SIMULATING THE DYNAMICAL INTERACTION OF OFFENDERS, TARGETS AND GUARDIANS

Tibor Bosse*, Henk Elffers**,, Charlotte Gerritsen*[1]***

Routine Activity Modelling

Within the routine activity paradigm (Cohen & Felson, 1979; Felson, 2008), it is argued that crime takes place when a motivated offender finds a suitable target, while capable guardians are lacking. The beauty of this theory lies in its clarity and simplicity on a sufficiently abstract level (Elffers, 2004). Its simplicity dissipates, however, when moving from an abstract level to questions of underlying processes such as what governs whether a motivated offender will find an attractive target. The answer is dependent on the movement of offenders and the whereabouts of targets. For instance, the likelihood of such meetings will be dependent on the distribution of targets' attraction levels, their positions in space, whether they move or not, and whether their attraction levels are constant over time or not, and if not, what is governing their change. Likewise, the occurrence of a meeting between offenders and targets will be influenced by the movement pattern of motivated offenders, may be dependent on their knowledge of target availability or on other business of the offenders, on their preferences for certain attraction levels, and on whether these characteristics are influenced by having successfully or unsuccessfully attacked a target previously. Targets may have a movement pattern based both on their perception of criminal risk as well as of parameters governing their non-crime related behavior (e.g., the route they take to go to work), which will also be influenced by experiencing crime. The third routine activity factor, availability of capable guardians, has to be taken into account as well. For example, whether there are formal guardians, such as police officers and security personnel, or are informal or natural guardians, such as inhabitants and passers-by. The temporal and spatial dynamics of such offender, target and guardian processes is paramount for the occurrence of crime within a routine activity context. This becomes problematic in real life situations, as it seems rather optimistic that all of these processes can be specified, estimated, and analyzed. Measurement problems as well as analytical problems will be formidable.

A way to deal with such a complex case is simplifying the problem by holding constant as many parameters in the processes as is feasible. For example, research could

[1] **Department of Artificial Intelligence, Vrije Universiteit Amsterdam, ** Department of Criminal Law and Criminology, Vrije Universiteit Amsterdam, *** Netherlands Institute for the Study of Crime and Law Enforcement NSCR, Amsterdam*

compare pick pocketing rates in two neighborhoods close to each other, each with comparable population composition, but where one having houses with small windows is deemed to have low natural guardianship levels while the other neighborhood having buildings with large windows considered having a better guardianship structure. Assuming that offender routine patterns and target routine patterns are alike in both neighborhoods, comparing them is a fit method to investigate the effect of natural guardianship.

A second method is experimenting, for example by varying police surveillance intensity (as one of the guardianship parameters) over time periods in a given neighborhood. This research approach is, of course, also only feasible when other parameters are held constant. Dynamic aspects of the routine-activity-models are particularly problematic to this kind of research because the designs attempt to exploit the "ceteris paribus" of all other parameters than the one under scrutiny, and hence implies an incentive on static processes, thus defying investigation of dynamics.

In the current paper, however, we examine dynamic routine activity processes by means of (agent-based) simulation methods (David & Sichman, 2009) in which some routine activity processes are built into an artificial society of offenders, targets, and guardians. We then investigate what happens if offenders, targets, or guardians react to a situation by increasing or decreasing parameters of their preferences and by choosing the direction in which they move as a function of what is happening around them.

Simulation as an Analytical Tool

Simulation is used in the present research as an analytical tool that makes it possible to investigate events in an environment, given a set of rules, whose mutual interactions are too complex to analyze with traditional methods (see, e.g., Brantingham & Brantingham, 2004). Simulation is, in such an application, not an empirical but a theoretical method that uses computer generated instances of realizations of processes. It is meant for those cases where complexity outstrips the capability of theoretical or mathematical analysis. Simulation departs from a given theory (here routine activity theory) and examines the dynamic interplay of various processes as specified by that theory at a local level. As such, simulation is not testing the theory from which it departs, but, on the contrary, it is exploring it, bringing forward global level implications of the local level assumptions of the theory that were not straightforward and clear before. The resulting outcomes of a set of simulation runs should then be studied and are meant to generate a deeper insight in the process that, implicitly, has been specified by the simulation model. Observing and analyzing a number of simulation runs of the dynamic development of resulting crime processes may enhance the understanding of the dynamics of routine activity in a given context. This usually takes the form of an input-output analysis where, specific parameters of the process to be simulated are input and the outcomes observed. Applications of simulation as a tool for understanding can be found in various criminological fields. For example, Van Baal (2004) used it to study perceptual deterrence; Bosse, Gerritsen & Treur (2007, 2008) used it to study psychological processes that trigger violent behavior; and Bosse, Gerritsen, Klein & Weerman (2009) used it to study social learning of delinquent behavior in adolescents.

Developing a useful simulation model is not an easy task because simulation generates a great deal of output from which the researcher must make sense, either by insight or through systematic statistical analysis of the input-output connections. It is therefore wise for researchers to start with simple simulation models. Experience shows that interpreting and understanding input – output relations is quite a task even in simple models. A stepwise approach starts with a simple simulation model that can be made more complex after interpreting the output of the simpler case.

