The Tyranny of Small Steps: Discovery of a reoccurring behaviour

Hörður V. Haraldsson[a♣], Harald U. Sverdrup[a], Salim Belyazid[a], Johan Holmqvist[b], Robin C.J. Gramstad[a]
[a]Department of Chemical Engineering, Lund University, Box 124 Lund, Sweden
[b]SWECO VIAK, Gejersgatan 8, 21618 Malmö, Sweden

Abstract
The Tyranny of Small Steps (TYST) has been discovered to be a systemic reoccurring behaviour. Explained through a system dynamics perspective, the behaviour TYST is an unwanted change to a system through a series of small activities that may be independent from one another. These activities are small enough not to be detected by the 'surveillance' within the system, but significant enough to encroach upon the "tolerance" zone of the system and compromise the integrity of the system. TYST is an unintentional process that is experienced within the system and made possible by the lack of transparency between an overarching level and a local level where the encroachment is taking place. The Örby case study illustrates a real life manifestation of the TYST behaviour in planning. The TYST illustrates the necessity for total transparency in any systems in order to avoid unintended consequence of the behaviour. The TYST process may be regarded as a part of wide range of complex systems but depending on the conditions, it can remain dormant, and only become active when the conditions for lack of transparency are fulfilled.

Keywords: reoccurring behaviour, Tyranny of Small Steps, TYST, Tolerance Zone, Core Zone, planning

1 Background

In many organisational systems we are steadily frustrated by the inefficiencies of our policies. Our carefully designed policy, based on good intentions and careful planning, simply turns out to be powerless when it comes to dealing with the problem we wish to address. There is a tendency for project development to be influenced by a series of small decisions. Kahn (1966) discusses how consumers through their decisions can possess much power on the market development through a concept called "the tyranny of small decisions". Resources in the market economy are highly dependent on the cumulative market transactions of the individual consumers. Although not intentionally made, each market transaction by the consumer is a "vote" for a certain product or service. Odum (1982) and Burnell (2002) have further elaborated the "tyranny of small decisions" concept. Odum refers to "small" independent decisions, insignificant to the individuals who make them, that have been responsible for the loss of the natural swamps in the Florida Everglades. Burnell, has recently looked into the role of the tyranny of small decisions in public policy making and uses the 2001 election in Zambia as an exam-

♣ Corresponding author: Hordur.haraldsson@chemeng.lth.se
Tel: +46 46 2224866, Fax: +46 46 149 156

ple where a certain type of information was made gradually dominant in the campaign, thus affecting the outcome of the election. What these observations have in common is that cases are seldom a single event but a gradual build up of multiple actions over a certain period of time.

Simon (1969) distinguishes between an outer environment and inner environment within a system where the property of one only indirectly affects the outcome of the other. According to Simon, a complex system is hierarchical in character, where the basic understanding of it comes through the emerging behaviour of the system. The understanding of the system goals does not require a detailed understanding of the lower hierarchical levels. Also, the higher level may in fact react on the 'super signals' emerging from its lower levels (Dörner, 1996). A concealed mechanism working on a lower level may delay any super signal that is supposed to be interpreted on a higher level and render any decision on the system useless if no historical references are available for it. Thus decisions made on the current state of a system with lack of long-term reference to how a specific case has developed could have undesirable effects.

Within system dynamics research, reoccurring behaviours may fall into a category called archetypes. An archetype is an explanation of a system behaviour that has certain properties which can be identified in different problems. Archetype is a collective name for definitive system properties which can be used to explain comparable reoccurring behaviours in systems that are independent from one another. Archetypes are used to explain an outcome from an analysis of system behaviour (Sterman, 2000). By applying an archetype to explain system behaviour, one can get more rapid understanding of the overall behaviour of the system.

2 Purpose and objective

The purpose of this paper is to illustrate how the "tyranny of small steps" model can be used to explain reoccurring behaviour in land use and resource management decision-making processes. We will also discuss whether the tyranny of small steps has the qualities that are recognised in an archetypical behaviour.

3 The theory and principles of the TYST behaviour

Here the concept from Kahn is further developed into the behaviour called the Tyranny of Small Steps (TYST). Explained through a system dynamics perspective, TYST is an unwanted change to a system through a series of small activities that may be independent from one another. These activities are small enough not to be detected by the surveillance within the system, but significant enough to encroach upon the "tolerance" zone of the system. The concept 'zone' is here considered a realm or domain of a system which undergoes activities that influence the system properties. These activities either increase or reduce one zone at the expense of another within an enclosed system domain. The ideally desired state of the system is to maintain the integrity of the whole by keeping the core zone intact. It may occur that part of the overall system is not strictly protected from change, e.g. due to a lax surveillance of the state of the system. As a result of this unintentional tolerance for change, a tolerance zone emerges where small enough changes are individually allowed to happen.

A system is considered to possess two properties within the inner environment, a Core Zone and a Tolerance Zone. The Core Zone is the rigid part of the domain that cannot be altered by external activities whereas the Tolerance Zone is a proportion of the overall domain where

changes are allowed. If part of the Tolerance Zone is changed into another state within the inner environment (called the Encroachment Zone), the only way to replenish it is to allocate that missing part from the Core Zone since the Tolerance Zone is a constant proportion of the Core Zone. Like the emergence of the Tolerance Zone itself, its replenishment is the result of the indulgence or lack of rigidity of the system. The Tolerance Zone can be regarded as a dispensable 'buffer' between the Core Zone and the outer environment. It can actually exist anywhere within the domain but it has the clear distinction from the Core Zone of being consumable and renewable to the extent allowed by the domain. The Core Zone and Tolerance Zone are part of the inner environment which makes up the total domain, but as soon as the Tolerance Zone is being encroached, that part is transformed into an Encroached Zone. The Encroached Zone then becomes a part of the inner environment. However, the encroachment activity is still a part of the outer environment since it is governed by principles not residing within the inner environment. Refer to Fig. 1.

