Using genetic algorithms to get an Optimal Expansion Strategy for Innovative Storage Services

Richard Lackes, and Markus Siepermann

***Abstract*— In the last years new storage services, so-called self-storage-concepts, were installed in the logistic market. The main business idea of self-storage systems consists in providing flexible storage space to customers. Customers can rent storehouse capacities temporarily and can access the storehouse whenever they want to. The choice of a storehouse location plays an important role for its economic success. Because of the increasing demand for such services an adequate expansion strategy for self-storage enterprises had to be developed. Given a huge amount of several possible locations enterprises have to decide where a location should be built at which point in time for the next five years. For that it has to be considered the growth of the market itself, the competitors in the market and the local binding of this service. It means that one can get only such people as customers that stay in the near environment of the location. To calculate the net present value of the expansion strategy both the investment costs for real estates and equipment both the sales volume and profit hast to recognized. Thereby, we can distinguish two levels of decision making: The macro level is engaged with the decision on the region or town where a storehouse should be built. Within the micro level the concrete location in town is to be determined. This paper focuses on the macro level. For this, the decision model based on binary decision variables is developed that decides the expanding strategy for several years. As the problem cannot be solved in acceptable computational time a genetic algorithm is developed and implemented to solve the problem.**

***Keywords*— Expansion strategy planning, genetic algorithm, location planning, self storage, optimization, simulation.**

I. Objective

In the past decade, an innovative concept for storehouses evolved with its origin in the USA [17]. For outsourcing purposes, service providers offer storage capacities for individuals as well as for business users. The market is promising because the investment in storehouses, the operating costs and the market penetration are relatively low while the potential demand is high [5]. The basic idea is as follows: The service provider procures standardized storage room for a short period of time, the storage equipment (roller shutter, fork lift etc.) and administers the storehouse, but stockpiling and stock removal have to be done by the customers themselves. Due to an electronic entry system customers can access their rented storage capacities at any time independent of the presence of warehouse employees. For renters, this concept allows to reduce fixed storage costs that can now be replaced by usage dependent variable costs [13].

Because of the innovative character of the service and the developmentally chances many new sites will emerge in the next few years [5]. Therefore, it is very important in this stage to choose appropriate locations. Densely populated areas are attractive because of the restricted catchment area of a storehouse and the closeness to the potential target group. But the competitive situation and the investment costs in these areas are normally inauspicious. Thus, we are facing a complex long term site planning problem: How to choose the site that is the economically favorable one for the next years? [6] In the following we present a multi periodic optimization model for this problem and show how this problem can be solved.

II. Development of the Optimization Model

A. Characteristics and Goal

The characteristics of self-storage storehouses (SSS) are [5]: (1) Construction and equipment of SSS are considered as a medium-/long-term investment. (2) Once a decision on investment and location is made, a revision cannot be taken without greater loss. (3) SSS provide a certain capacity of storage space. (4) The offered product „storage possibility“ is not affected by usage concerning its quality and life expectancy. (5) Operating costs of an SSS are not constrained by use and load. They just ensure the disposability (availability fees). Thus, the marginal costs of an additional contract, if it lies within the capacity limits, matches 0. Non-use of storage capacity does not diminish the operating costs. (6) The sales market of an SSS is locally bounded to the location of choice. Main target group are individuals and craftsmen. (7) Even if the rental contracts allow flexible durations, most of the contracts are on a long term basis. To convince a customer once is important for the „natural“ customer loyalty.

The location planning for self-storage enterprises is a multi-periodic dynamic decision problem. The planning horizon amounts to T years, scaled in $t=1,2,...,T$ periods. Opening of storehouses takes place at period begin. The initial point in time is $t = 0$. The goal is the maximization of the net present value that is determined by all site decisions made within the planning horizon. The decision concerns the expansion strategy. That is if and when storehouses should be built at a location within the planning horizon.