It seems worthwhile to stress explicitly that simulation models in the above sense are not yet meant as theories of reality. We know beforehand they are gross simplifications of reality, but this is also a unique strength. By rigorous simplification, researchers optimize the conditions for understanding the complex interplay between various parts and rules in the model. Only after having understood a relatively simple model thoroughly, may researchers go further and build complex models of reality, using as building blocks what was learned from the simple simulations. This modest view on simulation research rules out testing model results against empirical data, which is not an issue as we already know the models do not fit reality.

Other uses of the term "simulation research" and other visions on the effectiveness of simulation may be found in the literature (see, for example, Liu & Eck, 2008) and may be useful for their own purposes as well. Many researchers even propose their simulation models as fair approximations of reality. Some first successful attempts in this direction can be found in Brantingham et al., (2005), Groff (2005, 2008), Hayslett-McCall et al. (2008), Liu et al., (2005), and Melo et al. (2005). Nevertheless, it is our conviction that, at least concerning the dynamics of routine activity models, that stage has not been reached completely (see Elffers & Van Baal, 2008; for an attempt to analyze the dynamic structure of a model within a real life environment, see Malleson & Brantingham 2008).

A Simple Routine Activity Model, Global Description

In the present project, we examine a small society of immobile targets (*houses that can be targeted for burglary*), located in geographical space (*town*), with standard characteristics of *neighboring relations* and *distance to each other*, and having a certain distribution of attraction levels over space (*spatial autocorrelation of wealth*). The targets have a time dependent *reputation*, which is high when a property has been burglarized in the recent past and erodes again when nothing untoward is happening for some time. Through that society, a number of motivated burglars move around. They take one step every period (*day*), and have a preference of moving to more attractive targets.

They are rather short-sighted, however, and can see only targets one step away from their previous position. They chose a move with a certain probability proportional to attraction levels of targets in sight. Offenders (burglars) have a characteristic of *choosiness* such that every offender has a certain minimal attraction threshold that differs from other offenders. When arriving at a target, an offender intends to burgle it if and only if it is worthwhile, which is the case if the attraction level of the prospective target surpasses the minimal attraction threshold of that offender. This decision making process is similar to the ideas put forth by Brantingham & Brantingham (1993), who stated that offenders match the situations they observe against their crime templates (i.e., perceptions of which targets are appropriate). A target that is eligible for burgling to one offender may be passed over by another offender.

The last element in the model is the guardians, also moving around through the town. Guardians in this model are what has been called formal guardians, that is agents having an official guardian task (such as police officers or security personnel), as opposed to informal guardians, who may be present on the spot for other reasons (inhabitants, passers-by) and then nevertheless can preclude crime from happening (Felson & Cohen, 1980; Reynald, 2009). Guardians, like offenders, walk around one step at a time, and see only targets one step away. Guardians either have *no preferences*, i.e. they move around randomly (random policing), or have a preference for moving to targets with high reputations (vulnerable targets). The probability of moving to a target is proportional to the reputation being visible from the present position. This is hot spot preferences or hot spot policing. Such strategies are compatible with the often observed behavior of burglars called the *(near) repeat phenomenon* (Johnson & Bowers, 2004; Ratcliffe & Rengert, 2008; Townsley, Homel & Chaseling, 2003), where offenders prefer to strike targets they previously victimized (or those in near proximity thereof, although this second phenomenon is not addressed by our definition of reputation).

A guardian present at a target completely precludes a burglary taking place. So if an offender intending to burgle a house meets a guardian at the spot, the offender will not act. Of course, burglars who judged a target as not worthwhile will not be affected by guardians; they go on behaving themselves at that moment.

Research Questions

Within the framework of the model, we intend to investigate the effectiveness in crime prevention of various guardianship policies. This is the output variable, operationalized as 1 – crime rate, where the crime rate is the observed number of crimes per spatio-temporal unit in various circumstances, as specified by the spatial attraction patterns of the targets, the number of offenders and guardians, and the distribution of the attraction thresholds of the offenders (which are all input variables).

Guardian policies to be investigated here are random policing, hot spot policing, area (or beat) hot spot policing. The last of those policies is a hot spot policing scheme but with mutually exclusive zones allotted to the guardians, zones that they may not leave.

Circumstances varied in the model include the number of guardians and distribution of target attraction values. Concerning the former, we are interested in the extent to which the effectiveness in crime prevention is influenced by the amount of guardians present in the model. To this end, the number of guardians was varied between only 2 guardians and almost one guardian at every location. The other circumstance varied over the different simulations is the distribution of target attraction values. This choice was based on the hypothesis that differences in geographical makeup between areas may result in different burglary patterns (e.g., the burglary patterns in an area where all expensive houses are clustered will be different from those in an area where all expensive houses are spread), see, for example Rengert & Wasilchick, 1985. Other parameters of the model were the number of offenders present in the simulation and the distribution of threshold values of the offenders (i.e., the individual attractiveness levels of the offenders that a certain target should surpass to be judged sufficiently attractive to burglarize). However, these two parameters are kept constant over the different simulation runs.