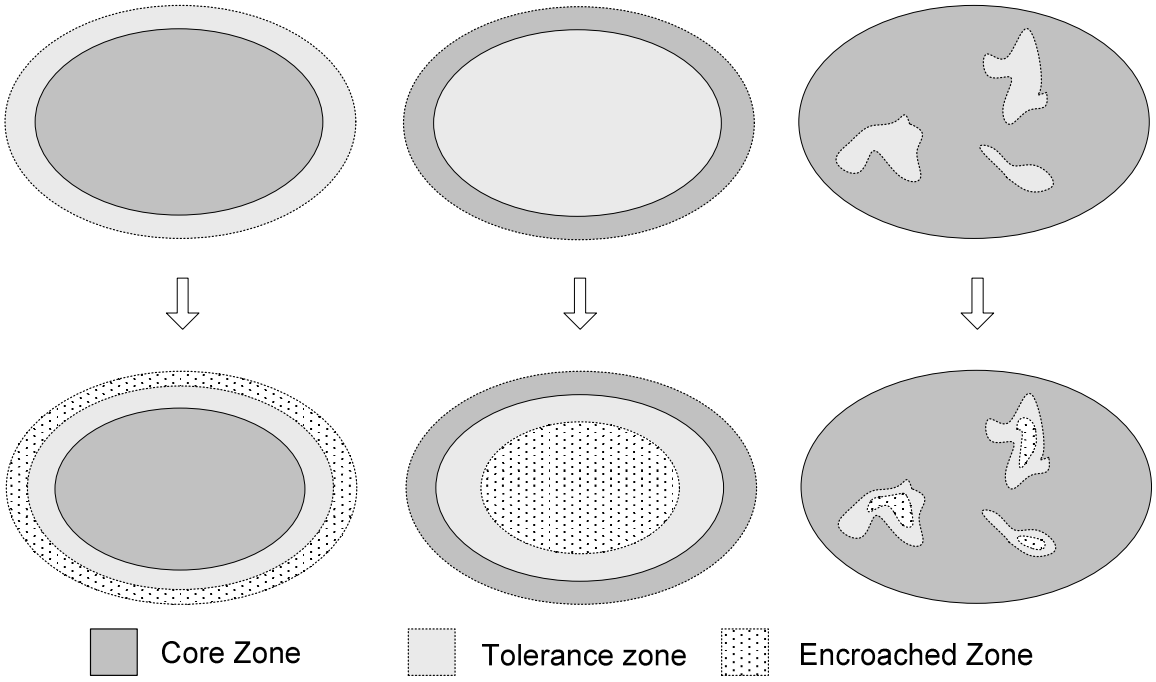

Fig. 1: The Tolerance Zone is a proportion of the Core Zone and can exist within the domain in any form. Encroachment Zone becomes part of the domain after encroachment has taken place.

The outer environment only communicates with the inner environment through the encroachment. The Encroached Zone is still part of the total domain (i.e. the inner environment) since the domain has not changed its boundaries, only the properties of the zones residing inside it.

The TYST behaviour describes the process of how, within a certain domain, the Core Zone is gradually transformed into an Encroaching Zone only through the intermediary of the Tolerance Zone. The reduction of the Core Zone, transmitted through the occurrence of consuming activity in the Tolerance Zone, is an unwanted effect, and is a result of the system not being able to detect the consuming activity. The TYST behaviour works then on two levels. First, there is a local level that enables encroachments on the Tolerance Zone as long as it is not detected. Second, there is an overarching level that prevents any encroachment on the Core Zone but is only able to detect activities that are over a certain detection limit. External activities that are smaller than the detection limit will encroach on the Tolerance Zone. This change is automatically transmitted to the Core Zone. External activities that are larger than the detec-

tion limit will be halted by the overarching level. The TYST behaviour is based on four main assumptions, without which the undesired behaviour, the depletion of the Core Zone, is avoided. The assumptions are:

(1) A Tolerance Zone is able to emerge in a system with lax surveillance so that change can occur in the Tolerance Zone.
(2) Whenever depleted or reduced, the Tolerance Zone is replenished, i.e. the Tolerance Zone is always present as long as the detection precision of the system remains unchanged.
(3) The Tolerance Zone is only replenished at the expense of the Core Zone, and not the systems outer environment.
(4) The systems to which the TYST behaviour is applicable are finite.

The assumptions above can be stated mathematically as follows:

$$O=CZ+TZ+EZ \qquad (1.1)$$

Where O is the overall domain, CZ the Core Zone, TZ the Tolerance Zone, and EZ the Encroached Zone. The overall zone is a finite constant (cst) (assumption 4). From (1.1) we can deduce that the change over time of the overall domain is equal to the sum of the changes over time of the individual zones:

$$\frac{dO}{dt}=\frac{dCZ}{dt}+\frac{dTZ}{dt}+\frac{dEZ}{dt} \qquad (1.2)$$

Yet, because the overall domain is constant,

$$\frac{dO}{dt}=0 \qquad (1.3)$$

Consequently, (1.2) becomes:

$$\frac{dCZ}{dt}+\frac{dTZ}{dt}+\frac{dEZ}{dt}=0 \qquad (1.4)$$

The Tolerance Zone is a property of the system, as it is defined as the result of the precision of the overarching system's detection. It is then possible to say that the Tolerance Zone remains constant, in which case equation (1.4) becomes:

$$\frac{dCZ}{dt}=-\frac{dEZ}{dt} \qquad (1.5)$$

This means that a change in the Encroaching Zone, although it happens through the intermediary of the Tolerance Zone, means a change in the opposite direction in the Core Zone. In other words, the expansion of the Encroaching Zone implies a decline of the Core Zone.

With a wide enough time step dt, the argument above holds even for a fluctuating Tolerance Zone as long as this latter is replenished at each revision of the system. This behaviour gives a hint about how to avoid or fix the TYST behaviour through nullifying the Tolerance Zone and

countering any positive change in the Encroaching Zone. This will be further discussed later in the paper.

The TYST behavior consists of four balancing loops, as seen in the causal loop diagram (CLD) in Fig. 2 and Fig. 10. Three loops, B1, B2 and B3 make up the behaviour of encroaching on the Tolerance Zone (TZ) and the Core Zone (CZ) and loop B4 regulates the rate of encroachment, Fig. 5 and 10. An External activity has a certain Encroachment rate (r_E) that invades the Tolerance Zone and increases the Encroached Zone (EZ). Reduction in the Tolerance Zone will trigger an Adjustment rate (r_A) that tries to compensate for the loss in Tolerance Zone by converting a part of the Core-Zone into a Tolerance Zone. Thus the Tolerance Zone maintains its size at the expense of the Core Zone. Encroachment is only halted through Detection. In a self regulating system, it is possible that the size of the Core Zone sets the Detection limits (a link between CZ and detection threshold). If the Core Zone has not been encroached, it maintains a high detection threshold, i.e. the Core Zone endures a high magnitude of encroaching activity, but the detection threshold is lowered each round the Core Zone is reduced. However, it is also possible that a decreasing Core Zone means less resistance to the Encroachment and Adjustment rates, making the encroachment grow faster with the decline of the Core Zone. In Fig. 2, the reference behaviour of the TYST system is plotted over time where encroaching activities are successful every fifth time interval. Fig. 2 shows the case when no feedback is present from the Core Zone to the Detection limit.