Richard Lackes, and Markus Siepermann, are with TU Dortmund, Department of Business Informatics, Germany

B. Optimization Model

1) Site Alternatives and their Characteristics

The investigation area shall be split into equal grid boxes (e.g. 5*5 km), each regarded as an „atomic“ location element. A location will be determined by its x- and y-coordinates (x,y). Let x=1,…,X and y=1,…,Y be the relevant coordinates of all locations, so that the complete surface of the investigation area can be covered. Irrelevant locations that lie outside the grid because of the irregular shape of the investigation area are initially kept for an easier, formal description even if they are omitted later on. Each location is characterized by a set of attributes. Depending on their values a location rating can be computed. The relevant attributes of a location (x,y) for period t = 0,…,T are:

Outpayment: Land prices $GP_{x,y,t}$ [\$]; storehouse equipment costs $LEQ_{x,y,t}$ [\$]; labor costs index $LNIV_{x,y,t}$; annual outpayment-effective operating costs $K_{x,y,t}$ [\$/period].

The storehouse equipment costs usually are several hundred thousand \$. The labor cost index ranges around 1. The labor costs of a sub region (here: one grid of the investigation area) are set into relation to the average labor costs of the complete investigation area.

In-payment: Population $POP_{x,y,t}$ measured in 1000; purchasing power of population, measured by purchasing power index $KKI_{x,y,t}$; market range of coverage, attainable price per square meter $P_{x,y,t}$ [\$/sqm]; average rented storage space per contract [sqm]; life cycle curve of „salable“ storage space (contracts or rather rented space) conditioned by age of the storehouse; competitive situation (foreign as well as one's own SSS in catchment area); economic trend. The value of the population of one grid depends on the size of the chosen grids. In big towns the population may range from several ten thousand to hundred thousand people on the countryside there can be less than 1000 people in one grid. The purchasing power index like the labor cost index ranges around 1. The attainable prices per square meter vary not only from town to town but also from location to location in one town.

2) Prerequisites and Decision Variables

For the optimization, the following conditions shall hold:

(C1) At each location should be built a maximum of one storehouse. Locations with an already existing storehouse are not considered any further (see further C2).

(C2) Shutting down of storehouses will not be allowed.

(C3) There exist competitors on the market.

(C4) Due to financial shortage or other bottlenecks only Bt>0 storage houses can be built in one period t.

(C5) Each storehouse provides a certain maximum capacity of storage space $KAP_{x,y}$ measured in sqm.

(C6) The periods are not subdivided any further. All payments, except acquisition payments, occur at the period-end.

The decision variables consist of binary variables differenced after the locations and the construction periods [18]. Because of condition C1, only the values 0 (no construction) and 1 (construction of an storehouse) can occur so that the optimization model is a binary decision problem with the decision variables $S_{x,y,t}$:

$$S_{x,y,t} = \begin{cases} 1 & \text{if a storehouse is built at (x,y) in t} \\ 0 & \text{else} \end{cases} \quad (1)$$

$$\text{with } x \in \{1,...,X\},\ y \in \{1,...,Y\},\ t \in \{1,...,T\}$$

At the start of planning, already existing storehouse locations are such (x,y) ∈ X×Y with $S_{x,y,0} = 1$. Because of condition C1 and C4 it applies formula (2) and (3):

$$\sum_{t=0}^{T} S_{x,y,t} \le 1 \text{ for all } (x,y) \in X \times Y \quad (2)$$

$$\sum_{x=1}^{X}\sum_{y=1}^{Y} S_{x,y,t} \le B_t \text{ for all } t = 1,...,T \quad (3)$$

3) Determination of Outpayments for Equipment and Operation of a Storehouse

With regard to the outpayment, we have to consider site specific land prices $GP_{x,y,t}$ and site neutral payments for storage equipment $LEQ_{x,y,t}$. Furthermore, there occur operating costs which are almost fixed costs. With approximately 50%, labor costs are the biggest cost pool as surveys are showing. That means the annual site neutral costs affecting payments are K_t [\$/year] and the site specific costs – affected by the labor costs index $LNIV_{x,y,t}$ – are represented by K_t $LNIV_{x,y,t}$. The labor costs index $LNIV_{x,y,t}$ indicates the multiplier referring to a base salary (e.g. 1.07). From this, the annual costs affecting payments for the location (x,y) result in: $K_t \cdot (1 + LNIV_{x,y,t})$.