Simulation Model

In this section, the simulation model is discussed in greater detail. The main component of the model is a virtual environment, a world that is represented mathematically by a matrix of m*n elements (and can be visualized as a grid of m*n adjacent locations). Thus, each location has maximally 4 neighbors (in case of central locations) and minimally 2 neighbors (in case of corner locations). This is illustrated in Figure 1, where each intersection represents a location and the dashed lines represent connections between locations. In addition, each location (or house) has a *level of attractiveness* attached represented by a natural number between 1 and 10. This number is assumed to represent the attractiveness of that particular location to burglars (a high number may stand for an expensive house without surveillance cameras). Finally, to enable the guardians to prevent near repeat burglary, each location has a *reputation* attached represented by a real number ≥ 1 and is assumed to represent the reputation of that location with respect to burglary (a high number stands for a house where many burglaries have taken place). Initially, the reputation of each location is set to the value 1. Reputation increases by 1 after a burglary takes place at that location and decreases by 0.5 when no burglary takes place.

Within a given simulation run, the world is populated by artificial *agents* (David & Sichman, 2009). Two types of agents are distinguished: *offenders* (i.e., potential burglars) and *guardians*. Each offender has an individual *burglary threshold*, represented by a natural number between 0 and 10, which represents the threshold above which the agent considers a house sufficiently attractive to burgle it (a high number denotes a person that will only select very attractive targets). Offenders travel through the environment by moving to locations with a probability that is proportional to their attractiveness. To be able to compare different surveillance strategies, the guardians exist in three different types:

- *type 1 guardians* follow a random strategy: they move randomly through the environment
- *type 2 guardians* follow a hot spot strategy: they select adjacent locations with a probability that is proportional to the reputations of those locations
- *type 3 guardians* follow an area hot spot strategy: they select adjacent locations with a probability that is proportional to their reputation, but only within their individually assigned surveillance area. This means that each guardian of type 3 has a number of locations assigned (an area), which it is not allowed to leave.

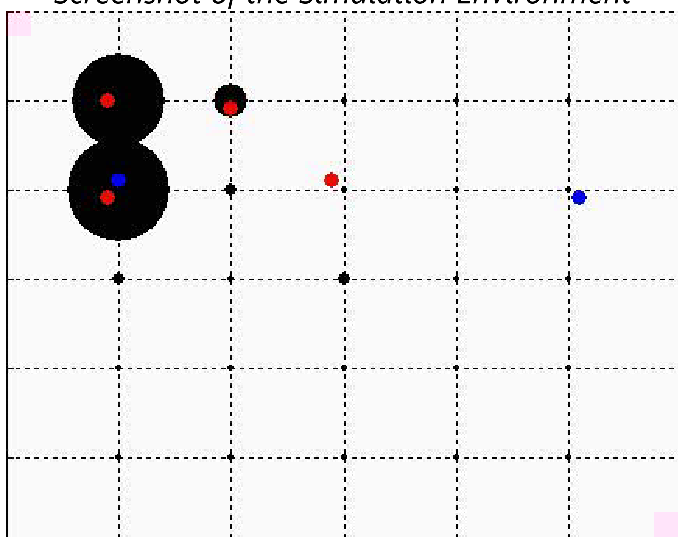
To generate a simulation run, the following algorithm is performed (denoted in pseudo-code):

1. *Initialize the simulation (either randomly or according to some setting defined by the user) according to the following steps:*
   a. *Determine the size of the world.*
   b. *For all locations, set the initial reputation to 1 and assign attractiveness levels.*
   c. *Determine the amount of agents of the different types.*
   d. *Assign burglary thresholds to all offenders.*
   e. *Assign personal areas to all Type 3 guardians.*
   f. *Place all agents at their start locations.*
2. *For each time step until the end of the simulation, repeat the following cycle:*
   a. *For each location, if it contains at least 1 motivated offender (the individual burglary threshold is lower than the attractiveness of the location) and no guardians of any type, then count a burglary for that location.*
   b. *Increase the reputation of each location that is burglarized by 1.*
   c. *Decrease the reputation of each location that is not burglarized by 0.5.*
   d. *For each offender, move to one of the adjacent locations (including the current location) with a probability that is proportional to its attractiveness. For example, suppose an offender is at a (corner) location A with two neighbors, B and C, and that the attractiveness of A, B, and C is 3, 5, and 7, respectively. Then, the probability that the agent will stay at location A is 3/(3+5+7) = 0.2. Similarly, the probability that it will go to location B is 0.33, and the probability that it will go to C is 0.47.*
   e. *For each Type 1 guardian, move randomly to one of the adjacent locations (including the current location). For example, if a guardian is at a central location, it may go north, south, west, or east, or stay at its current location, each with a probability of 0.2.*
   f. *For each Type 2 guardian, move to one of the adjacent locations (including the current location) with a probability that is proportional to its reputation. For example, suppose a guardian is at a (corner) location A with two neighbors, B and C, and that the reputations of A, B, and C are 4.5, 7.5, and 2.0, respectively. Then, the probability that the agent will stay at location A is 4.5/(4.5+7.5+2.0) = 0.32. Similarly, the probability that it will go to location B is 0.54, and the probability that it will go to C is 0.14.*

g. *For each Type 3 guardian, move to one of the adjacent locations (including the current location) within its own area with a probability that is proportional to its reputation.*

As can be seen in this pseudo-code, in principle it is possible to have guardians of different types in the same simulation; however, in the simulations discussed in this paper, this is not the case (only one type of guardian is placed in each simulation run).