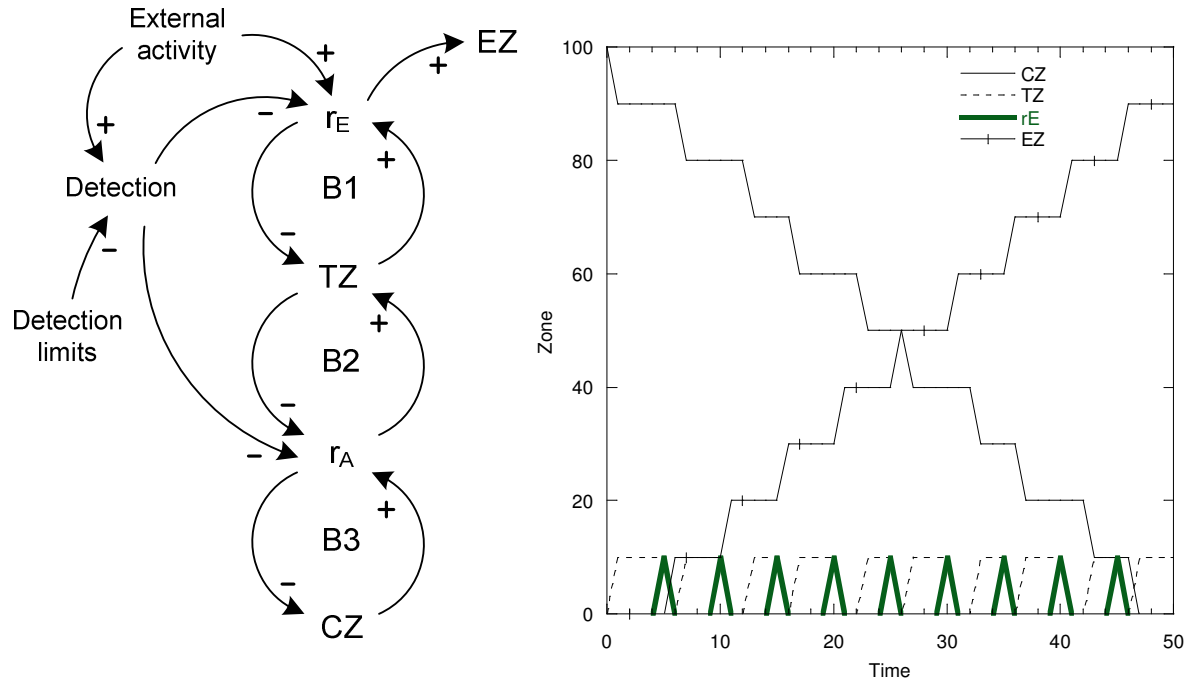

Fig. 2: The basic function of the TYST and its reference behaviour.

When translating the TYST model CLD into a Stock and Flow Diagram (SFD) the Encroached Zone, Tolerance Zone and Core Zone are defined as 'stocks', Fig. 3. Describing TYST in mathematical terms of the CLD reveals the following. TYST consists of two levels; the lower level consists of the "small steps" encroaching onto the Tolerance Zone (Eqs. 2.1, 2.3-2.6), whereas the higher level, the detection, is the "tyranny" part of the system (Eqs. 2.2 and 2.7). The tyranny is only made possible by the irreversibility of the system flows. The fact that the Encroached Zone is never a provider requires that the Tolerance Zone can only be replenished from the Core Zone.

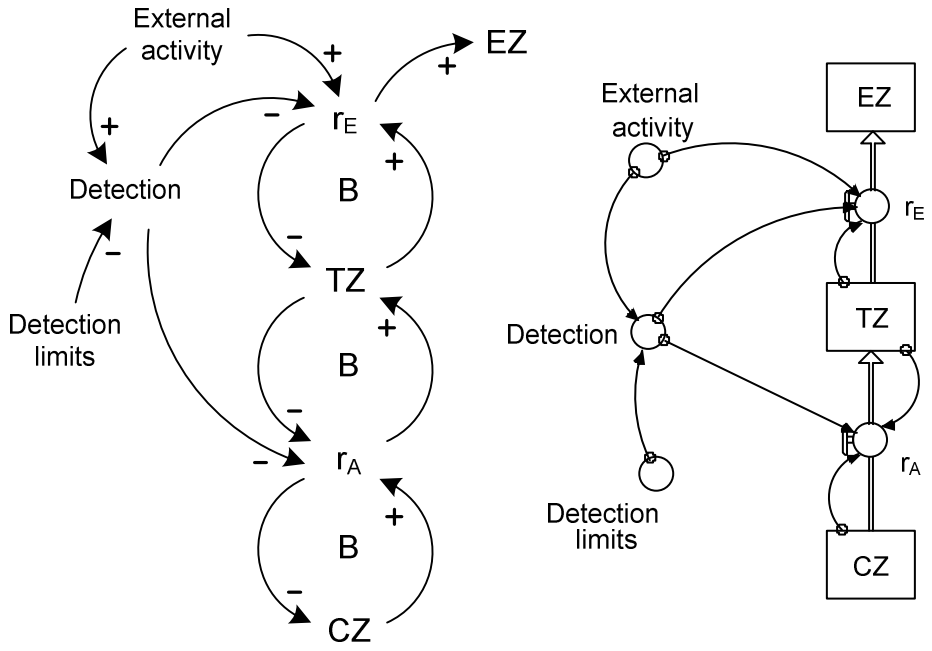

Fig. 3: The translation of the TYST CLD to SFD.