4) Determination of In-Payments

a) Calculation of Market Potential

A storehouse's market range of coverage is determined by its catchment area. It may reach beyond its own location (x,y) and can also contain the ones nearby. Therefore, we define a degree of proximity $1 \geq Ng((x_1,y_1),(x_2,y_2)) \geq 0$ for all pairs of locations in such way, that they decrease with increasing distance from the observed location. It indicates which share of the population in (x_2,y_2) can be reached by a storehouse in (x_1,y_1) due to distance and transportation infrastructure. The degree of proximity of one's own location obviously is 1. Symmetry shall always apply. The nearer two locations are or the better the transportation infrastructure between them is the more the degree of proximity approaches the value 1. The degree of proximity negatively correlates with the distance between two locations or the time that is needed to move from one location to the other.

All locations in the neighborhood with a positive degree of proximity are relevant for the site decision. With the help of this environment information the potential reachable customers $KUZ_{x,y,t}$ of a location (x,y) ∈ X × Y in period t=1,⋯ T is determined as:

.

$$KUZ_{x,y,t} = \sum_{i=1}^{X}\sum_{j=1}^{Y} POP_{i,j,t} \cdot Ng\left((x,y),(i,j)\right) \quad (4)$$

With $POP_{i,j,t}$ is the population of location grid box (i,j) in period t. If there are competing storehouses (own or foreign) that have access to the same market potential then the market potential has to be split. It has to be noted that not only storehouses of competitors but also own storehouses may reduce the market potential of a location (cannibalization effects).

Let $L_{x,y,t}$ be the number of storehouses at the beginning of period t in location (x,y) without differencing of own and foreign storehouses. Thus, the starting situation is described by $L_{x,y,1}$ with $L_{x,y,1} \geq S_{x,y,0}$ because of the competing storehouses. Then, the value of $L_{x,y,t}$ (t>1) is the sum of the starting situation and all site decisions before period t:

$$L_{x,y,t} = L_{x,y,1} + \sum_{t'=1}^{t-1} S_{x,y,t'} \quad \text{with } (x,y) \in X \times Y;\ t=2,3,\cdots,T \quad (5)$$

Having a look at a location (x,y) its market potential is influenced by surrounding storehouses that are already built. That means surrounding storehouses in the neighborhood usually reduce the number of customers that can be reached by a storehouse in (x,y). Assuming that the influence of a location (k,l) on a location (x,y) is only affected by the distance between them the „access intensity“ $ZUG_{x,y,t}$ that describes this influence of surrounding storehouses in period t can be calculated as follows:

$$ZUG_{x,y,t} = \sum_{k=1}^{X}\sum_{l=1}^{Y} Ng\left((k,l),(x,y)\right) \cdot L_{k,l,t}$$
$$\text{with } (x,y) \in X \times Y;\ t=1,2,\cdots,T\ . \quad (6)$$

Consequently, in period t the relevant market potential (in thousand inhabitants) of a storehouse to be built in location (x,y) is determined by:

$$MP_{x,y,t} = \sum_{i=1}^{X}\sum_{j=1}^{Y} POP_{i,j,t} \frac{Ng\left((x,y),(i,j)\right)}{\max\left\{Ng\left((x,y),(i,j)\right) + ZUG_{i,j,t};1\right\}} \quad (7)$$