Figure 1
Screenshot of the Simulation Environment



During a simulation, various types of relevant information are stored, such as the total number of burglaries, the amount of times offenders encounter guardians (prevention rate), and the amount of times 2 or more guardians are present at the same location (idleness rate). Since the model contains probabilistic elements, multiple runs will provide different results; therefore, to obtain reliable results, the model is run many times to generate a large number of simulated traces (developments of all dynamic parameters over time), of which the average is then taken.

The simulation model was implemented in Matlab. To provide the user more insight into the spatial dynamics of a simulation run, the implementation offers the possibility to visualize each simulation run in terms of an animation (which can be stored as an .mpg-file). In Figure 1, a screenshot of such an animation is shown. Here, each intersection represents a location in a city. In the example addressed here, there are 25 locations in total that are connected through edges (according to a grid or 'block' structure). Furthermore, there are 4 offenders (represented by the red dots) and 2 guardians (the blue dots). The black dots represent the reputation of a particular location: the bigger the dot, the higher the burglary reputation of that location. As an illustration, a number of animations (for different guardian strategies) can be found at: http://www.cs.vu.nl/~wai/crimesim/.

Input Parameters That Are Varied Over Different Runs

A large number of simulations were generated under different settings (input parameters). First, we used different settings for the distribution of the attraction values of the targets. In this way, four types of worlds were created (see Figure 2). In the first world type, all targets had the same attraction value (equal world). In the second world type, the attraction values were distributed without structure over the community (distributed world). Actually, in the present set of simulations, we manually distributed values between 1 and 10 in an unsystematic way over the society. In the third world type, the values were distributed according to a concentric ring structure (ring world), with the highest attraction value in the south-west corner of the world and attraction values decreasing linearly with the number of concentric rings. This can be compared to a city where the most expensive houses are located close to each other and the less attractive the houses are located further away from that wealthy centre. In the fourth world type, there were two distinct areas in which the expensive houses were located (segregated world), separated from each other by houses that were less attractive.

Figure 2
Types of Simulation Worlds

For each world, simulations were run with different numbers of guardians (i.e., 2, 3, 4, 5, 6, 10, 15 and 20 guardians), which were either all of Type 1 (random strategy), Type 2 (hot spot strategy), or Type 3 (area hot spot strategy). In each simulation, 4 offenders were present, with *burglary thresholds* 4, 5, 6, and 7. For each setting, 1000 simulations were run (of 200 time steps each), for a total of 96000 simulations (4 worlds * 8 amounts of guardians * 3 guardian types * 1000 simulations). The most interesting results are discussed below.

