups appeared to adopt a collaborative model, by dividing up tasks amongst group members after formulating a common vision or objectives for the next round of the game. Some students were made responsible for land use planning and zoning calculations, others for transport demand analysis and updating of network files, and others for writing reports. This spontaneous specialization of tasks reflects the more formalized specialization tendencies found in professional practice.

We also asked students for an unprompted reflection on what they had learnt while playing the game. The answers suggested that many students succeeded in grasping the cooperative nature of planning. In particular:

- Many students learnt to appreciate the limits of the planning and investment mechanisms that the public sector in a democracy may use in pursuit of its goals. One student commented that "it is incredibly difficult to try to make people settle where you intend them to."

- Some students explicitly identified the need for cooperation and strategic alignment between public and private sector visions. A student observed "As a group we soon realized that as developers we are dependent on the strategies and decisions of our planners"; another expressed frustration that "… we never really worked together, but rather against each other. It is hard to work together if you do not fully understand the strategy and plans of the other parties."

- Students saw the most successful collaborative strategies between Planners and Developers as those which synchronize the location and pace of development with the provision of public infrastructure. Said one student: "What I learned is that 'clever' development is needed, meaning that if a zone is extensively developed then [effort] should go into planning a transportation system … that can cope with the large influx of people." Interestingly, effective coordination was seen as more important to success than the *specific* land use strategy pursued: "In retrospect neither strategy [sprawl or containment and densification] is ideal … but rather a mixture of the two."

- The importance of clear communication was mentioned by almost every student. For instance, one said that "once communication [between role-players] had been established, more focused planning and development was possible."

Conclusions

The paper describes the application of a gaming simulation approach in the teaching of integrated land use-transportation planning as a part of an undergraduate civil engineering course at the University of Pretoria, South Africa. The game is explicitly structured to allow students to explore aspects of the land use-transportation relationship in a hypothetical setting, whilst practicing working on complex problems in a collaborative teamwork environment.

Self-assessments of student performance showed that the game contributed to the ability of students to master the course subject matter. Interestingly, students who faced more complex tasks (those playing the role of Planners, as opposed to private sector Developers) performed better, and reached higher levels of competence earlier on in the game. It appears that being forced to grapple with complexity and a larger action space leads to a better grasp of the material, and better achievement of the learning outcomes.

We find the game's key innovation over existing urban simulation software – its insistence on cooperation as a mode of interaction between private and public sector actors – to be particularly useful as a learning strategy. It allows students to experience the benefits of collaboration with others who have different objectives to their own – a key skill needed in the multidisciplinary environment that civil engineers work in. In the process, they learn syncretic thinking, clear communication, and compromise. The role-playing simulation approach allows students to explore experientially what it means to "be" a planner, thus helping to prepare students for eventual entry into a community of practice.

Some improvements can be made to the game to enhance its usefulness as a learning experience. The first is to rotate students through being both Planners and Developers, over the course of the game, to allow all students the opportunity to grapple with the issues faced by both public and private sector agents. This would probably help to equalize the achievement of competence across the class. Some students expressed a need for greater guidance and more extensive feedback from the lecturers. Some students lack the skill to identify causal relationships between their own decisions and actions (as Planners or Developers) and the subsequent performance of their town. While it is deemed important to preserve the self-guided exploratory character of the game, it might be useful to spend more time modeling critical analysis and problem solving skills for such students early on in the game. Lastly, the simulation engine needs to be migrated to an open-source platform to make it directly available to educators at other institutions. However, the structure and principles described here might already be usefully applied to the design of gaming exercises in current curricula.

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