If there are no surrounding storehouses in the neighborhood location (x,y) catches all possible market potential of a location (i,j) as long as the neighborhood is not zero. In a bottleneck situation, the market potential is distributed proportionally in accordance to the degree of proximity. That means, if there are storehouses in the neighborhood of location (i,j) a new storehouse in (x,y) can only take a share of the complete market potential of (i,j). The influence of the existing storehouses in the neighborhood is given by $ZUG_{i,j,t}$ and the new influence in total by $ZUG_{i,j,t}$ plus the influence of the new storehouse in (x,y) given by Ng((x,y),(i,j))

b) Attainable Price and Quantity of sales

Empirical studies have shown that the price per sqm $P_{x,y,t}$ correlates positively with the purchasing power index $KKI_{x,y,t}$. The capacity utilization depends except for the market potential $MP_{x,y,t}$ on the the age of a storehouse. Thus, there is a „life cycle curve“ that can be described with the age dependent success rate $SUCCESS_s$ ($s=1,\ldots,T_L$) measured in contracts per 1000 reachable customers. T_L is the lifetime of a storehouse. In its beginning a storehouse becomes known and gets used until the capacity limit is reached. The typical curve is first ascending continuously up to a certain absorption point and then stagnating. Practical experiences have shown that this point usually is reached after six years. The reason for this phenomenon is that many customers are storing goods during a long period of time. Once a storehouse has gained a customer he most likely will rent his storage box over the next years. This effect is enhanced by relatively high costs for stock transfer if another storehouse will be chosen for rental. Therefore, the number of contracts $AK_{x,y,t}$ is determined by (t is the storehouse's building time):

$$AK_{x,y,\tau} \leq SUCCESS_{\tau-t+1} \cdot MP_{x,y,\tau} \qquad \tau = t, t+1, \ldots T \quad (8)$$

Additionally, the number of contracts is limited by the capacity of a storehouse. Let $LF_{x,y,t} = f_L(KKI_{x,y,t})$ with $d_{LF}/dKKI_{x,y,t} \geq 0$ be the averaged storage space per contract. Then, the demand is determined by the number of contracts multiplied with the averaged storage space per contract.

c) The Investment's Residual Value

Let $RW_{x,y,t}$ be the residual value of a storehouse built in period t at location (x,y). This value represents a storehouse's value at the end of the planning horizon T. It is needed because the revenue of such an investment takes place after a certain period of time that might lie beyond the planning horizon. If $RW_{x,y,t}$ would not be taken into account investments at the end of the planning horizon would be monetarily misinterpreted

5) Objective Function

The acquisition value $AW_{x,y,t}$ of a storehouse at location (x,y) at the beginning of period t has two components: The site specific land price $GP_{x,y,t}$ as well as the site neutral payments for the storehouse equipment $LEQ_{x,y,t}$:

$AW_{x,y,t} = GP_{x,y,t} + LEQ_{x,y,t}$. (9)

Then, the net present value $CV_{x,y,t}$ of a storehouse in location (x,y) built at the beginning of period t ($x \in X$, $y \in Y$, and $t=1,\cdots,T$) with interest rate i will be:

$$\begin{aligned} CV_{x,y,t} = & -AW_{x,y,t} \cdot (1+i)^{-(t-1)} \\ & + RW_{x,y,t} \cdot (1+i)^{-T} \\ & + \sum_{\tau=t}^{T} \begin{pmatrix} AK_{x,y,\tau} \cdot LF_{x,y,\tau} \cdot P_{x,y,\tau} \\ -K_{x,y,\tau} \cdot \left(1 + LNIV_{x,y,\tau}\right) \end{pmatrix} \cdot (1+i)^{-\tau} \end{aligned} \quad (10)$$

The discounting always is for the planning horizon begin, i.e. t=0. The acquisition payments accrue at period begin, all other payments at period-end. Naturally, the following condition must hold:

$CV_{x,y,t} \geq 0$ with $(x,y) \in X \times Y$; t=1,2,…,T . (11)

Now, the objective function consists in the maximization of the total net present value:

$$\text{Max} \sum_{t=1}^{T}\sum_{x=1}^{X}\sum_{y=1}^{Y} CV_{x,y,t} \cdot S_{x,y,t} \; . \tag{12}$$