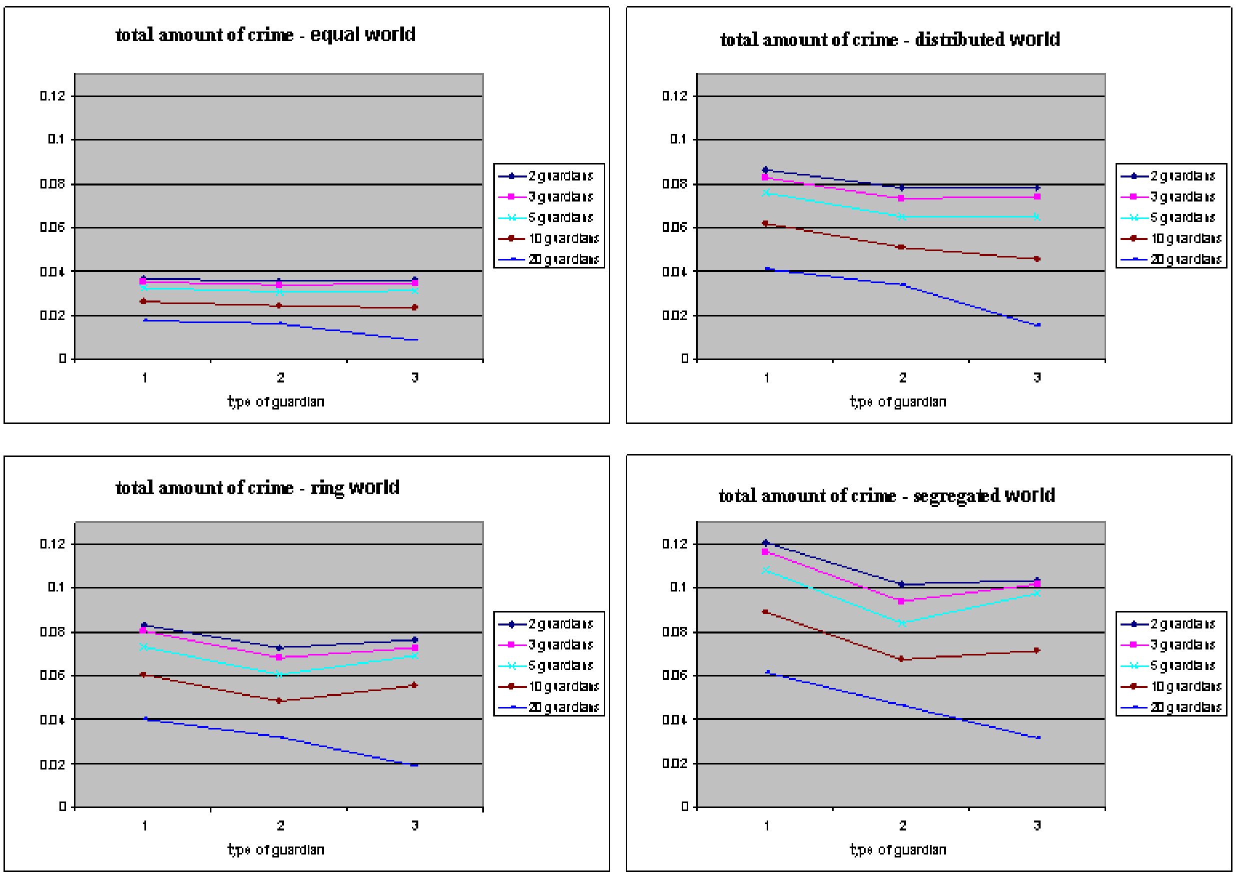
Simulation Results

In this section, the results of the simulations are discussed with respect to total crime rates, crime hot spot rate, guardian hot spot rate, guardian efficiency, and the effect of larger geographical areas.

Total Amount of Crime

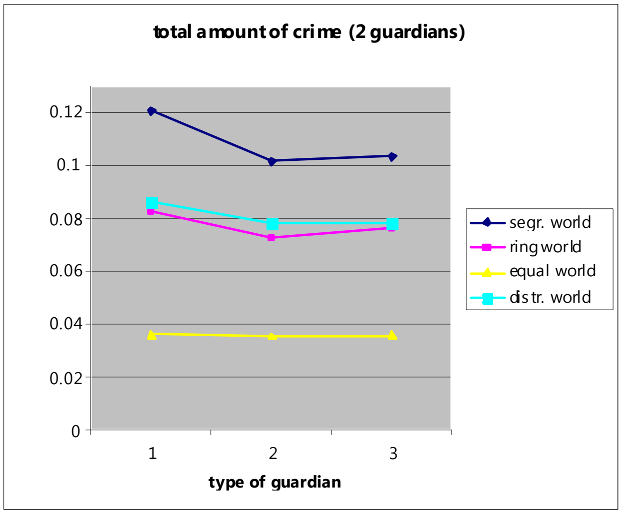
In Figure 3, the average crime rate is shown for the different worlds. In these graphs, the horizontal axis shows the different types of strategies, and the vertical axis shows the average amount of crimes per location per time point. Note that the results for 4, 6, and 15 guardians have been left out to improve readability. The different strategies seem to have the same effect in the segregated, ring, and distributed society. In these societies, both hot spot policing and area hot spot surveillance work better than random patrolling. Furthermore, hot spot patrolling is better than area hot spot surveillance until the number of guardians exceeds 5. Only in the equal society does the type of guardian have little influence. Overall, when there are more than 5 guardians, the guardians that patrol in an area hot spot manner are more effective than the other types of guardians.

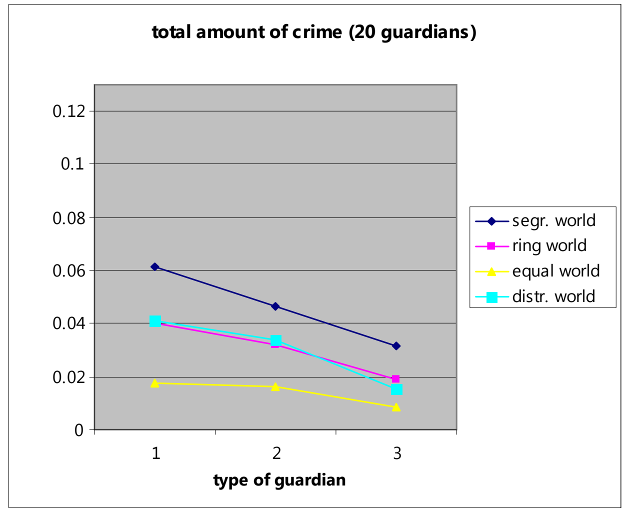
Figure 3
Total Crime Rate - Comparing Different Numbers of Guardians within One World.



When the crime rates are compared in the different worlds (see Figure 4), they are the highest in the segregated community. In the ring and distributed society, the crime rates are about the same, and the equal society is the world with the lowest crime rate.

Figure 4
Total Crime Rate - Comparing Different Worlds for One Number of Guardians.