The tyranny would not work if the Tolerance Zone were able to reclaim the encroached portion. Moreover, the encroachment activity is an exogenous impact imposed on the system.

$$\frac{dTZ}{dt} = r_A - r_E \tag{2.1}$$

$$\frac{dCZ}{dt} = -r_A \tag{2.2}$$

$$\begin{aligned} &if\,|r_E| > x, then, r_E = 0 \\ &if\,|r_E| < x, then, r_E = r_E \end{aligned} \tag{2.3}$$

Where x is the detection limit of the system. In a continuous system where

$$\frac{dTZ}{dt} = 0 \tag{2.4}$$

$$r_A = r_E \tag{2.5}$$

In a discontinuous system,

$$r_A = \sum_{t-1}^{t} r_E \tag{2.6}$$

And $r_E = f(TZ, External\_activity)$ (2.7)

Change in the Tolerance Zone over time is the difference between the Adjustment rate and the Encroachment rate (2.1). Encroachment rate is the function of the size of the Tolerance Zone and intensity of External activities (Eq. 2.7). If the Encroachment rate is higher than the detection limits, then the encroachment is halted, while if the encroachment rate is lower than the detection limits, then the encroachment continues (Eq. 2.3). The encroaching activities continue as long as the rate of encroachment is under the detection limits. If the intensity of the activity increases, it enters the detection zone where it is discovered and halted (Fig. 3). As

long as the encroachment activity happens with steps smaller than the detection limit, the Tolerance Zone is allowed to compensate through growing on the expense of the Core Zone (2.1). The Core Zone is changed by subtracting the Adjustment rate (Eq. 2.2). Adjustment rate compensates for the loss in the Tolerance Zone due to the Encroachment rate, and is equal to the Encroachment rate (Eq. 2.4).

The Tolerance Zone represents the limit of detectable activity. It is a property of the local system which is defined by the precision of the overarching system detection. As long as the overarching system is unchanged, the Tolerance Zone remains the same. For this condition to be fulfilled, the Adjustment rate r_A must remain equal to the Encroachment rate r_E. The change in the Tolerance Zone is then equal to zero when measured on large enough time steps that contain the encroachment and the adjustment activities. The typical behaviour of the TYST model emerges as being a transmitted expansion of the Encroaching Zone over the Core Zone, only possible through the intermediate of the Tolerance Zone. The speed of the encroachment is also defined by the size of the Tolerance Zone, which in turn is set by the precision of the overarching system detection.

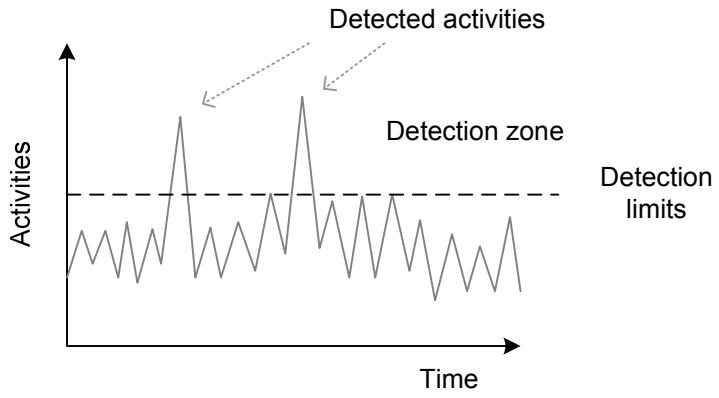

Fig. 4: Once activities enter the detection zone they are discovered and halted.

In general terms, the detection limits represent the ability of the system to discover encroaching activities. Lack of intervention to continuous encroachment indicates a lack of transparency within the system. If the detection limits for activities are high, this enables large encroachments on the Core Zone. On the other hand, if there is a clear transparency between the overarching level and the local level, where the actual Tolerance Zone can be observed, the detection limits will be low and encroachment small. The TYST process is therefore only successful if there is a lack of transparency within the system. In order to detect and minimise the TYST process, there needs to be a 'System vigilance'. 'System vigilance' keeps the detection limits, and therefore the tolerance limit, low by introducing the necessary transparency into the system. Lowering the detection limits furthermore reduces the Adjustment rate. An encroaching activity that is detected on the Tolerance Zone can develop in two ways. The system may choose to slow down the activity, or it can halt the process completely. Only when the process is completely halted can the Encroached Zone be reversed into the Core Zone (if that is the choice).

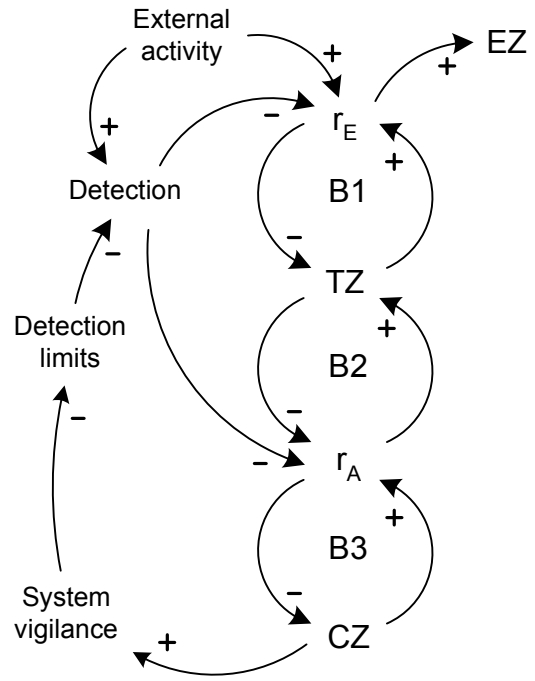

Fig. 5: A 'System vigilance' is introduced to minimise the effect of the TYST process.

Although there appears to be many stages involved in the TYST process, it can be summarised by three phases; Establishment, Transformation and Revision.

> **Establishment:** A domain that is confined by a boundary, which contains two types of zones, a Core Zone and a Tolerance Zone. The size of the Tolerance Zone is proportional to the Core Zone and depends on the system properties of the domain, e.g. how vigilant the system is to allow for a large or small Tolerance Zone. System vigilance is related to the detection limits.
>
> **Transformation:** A series of small encroachment activities that are not detected by the overarching system as long as they happen within the detection limits. Larger encroachment activities go beyond the detection limits and are detected and halted. The encroachment activities becomes an Encroachment Zone that remains part of the domain.
>
> **Revision**: Any change in the Tolerance Zone is met by an adjustment to the Core Zone in order to maintain the proportion of the Tolerance Zone in the system. The system vigilance sets the detection limits. Transparency increases the vigilance within the system and lowers the detection limits, making the Tolerance Zone narrower and therefore limiting the steps of the encroachment activities.