Because $S_{x,y,t}$ are binary variables we are facing a binary decision model. The number of decision variables is X·Y·T. In order to compute the access intensity $ZUG_{i,j,t}$ all existent storehouses in t plus those storehouses to be built (represented by $S_{x,y,t}$) including the proximity index have to be considered. Additionally, the access intensity is a determination factor of the market potential. Thus, the decision model is highly complex. Because of the huge number of decision variables and the impact of decisions in former periods on later periods commonly known optimization algorithms cannot solve the problem in an acceptable calculation time. Only with proximity index 0 for all neighbor grid boxes a classical binary optimization algorithm could succeed because then, the access intensity only depends on the known starting situation at the beginning of the planning horizon.

III. Decision Problem to determine the Expansion strategy and Locations

A. *Characteristics of the Decision Tree*

The dynamics of the problem we described above consists in the fact that the decision to build a storehouse in location (x,y) affects the profitability of all alternatives in the following periods. Therefore, the optimal solution can only be achieved if it is computed simultaneously for all points in time of the planning horizon. Thus, the complete decision tree that represents the solution space has to be examined before the optimal solution is found. A classical greedy-algorithm that chooses the best „local“ alternative in each point in time usually does not lead to the optimal solution. The size of the decision tree and therefore the solution space is growing exponentially with the number of periods. After the first period t=1, with is the number of free locations and B_t is the number of storehouses that can be built in period t, the number of possible situations is:

$$\sum_{i=0}^{B_2}\binom{X \cdot Y}{i} = \sum_{i=0}^{B_2}\frac{(X \cdot Y)!}{i! \cdot ((X \cdot Y) - i)!} \tag{13}$$

Even if we assume that the number of storehouses that can be built in each period is exactly B_t=1 (t=1,…,T) there are $X \cdot Y$ possibilities in the first period. In the second period there are $X \cdot Y - 1$ possibilities and so on. If the planning horizon is T periods the number of leafs in the decision tree is:

$$\frac{(X \cdot Y)!}{(X \cdot Y - T)!}$$

Each leaf characterizes the state of locations at the planning horizon’s end. The path leading from the root to a leaf represents the state transitions. Different leafs may represent the same state that can be achieved in different ways. The computation time is not determined by the number of different states but by the number of different ways to the states. Assuming the time t as the third dimension in addition to the location coordinates x and y the solution space is a cube. Let X and Y be 100 and the planning horizon be 5 then we are facing a solution space of 9.5 billion elements!

B. *A Genetic Algorithm to solve the Problem*

1) *Individuals*

In the following we assume B_t = 1 for simplification. A solution can be described via a 3D-cube with the location coordinates and the periods as dimensions (in the following see [14], [20]). Then, an individual of a genetic algorithm is one solution alternative that can be defined as follows: The individuals can be represented as a X × Y-matrix M. The matrix contains a maximum of T values between 1 and T whereas no value occurs twice. The other values of the matrix are 0. A value $M_{x,y} > 0$ in the matrix indicates that a new storehouse is built at site (x,y) in period $M_{x,y}$. The value 0 indicates that no storehouse is built at site (x,y). Then, the solution of the decision problem is:

$$S_{x,y,t} = \begin{cases} 0 & \text{if } M_{x,y} = 0 \\ 1 & \text{if } M_{x,y} = t \end{cases} \tag{14}$$
$$\text{for all } (x,y) \in X \times Y \text{ and } t = 1,\dots,T$$

The population of the genetic algorithm consists in a set of individuals M^1, M^2, ..., M^P

2) *Mutation*

Let M be an individual to solve the location planning problem. Then, the mutation operator can be defined as follows: Randomly choose one cell (i,j) of matrix M ($1 \leq i \leq X$; $1 \leq j \leq Y$). If $M_{i,j}$=0 then randomly choose a second cell (k,l) of matrix M ($1 \leq k \leq X$; $1 \leq l \leq Y$) with $M_{k,l} > 0$ (case 1), else randomly choose a second cell (k,l) of matrix M ($1 \leq k \leq X$; $1 \leq l \leq Y$) with any value (case 2). Now exchange $M_{i,j}$ and $M_{k,l}$ i.e.: $M'_{i,j} = M_{k,l}$ and $M'_{k,l} = M_{i,j}$ Every cell $\neq M_{k,l}$ or $M_{i,j}$ keeps untouched.