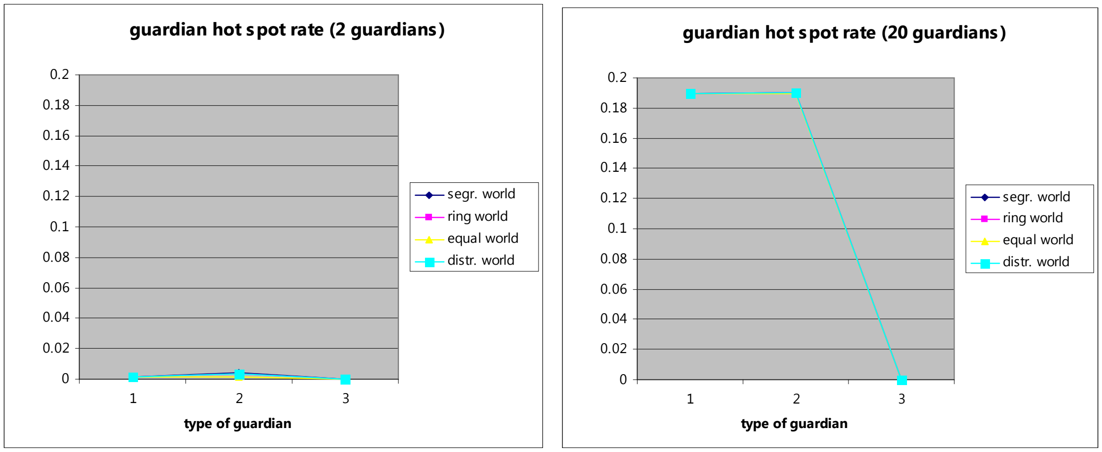
Crime Hot Spot Rate

For each location, we also counted the amount of times that it was populated by two or more motivated offenders per time point. Encounters between motivated offenders are independent of the amount and the type of guardians (since offenders move around in a random manner), therefore we do not show the results graphically as a function of the types of guardians. The motivated offenders encounter each other most often in the segregated world (0.017 times per location, per time point). The ring society is second (0.0095 times), the distributed society is third (0.0075). The offenders have the least encounters in the equal society (0). There were no encounters between motivated offenders in the equal society because, in this society, there was only one offender of which the burglary threshold was lower than the attractiveness of the houses.

Guardian Hot Spot Rate

Next, we investigated the average amount of times per location that each location was populated by two or more guardians per time unit. The results (for the case of two guardians and the case of twenty guardians) are displayed in Figure 5. Our main finding is that guardians using a hot spot strategy have more encounters than guardians that move randomly. Guardians that have an area hot spot strategy never meet each other because they are restricted to certain areas. Although this cannot be seen in the figures (since all points overlap), the guardians encounter each other most often in the segregated world. The ring society is second, the distributed society third, and the guardians have the least encounters in the equal society. However, these differences are very small.

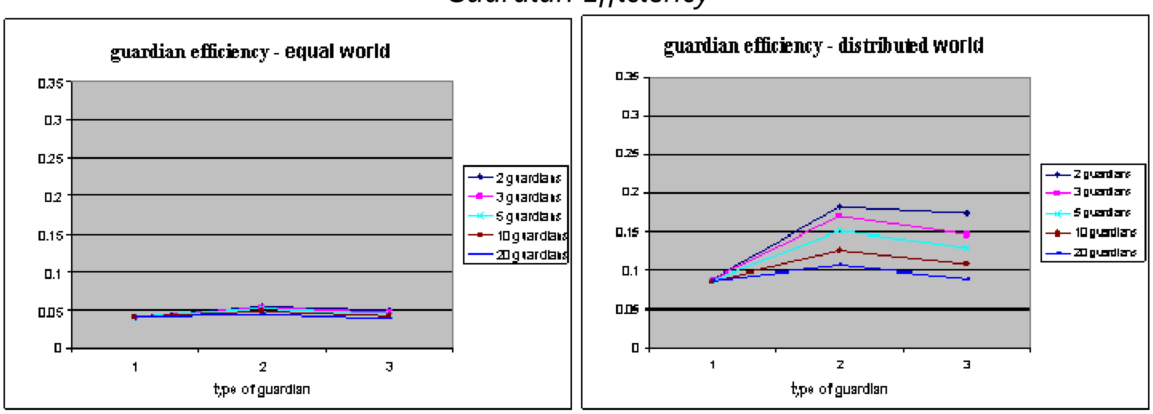
Figure 5
Guardian Hot Spot Rate.

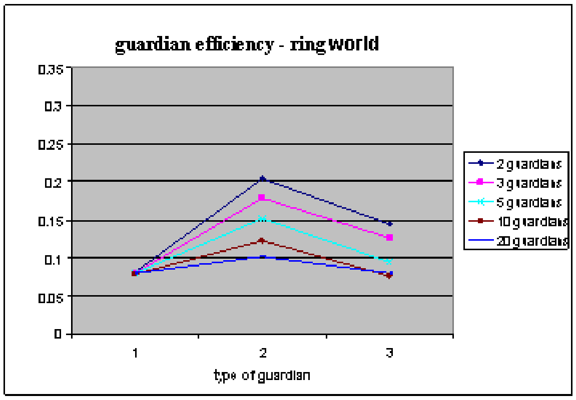


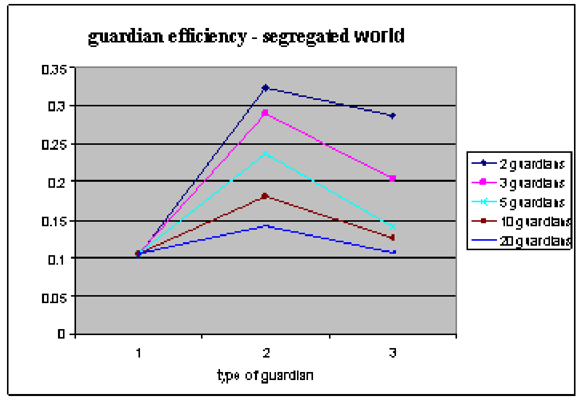
Guardian Efficiency

Guardian efficiency is the average amount of times that a guardian meets at least one offender per time point. The results of this are shown, for the different worlds, in Figure 6. In the

Figure 6
Guardian Efficiency







segregated, ring and distributed world, hot spot patrolling is more efficient than random patrolling area hot spot patrolling. Random patrolling and area hot spot patrolling are just as efficient in these worlds, at least for large amounts of guardians.; however, when there are fewer than 10 guardians, area hot spot patrolling is more efficient than random patrolling. In the equal society, hot spot patrolling is slightly more efficient than random patrolling and area hot spot patrolling. Random surveillance and area hot spot surveillance are equally efficient. Overall, guardians are most efficient in the segregated society. Both the ring and the distributed society are second, and guardians in the equal society are least efficient.