The Tolerance Zone is the key feature in the TYST behaviour. The only thing perceived in reality is the encroachment activities and the reduction in the total Core Zone. The Tolerance Zone is thus a result of the systemic properties within the system. It is a buffer that is part of the system, an important non-visible feature imperceptible by the overarching system but made possible by lax surveillance of the system. The TYST behavior appears to have delay properties, i.e. the encroachment reduces the Core Zone in steps. But that is only a behaviour

that is observed from a distance. Looking more closely, the encroachment behaviour can be a continuous process that is only interrupted (halted) by the detection mechanism within the system. Therefore the properties of the detection within the system determine the pace of erosion of the Core Zone.

3.1 Explaining urban encroachment through TYST

It is possible to explain urbanisation through the TYST process. In urban planning in Sweden, so-called master plans (or comprehensive plans) are developed that may span 10 to 30 years into the future to form the trends on where to place industry, commercial and housing projects. Master plans require updates on a periodic basis (that usually follow a election period every 4 years) to assess the current status by looking at what has been accomplished since the last revision (Boverket, 2005). The master plan is revised to investigate the extent to which urbanisation has followed or deviated from the planning document and what revisions are necessary to accommodate for the unforeseen effect. The master plan in this case becomes a review document of effects in which the updated master plan tries to adapt towards.

This situation can be illustrated in the following case in Fig. 6. A master plan is drafted on a national level and is enforced by the local authorities. This case consists of an open space allotted for protection by the master plan which is surrounded by residential areas. Since there are no physical barriers that protect the area, the protection only exists on the planning document. A Tolerance Zone exists within the rims of the whole area where encroachment activities can go unnoticed. For example, residents A, B and C can extend their properties into the protected area on the rims of the boundaries and since the activity is small it goes unnoticed by the local authorities (phase 2). At the same time, any attempts to make large development on the field would be detected and halted by the local authorities, since it would encroach onto the Core Zone. During a periodic revision of the master plan, it is noticed that the total protected area has been reduced in size. The authorities have the option of either reclaiming the encroached area, or readjusting the boundaries of the protected area. If too much resistance is faced when trying to reclaim the encroached area, the TYST arises and as a result the protected area is reduced (phase 3).

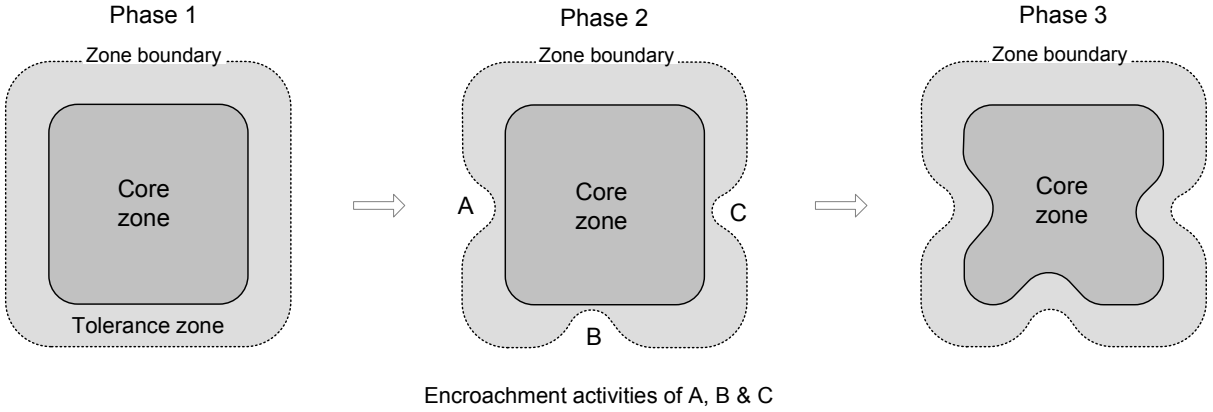

Fig. 6: Encroaching activities into the Tolerance Zone will force adjustment to the Core Zone.

The TYST process can also explain expansion into a new territory. The process is reversed where the Core Zone encroaches into the Tolerance Zone and results in a new adjustment of the Tolerance Zone, as seen in Fig. 7.

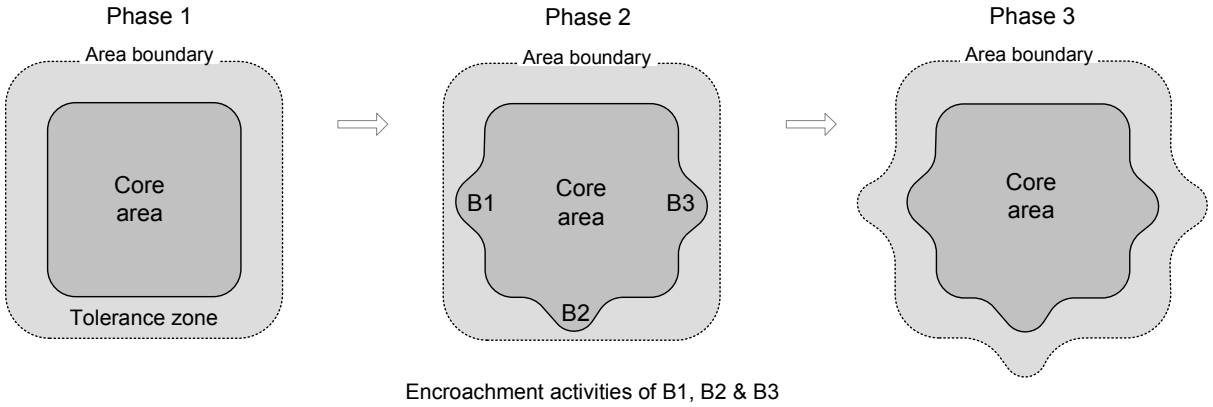

Fig. 7: The TYST process reversed. Expansion of the Core Zone results in an adjustment of the Tolerance Zone, since the Tolerance Zone and the Core Zone are in fixed proportions.

A change within the system always involves an attempt to expand or reduce the Tolerance Zone since it is in this zone where changes are tolerated. In other words, only changes that can fall within the system's Tolerance Zone can take place. In Fig. 7, the phase 2 is a gradual expansion of the Core Zone into the Tolerance Zone, and phase 3 thus becomes an adjustment of the total area after the Core Zone has increased.