Because of the crossover we are discussing later on some values might be lost during the calculation. In order to reproduce those missing values between 1 and T we can insert them – randomly controlled – in the first case $M_{i,j}$=0. Because the mutation is a background operator in genetic algorithms in order to ensure the accessibility of the complete solution space the probability of using the operator should be low.

3) *Crossover*

Let M and N be individuals of the genetic algorithm. Then, the crossover operator [8] exchanges parts of the two individuals as follows: Randomly choose four numbers $1 \leq x_1 < x_2 \leq X$ and $1 \leq y_1 < y_2 \leq Y$. Then, (x_1,y_1) and (x_2, y_2) define a rectangle in the solutions M and N whereas (x_1,y_1) is the upper left and (x_2, y_2) is the lower right corner of the rectangle. Then, the rectangles are cut out of M and N and implanted into the other solution. The descendants M' and N' are defined as follows:

$$M'_{x,y} = \begin{cases} M_{x,y} & \text{if } x < x_1 \text{ or } \\ & x > x_2 \text{ or } \\ & y < y_1 \text{ or } \\ & y > y_2 \\ N_{x,y} & \text{if } x_1 \le x \le x_2 \text{ and } \\ & y_1 \le y \le y_2 \end{cases} \quad (15)$$

$$N'_{x,y} = \begin{cases} N_{x,y} & \text{if } x < x_1 \text{ or } \\ & x > x_2 \text{ or } \\ & y < y_1 \text{ or } \\ & y > y_2 \\ M_{x,y} & \text{if } x_1 \le x \le x_2 \text{ and } \\ & y_1 \le y \le y_2 \end{cases} \quad (16)$$

This operation may lead to invalid individuals. The number of values between 1 and T may now be greater than T (case 1). Values between 1 and T may occur twice but there are only T values greater than 0 (case 2). Therefore, a repair mechanism has to be installed. In the first case, we randomly choose a cell with a value that occurs twice and set the value of the cell to 0. This is done until there are only T values greater than 0. Now, either the individual is repaired or we are facing case 2. In the second case there are doublets as well as missing values. Therefore, we randomly choose a cell with a doublet value and set the cell's value to one of the missing value. This is repeated until no value occurs twice. The repair mechanism may be restricted to the cutting rectangle of the crossover in order to avoid an arbitrary creation of new individuals.

After the crossover there may be individuals that do not violate the criteria of allowed individuals but which have less than T cells with values greater than 0. These incomplete individuals may suffer from a bad fitness. Then two possibilities are feasible: Because of the bad fitness the incomplete individual will die off very probably so that nothing should be done. Otherwise, we can also fix those individuals in order to improve the fitness of the population. This can be done when the invalid crossover partner is being repaired: Every time a cell (i,j) of the partner individual is set to 0 the value of the partner's cell can be implanted into the incomplete individual. This can be done by choosing the same cell (i,j) or a random cell. As the repair mechanism implies many randomly generated modifications the mutation operator may be obsolete.