Scaling Up

The simulations discussed above all were performed in a world of 5x5 (25 locations), with 4 offenders and 2 to 20 guardians. To test whether these results are independent of the size of the society, we increased the size of the simulation. We created a larger world (10x10 = 100 locations), and also multiplied the number of guardians and offenders by 4. This yields a setting with 16 offenders and 8 to 80 guardians (for the time being we only considered the situation with 8 guardians). We only made a comparison between the randomly patrolling guardian (Type 1) and the hot spot patrolling guardian (Type 2). The results are shown in Table 1 and 2. As can be seen, scaling up does not have a significant influence on (normalized) findings.

Table 1

Comparing Worlds with Different Sizes - Type 1 and Type 2 Guardians

Type 1 Guardians

	5x5	10x10
crime rate	0.0368	0.0369

Type 2 Guardians

offender hot spot rate	0	0.0006
guardian efficiency	0.0412	0.0399
guardian hot spot rate	0.0015	0.0026

	5x5	10x10
crime rate	0.0357	0.0359
offender hot spot rate	0	0.0006
guardian efficiency	0.0544	0.0525
guardian hot spot rate	0.0017	0.0027

Discussion

The simulation experiments described above illustrate the usefulness of simulation as an analytical tool to investigate consequences of criminological theories under certain assumptions. In this project, the routine activity theory (Cohen & Felson, 1979; Felson, 2008) was taken as a point of departure, and a number of assumptions that form the basis of the theory were formalized in sufficient detail to be able to generate a simulation model. The simulation model was focused at the domain of burglary. It allowed us to create artificial societies and define varying circumstances for these societies, such as different attractiveness distributions of targets, different numbers of guardians, and different guardian strategies. By running the simulation model for these varying circumstances, various “experiments” were performed that enabled us to examine consequences of the theory (of course, still given certain assumptions) that we would not have been able to derive by means of traditional methods. For example, a first finding was that, in our simulations, hot spot surveillance and area hot spot surveillance turned out to work better than random patrolling, unless all targets were equally attractive. This makes sense, because, when all targets have the same attractiveness, probably no hot spots will occur at all. Moreover, hot spot surveillance turned out to usually work better than area hot spot surveillance, unless the amount of guardians was almost as big as the amount of locations. In such a situation, it is more efficient to distribute guardians over locations to prevent a situation where multiple guardians are guarding the same location and thereby wasting resources. With respect to the different geographical makeups of the societies, our simulations suggested that the crime rates were highest in situations where there were specific locations with a high concentration of attractive targets (such as in our segregated or ring society). Finally, the effect of scaling up the size of the society turned out to be small. Apparently, the (relative) crime rates do not increase much when a larger area is considered, as long as the number of offenders and guardians are increased proportionally.

Obviously, these results should be interpreted with some care. As discussed above, a simulation model is by definition an approximation of reality. As for any simulation model, some simplifying assumptions were made when developing the simulation model, (for example, about the distances between targets, the movement of the agents involved, and the individual decision making processes of the agents). In addition, the experiments described were only performed for some particular sets of parameter settings. Therefore, when interpreting the results, one should keep in mind that these were found under the given assumptions. Nevertheless, we hope to have convinced the reader that the results shed some light on interesting issues to be further investigated, such as the finding that area hot spot surveillance only works better than hot spot surveillance if the number of guardians is sufficiently large, to name a concrete example.

For future research, the current model can be extended in various directions. For instance, it would be interesting to investigate what happens if the offenders are made more intelligent (i.e., if they are able to "learn" the behavior of the guardians). Similarly, the guardians can be made more intelligent, for example, by having them anticipate the expected movements of the offenders instead of reacting to their actual movements. Finally, an interesting extension would be the addition of passers-by to the model (e.g., citizens that go to their work at 9 am and go back home at 5 pm, via some standard route) and study how the presence of these passers-by would influence the patterns found so far.

References

Bosse T. and Gerritsen C.(2008). Agent-Based Simulation of the Spatial Dynamics of Crime: on the interplay between offenders hot spots and reputation, In: *Proceedings of the Seventh International Joint Conference on Autonomous Agents and Multi-Agent Systems*, AAMAS'08, ACM Press, pp.1129-1136.

Bosse, T., Gerritsen, C., Klein, M.C.A., and Weerman, F.M. (2009). Development and Validation of an Agent-Based Simulation Model of Juvenile Delinquency. In: *Proceedings of the International Symposium on Social Intelligence and Networking, SIN'09*. In conjunction with the 2009 IEEE International Conference on Social Computing, SocialCom'09. IEEE Computer Society Press, 2009, pp. 200-207.