4 Identifying the TYST in a case study: The case of Örby

Helsingborg is a city that is situated in southern Sweden. Helsingborg enjoys very good water quality in its municipal water distribution network. The reason for this is a rather special water supply and quality control strategy that has been in place for the past 60 years. All the cities in the region take their water from the Lake Bolmen through a 100 km tunnel. This runs south to a site due east of Helsingborg, Ringsjöverket, where a first basic treatment is done on the raw lake water. After this treatment, most cities in the region extract their water and feed it directly on their networks, but in Helsingborg a special additional treatment is made. The water is seeped (through pumping) into a large natural gravel aquifer, The Örby Field recharge zone. This field consists of 10 000-year-old gravel produced during the last ice age and covers an area of 520 hectares. The water is filtrated through the gravel for approximately one week, and emerges from the ground in very good condition. The Örby aquifer has been in use since the 1940s but with urbanisation there has been a need to protect the field from any activity that can interfere with the aquifer such and construction of homes, industry or farming with modern chemicals. All such activities are basically prohibited and regulated in the overall city 'master plan'.

4.1 The general planning process in Helsingborg

The Swedish law requires that every municipality in Sweden follows a master plan that is up to date. This plan is not legally binding and only serves as a guideline for the municipal departments. The official urban planning document is a 'master plan' for urban design for the upcoming 20 years and is updated when a new mandate period begins. The update is a confirmation that the plan is up-to-date and may, if necessary result in a revision (Boverket, 2005). The last three revisions that resulted in changes in the master plan originated from 1989, 1997 and 2002 (Helsingborg, 2002). The city Planning office forms the master plan that is voted upon by the politicians of the municipality. Once the municipality agrees upon a master plan, it becomes a guiding document for the civil servants of the Housing office. The

Housing office is responsible for granting applications for development. Once an individual applies for a construction permit, it is the civil servant's responsibility to consult the master plan before granting any application. But since the master plan is a non-binding document, there is no real consequence if some of the principles in the master plan are not followed through. If the civil servant denies an application, the applicant has the possibility to appeal the decision to the authorities. Similarly if the granted application implies a controversy in the public forum, the public also has a possibility to appeal the decision to the authority. However, if a granted application goes through the process unnoticed, there will be none to make any objections on the application since there is no 'watch dog' guarding the interest of the master plan. That responsibility has been put onto the public. Applications are usually advertised openly, but through specialized media that reaches only a small number of the population who are not necessarily relevant stakeholders. Very seldom do somebody actually inspect and review the published permits. Also, public knowledge of master plans and regulations are virually non-existent, impeding public feedback. The public feedback practice looks very good on paper, but in reality, it does not work at all. Therefore, the civil servants possess great a deal of power in the planning process although they are not directly part of the overall urban planning process. There exists thus an incentive for the Housing office to grant applications since any appeals to the authorities will be costly and time consuming process for the Housing office and the municipality.

4.2 Field data on encroachment on the Örby field

Since the 1950s, 13.5% of the Örby field recharge zone has been converted through urban development (Gramstad, 2004). During the same period the municipality was forced to put restrictions on land use. Due to health regulations, once a part of the recharge zone has been converted to other land use purposes, it cannot be reversed to its previous state (Helsingborg, 2002). The field is fixed in size and extends only a few meters below the surface. Any disturbance, such as housing construction, will remove or contaminate a significant part of the layer and render it useless for filtration. Therefore the Planning office established a protection zone around the recharge zone to guard the remaining filtration activity. Initially the protection zone only covered the water plant area but later included most of the physical recharge zone (Fig. 8).

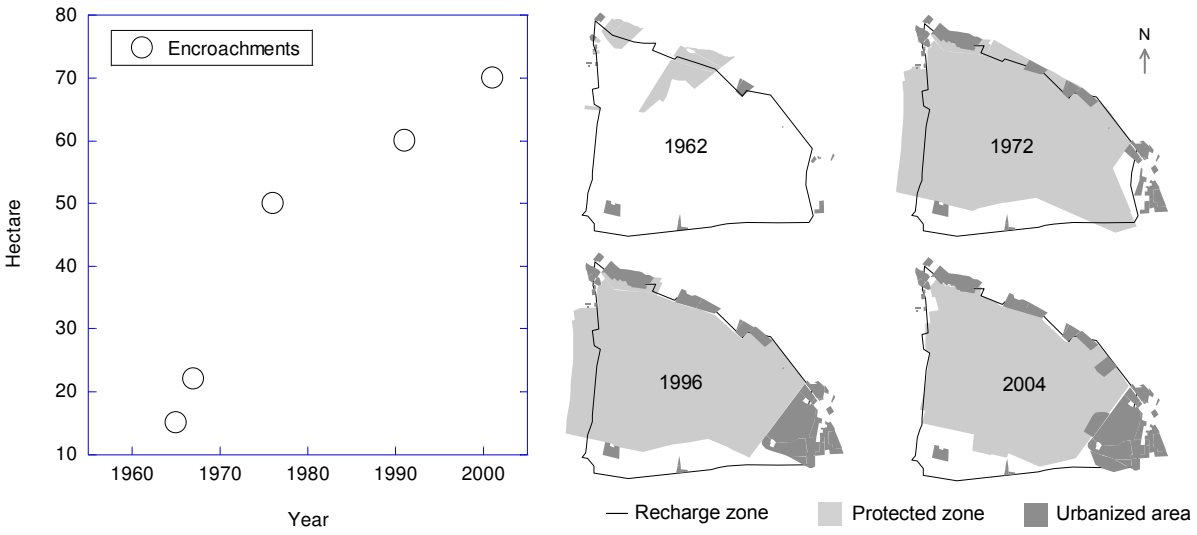

Fig. 8: Encroachments, in hectares, on the drainage area of Örby (left). Urbanisation versus recharge activity and protection zone from 1962 to present (right), (Gramstad, 2004).

The recharge zone co-exists with farmland activities (organic farming) but prior to the establishment of the protection zone, farmers sold off pieces of land that were later urbanised. The protection zone exists only on paper. Physically, what is seen in the field is farmland surrounded by suburbs. The protection zone around the recharge zone has been revised several times to accommodate for the encroaching activities on the field. Urban areas at the Örby field are clustered at its eastern end and urbanisation is favoured in a westward direction. In the current revision of the master plan, new proposals for housing are being submitted that will force further reduction in the protection zone.