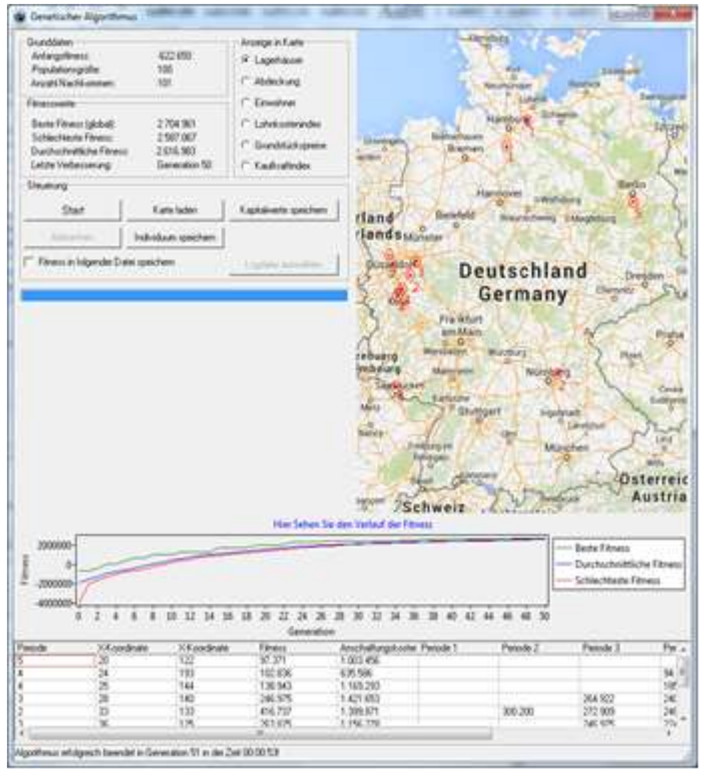

Fig. 1. Screenshot of the Genetic Algorithm Program.

4) Fitness

The fitness of an individual shall represent its excellence. It is used to choose the individuals for crossover and the selection of the next generation. Therefore, the net present value is used. The net present value can easily be calculated because an individual represents one complete solution of the decision problem. Each solution is allowed due to the construction rules and the repair mechanism

5) Algorithm Process

Starting with a randomly generated population with P individuals we create h(P) descendants with the help of crossover (primarily) and mutation (secondarily). Out of the P + h(P) individuals we choose the best P individuals for the next generation. The number of iterations may orientate to the improvement of the averaged fitness of a generation or to a computation time limit. [15]

Having finished that individual of the last generation with the best fitness can be assumed as the best solution.

IV. Conclusion and further Enhancements

In this paper we presented an optimization model for the location planning of self-storage enterprises concerning the expansion strategy. As this problem is a binary decision problem with many decision variables it can hardly be solved with deterministic algorithms. As genetic algorithms rapidly find good solutions [[1]] we designed a genetic algorithm that finds a good solution in an acceptable computation time.

Some enhancements are conceivable. Competing storehouses have a strong absorption influence on the market in the catchment area. Therefore, we can introduce a sales volume coefficient $UKO_{x,y,t} \leq 1$ that describes how the own sales volume is confined by other storehouses in the catchment area. This coefficient then affects the potential reachable customers $KUZ_{x,y,t}$ and therefore the income of a storehouse.

REFERENCES

[1] Alander. J.T., 1992, On optimal population size of genetic algorithm, [in:] Proceedings of computer systems and software engineering, 6th annual European computer conference, IEEE Computer Society, pp. 65-70. https://doi.org/10.1109/cmpeur.1992.218485

[2] Azamand, Z., Neishabouri, E., 2009, Location Allocation Problem, Facility Location: [in:] Contributions to Management Science, pp. 93-109.

[3] Crossland, A.F., Jones, D., Wade, N.S., 2014, Planning the location and rating of distributed energy storage in LV networks using a genetic algorithm with simulated annealing, [in:] Electronical Power and Energy Systems, Vol. 59, pp. 103-110. https://doi.org/10.1016/j.ijepes.2014.02.001

[4] Diaz-Gomez, P., Hougen, D., 2007, Initial Population for Genetic algorithms: A metric approach. GEM, pp. 43-49,

[5] Duffy, S., Kliebenstein, R.K., 2005, How to invest in Self-Storage, MiniCo Publishing.

[6] Fleischmann, B., Klose, A. (eds.) 2004, Distribution Logistics: Advanced Solutions to Practical Problems, Springer.