Bosse, T., Gerritsen, C., and Treur, J. (2007). Cognitive and Social Simulation of offender Behaviour: the Intermittent Explosive Disorder Case. In: *Proceedings of the Sixth International Joint Conference on Autonomous Agents and Multi-Agent Systems, AAMAS'07*. ACM Press, pp. 367-374.

Brantingham, P.L. and Brantingham, P. J. (1993). Environment, routine and situation: toward a pattern theory of crime. In: Clarke, R.V and Felson, M. (eds.), *Routine Activity and Rational Choice: Advances in Criminological Theory 5*. New Brunswick NJ, Transaction Publishers, 259-294.

Brantingham, P.J. and Brantingham, P. L (2004). Computer Simulation as a Tool for Environmental Criminologists. *Security Journal*, pages 22–30, 2004.

Brantingham, P.L., Glässer, U., Singh, K., and Vajihollahi, M. (2005). *Mastermind: Modeling and Simulation of Criminal Activity in Urban Environments*. Technical Report SFU-CMPTTR-2005-01, Simon Fraser University.

Clarke, R., and Felson, M. (eds.) (1993). *Routine Activity and Rational Choice: Advances in Criminological Theory*. Transaction Publications, 5.

Cohen, L. and Felson, M. (1979). Social Change and Crime Rate Trends: A Routine Activity Approach. *Am. Sociol. Rev*. 44: 588-608.

Cornish, D.B. and Clarke, R.V. (Eds.). (1986). *The reasoning criminal: Rational choice perspectives on offending*. New York, NY: Springer.

David, N. and Sichman, J.S. (eds.) (2009). Multi-Agent-Based Simulation IX. Springer-Verlag Lecture Notes in AI, vol. 5269, 2009.

Elffers, H. and Van Baal, P. (2008) Realistic spatial backcloth is not that important in agent based simulation research. An illustration from simulating perceptual deterrence. In: Lin Liu and John Eck (eds.) *Artificial Crime Analysis Systems: Using Computer Simulations and Geographic Information Systems*. Hershey, PA: Information Science Reference, pp. 19-34.

Elffers, H. (2004) The rational offender under a CCTV-camera: Conceptual clarification. In: A. Czerederecka, T. Jaśkiewicz-Obydzińska, R. Roesch & J. Wójcikiewicz (eds.) *Forensic Psychology and Law. Facing the challenges of a changing world*. Kraków: Institute of Forensic Research Publishers, p. 92-99

Felson, M (2008) Routine activity approach In: R. Wortley & L. Mazerolle (eds), *Environmental Criminology and Crime Analysis*. Cullompton: Willan Publishing, p. 70-77.

Felson, M and L.E. Cohen (1980), Human ecology and crime: a routine activity approach. *Human Ecology 8(4),* 389-406.

Groff, E.R. (2005). *The Geography of Juvenile Crime Place Trajectories*. Ph.D. Thesis: University of Maryland.

Groff, E.R. (2008). Characterizing the spatio-temporal aspects of routine activities and the geographic distribution of street robbery. In *Artificial Crime Analysis Systems: Using Computer Simulations and Geographic Information Systems*. Hershey, PA: Information Science Reference.

Hayslett-McCall, K., Qui, F., Curtin, K.M., Chastain, B., Schubert, J., and Carver, V. (2008). The Simulation of the journey to residential burglary. In: Liu, L. and Eck, J. (eds.), *Artificial Crime Analysis Systems*, Information Science Reference, 2008, pp. 281-300.

Johnson, S.D. and Bowers, K.J. (2004). The stability of space - time clusters of burglary. *British Journal of Criminology 44*, 55-65.

Liu, L. and J. Eck (eds.) (2008), *Artificial Crime Analysis Systems: Using Computer Simulations and Geographic Information Systems*. Hershey, PA: Information Science Reference.

Liu, L., Wang, X., Eck, J., and Liang, J. (2005). Simulating Crime Events and Crime Patterns in RA/CA Model. In F. Wang (ed.), *Geographic Information Systems and Crime Analysis*. Singapore: Idea Group, pp. 197-213.

Melo, A., Belchior, M., and Furtado, V. (2005). Analyzing Police Patrol Routes by Simulating the Physical Reorganisation of Agents. In: Sichman, J.S., and Antunes, L. (eds.), *Multi-Agent-Based Simulation VI, Proceedings of the Sixth International Workshop on Multi-Agent-Based Simulation, MABS'05*. Lecture Notes in Artificial Intelligence, vol. 3891, Springer Verlag, 2006, pp 99-114.

Ratcliffe, J.H. and Rengert, G.F. (2008). Near repeat patterns in Philadelphia shootings. *Security Journal*, vol. 21, issue 1-2, 58-76.

Rengert, G.F. and Wasilchick, J. (1985) *Suburban Burglary: A Time and Place for Everything*. Springfield, IL: Charles C. Thomas.

Reynald, D.M. (2009). *Guardianship in action : A theoretical & empirical elaboration of the routine activity concept*. Amsterdam: NSCR / Vrije Universiteit.

Townsley, M., Homel, R., and Chaseling, J. (2003). Infectious burglaries: a test of the near repeat hypothesis. *British Journal of Criminology 43*, 615-633.

Van Baal, P. (2004) Computer simulations of criminal deterrence. From public policy to local interaction to individual behaviour. Den Haag: Boom Juridische uitgevers.