The process of TYST can be used to explain the encroachment into the Örby field. The city Planning office maintains, through its master plan, the goal of protecting the recharge field. However, there is some existing housing sparsely sprinkled around the Örby field which sit densely up to the edge of the field. Exceptions to the construction limitations within the protection zone can be made by the local Housing office. Since the protection zone is a guiding principle and the Housing and the Planning office do not communicate directly with one another, application for small construction projects are granted by the civil servants of the Housing office. On existing farms, construction may take place for farm use in between or next to existing buildings. Also along the perimeter, small encroachments are permitted in the border zone. When the border zone is neighbouring to an already developed area it is of less value, therefore limitations are not enforced on the individual level with much strictness. The Housing office is therefore engaged in "virtual planning" that grants applications that are perceived as sufficiently small so as to have only minimal impact on the master plan (Fig. 9). Although the master plan provides for protection of the field, housing and infrastructure have steadily encroached on the field, and the sophisticated plan has merely slowed the pace to a certain degree. Even though the Planning office forbids any use of the Örby field, development permits are still being awarded at the by the civil servants of the Housing office. For example, children are allowed to build a house next to their father's on the farm, thus slowly shifting the border zone at the expense of the protected area. At the same time, a new border zone is created as the extent of the border zone is decreased by development. This change is mostly in the mental models of the stakeholders. The border zone stretches 50 m from the housing zone into the Örby field, and after some years, this distance is not from the old house, but the new house. Since each step is small and each, by itself, has little impact, the Örby field is slowly being encroached by urbanization. With time the small scale virtual planning has gained such a momentum that private contractors have started to bid to the Housing office for developing on the area. This is where the Planning office becomes aware of the problem and halts the process, and opts for revision of the master plan. The absence of detection (by the Planning office) increases the possibility of building activity to succeed within the municipality, such as is displayed in Fig. 9. Building activities increase the rate of encroachment on the Tolerance Zone (B1) which forces an adjustment upon the Core Zone, i.e. the Örby field (B2-B3). Increase in the urbanized area (the Encroached Zone) reinforces the virtual planning process by the civil servants since no apparent restrictions or objections are made on their decisions and the encroachment process (R1). Thus the detection limits for the encroachment are high, which lowers the detection on the rate of encroachment (B4). The Planning office (overarching system) makes its periodic revision on the master plan. The transition from recharge zone into urbanised area calls for a new revision on the total area. New boundaries are set for the zone and subsequently a new Core Zone and Tolerance Zone emerge. The revision on the master plan is only initiated by the periodic updates. In the master plan, Örby is a small piece of a large planning objective and therefore the problems associated with it are not perceived.

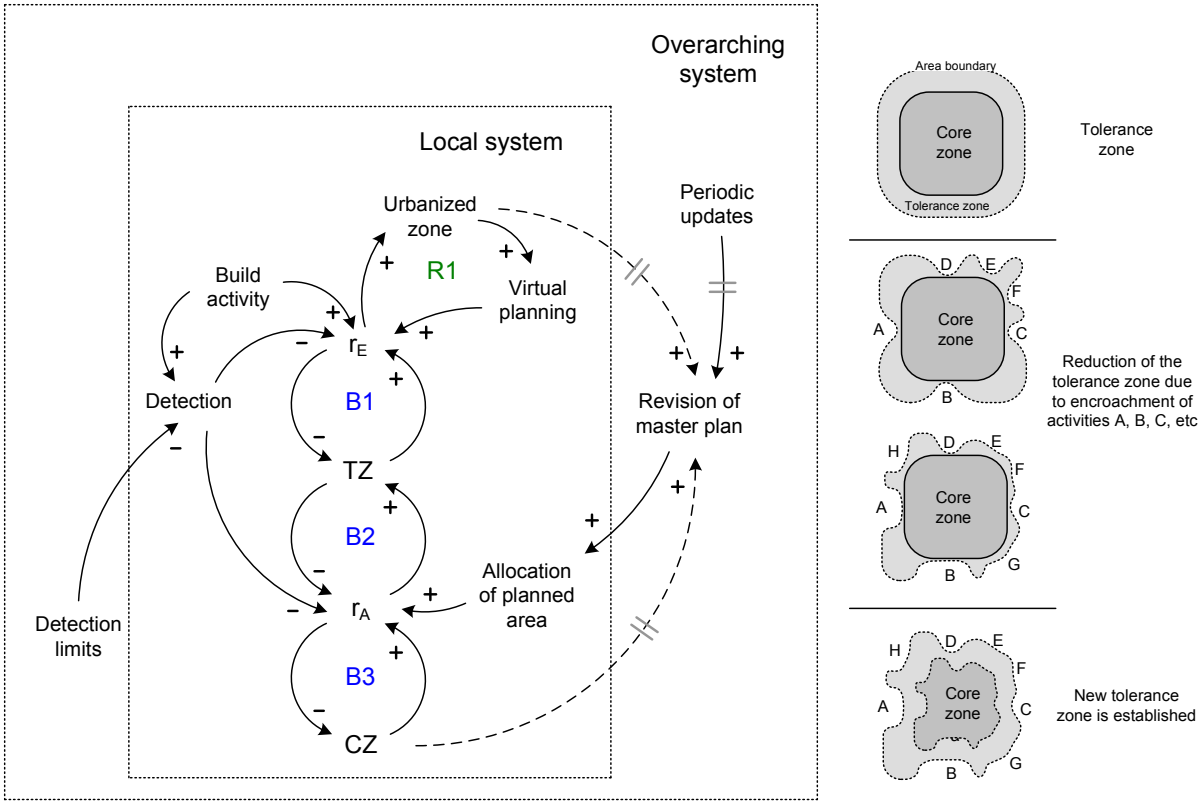

Fig. 9: The encroaching activities on the Örby field reduce the Tolerance Zone. When a new revision is made in the master plan the new borders for protection are established around the remaining intact field. The Tolerance Zone is automatically re-established in the process.