[7] Goldberg, D.E., 1989, Genetic algorithms in search, optimization and machine Learning, Kluwer academic publishers, Boston, MA.

[8] Gwiadzda, T., 2006, Genetic algorithm reference, Vol. 1, Crossover for single-objective numerical optimization problems, Lomianki: TomaszGwiadza E-Books. 2006.

[9] James, T., Vroblefski, M., Nottingham, Q., 2007, A hybrid grouping genetic algorithm for the registration area planning problem, [in:] Computer Communications, Vol. 30, pp. 2180-2190. https://doi.org/10.1016/j.comcom.2007.04.018

[10] Jaramillo, H.H., Bhadury, J., Batta, R., 2002, On the use of genetic algorithms to solve lovation problems, [in:] Computers and Operations Research, Vol. 29, pp. 761-779. https://doi.org/10.1016/S0305-0548(01)00021-1

[11] Koza, J.R., 1993, Genetic Programming, MIT Press.

[12] Kumar, R.S., Abraham, J.G., Mathew, V., Francis, J.J, Oommen, M., Mathew, N.O., 2013, Genetic algorithm for solving the uncapacitated facility location problem, [in:] International Journal of Engineering Research & Technology, Vol. 2, Issue 3.

[13] Mark, K., 2005, Leveraging Wal-Mart, eBay and USPS, in Morse, E. A., Mitchell, R. K., Cases in Entrepreneurship: The Venture Creation Process, SAGE.

[14] Mitchell, M., 1998, An Introduction to Genetic Algorithms, MIT Press.

[15] Razali, N.M., Geraghty, J., 2011, Genetic algorithm performance with different selection strategies in solving TSP, Vol. II, pp. 4-9.

[16] Ren, Y, Awasthi, A. 2012, Location allocation planning of logistics depots using genetic algorithm, Poznan University of Technology.

[17] Self Storage Association, 2007, US Self Storage Industry 1985 to 2005: Facilities, Square Meters, Revenue etc., Self-Storage-Conference 2007, Paris.

[18] Vahrenkamp, R., 2007, Logistik, 6. Auflage, Oldenbourg.

[19] Vargas, L.S., Jiminez-estevez, G.A., 2011, Genetic algorithms fort he capacitor placement problem in distribution networks, [in:] 1th international conference on intelligent system application to power systems (ISAP).

[20] Vose, M.D., 1999, The Simple Genetic Algorithm: Foundations and Theory, MIT Press.

[21] Vroblefski, M., Brown, E.C., 2006, A grouping genetic algorithm for registration area planning, [in:]Omega: The International Journal of Management Science, Vol. 34, pp. 220-230.

[22] Zhou, G., Min, H., Gen, M. 2003, A genetic algorithm approach to the bi-criteria allocation of customers to warehouses. [in:] International Journal of Production Economics, Nor. 86, pp. 35-45. https://doi.org/10.1016/S0925-5273(03)00007-0

Prof. Dr. Richard Lackes holds the chair of Business Information Management at the Faculty of Business, Economics and Social Sciences of TU Dortmund University since 1994. He studied Computer Sciences and Business Sciences at the University of Saarbrücken and graduated as a Ph.D. in 1989 with a doctoral thesis on cost information system. After his postdoctoral lecture qualification on just-in-time concepts he focused on the following research fields: Business Intelligence, Knowledge Management and Data Mining, E-Learning, Communications Management, and Supply Chain Management.

Dr. Markus Siepermann is Assistant Professor at the Department of Business Information Management at the Faculty of Business, Economics and Social Sciences of TU Dortmund University. He graduated in Computer Sciences at TU Dortmund University in 1999. Since then he worked as an assistant lecturer in Dortmund where we finished his Ph.D. in 2008 with a doctoral thesis on Risk Management Information Systems. He currently works on his postdoctoral lecture qualification on Supply Chain Risk Management. His main research interests are Business Intelligence, E-Learning, Social Media, Risk Management, and Supply Chain Management. .