4.3 Two system scales in the management of the Örby field

In the Örby case there are two systems working on different scales. The Planning office supervises the master plan and observes the Örby field only as a static object with fixed boundaries. The civil servants of the Housing office view the master plan document as a guiding document and officially it is non-binding, thus deviation from the plan due to political pressures is possible, thus allowing for small scale projects on the field. Because of the difference in resolution between the scales, the small activities are not detected. The detection level of the city planning office is not sharp enough to register the changes and stop the encroachment. Thus changes in the Tolerance Zone will not be recorded in the upper level until it has caused a large change in the field and in principle when it is already too late. The higher level is working on a longer time scale than the lower one and therefore cannot detect the changes taking place within the local scale. The two processes are therefore working in a different time scale where the decisions by the civil servants are made on a 'day to day' basis and decisions made through the master plan are on a 4 year basis. As a consequence, when the city Planning office reviews the master plan every 4 years and checks the situation, it adjusts the master plan to incorporate the changes of the past years, thus slowly but steadily the encroachment is allowed to continue. The two processes actually lack communication on a fine enough scale in order to detect an ongoing change. This emphasises the fact that it is sometimes more important for surveillance (or system vigilance) to observe changes in state rather than levels of intensity of system parameters. The Planning office tries to prevent the encroachment by implementing a more direct communication between the Housing office and the Planning office and make the master plan more rigid in its interpretation. The Planning office needs to maintain a system vigilance to detect and prevent building activities. A system

vigilance creates a direct observation for the planning office and reduces the detection limits, which is necessary for the planning office to increase detection. Currently, such surveillance is already in place as a part of the water resource management group at Örby. The key, however, is to allow their communication to come through to the Planning office (Fig. 10).

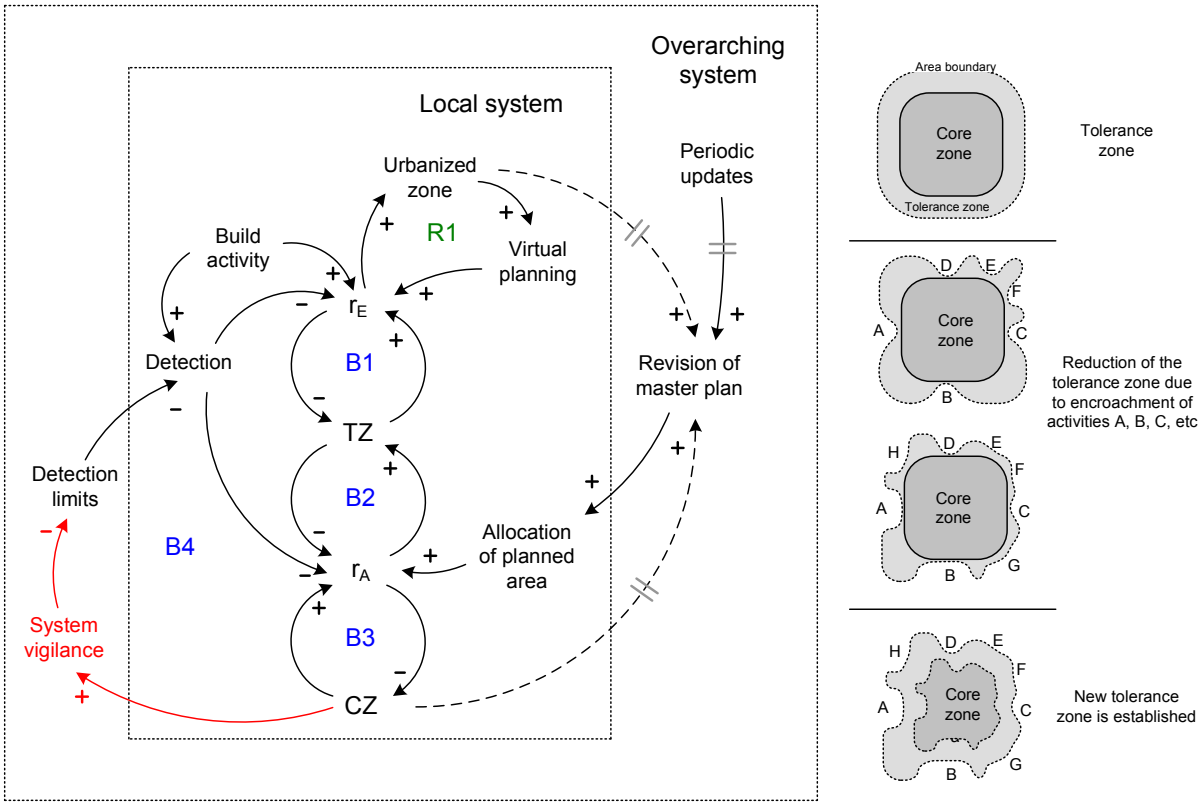

Fig. 10: The overarching system functions over a longer time scale than the local system. Therefore the changes made within the local system are not detected. Creating a system vigilance creates the necessary transparency for the overarching level to detect and prevent encroachment.

The behavior detected here has risen from an understanding of what has taken place at the Örby field. It is "The tyranny of small steps". The master plan has the goal of providing overarching support to the protection of the Örby field at the same time as the civil servants are acting in the interest of their organisation which unintentionally erode the intentions of the plan. This does not reflect conflicting goals but miscommunication of the main goal, i.e. the protection of the field. Because they are below the detection limit, each step alone is too small to trigger a reaction. The small scale use of the resource depends on the small scale tolerance limit. "We are only taking a little"… "just this little piece, so it does not matter so much". Each incremental step in itself is not seen as dangerous, and seen alone, it is probably not. But all steps taken together create a destructive action. After we have taken a little, we slowly adjust our tolerance limit to what it was before. Thus, slowly we encroach upon the resource. This is the process for example, by which large cities encroach upon excellent agricultural soil around its perimeter, and by which the violence limit in violent conflicts slowly is raised by small steps not really seen as dangerous.

5 The field test: Simulating the TYST model for the Örby field

Here the TYST behaviour is converted and applied for the Örby case. The CLD in Fig. 6 was translated into a stock and flow diagram, identical to the SFD shown in Fig. 3. There are basically three variables that are identified as stocks, i.e. the Core Zone, Tolerance Zone and Encroached Zone. For the Örby case, the Core Zone translates to the recharge zone and the Encroached Zone into Urbanised area. It is important to note that the Tolerance Zone is assumed to be a proportion of the Core Zone and therefore the model follows non-linear behaviour. In this case the Tolerance Zone is assumed to be 1% of the Core Zone. This is an arbitrary number. The simulation results presented in Figures 11 and 12 represent medians of 100 runs making up the results from a Monte Carlo sampling of the distribution of individual encroachment activities with a preset probability for each scenario (section 4.1 and 4.2). The following assumptions were made for the Örby case:

(1) The historical data of encroachment from the Örby field (Gramstad, 2004) was used to simulate the virtual planning by the local government.
(2) The periodic revision of the master plan was also simulated where each year of revision was interpreted as an adjustment to the urbanisation.
(3) The original size of the field in hectares in 1955 was used as the initial value for the recharge zone in the model.
(4) The simulated encroachment was created with a 30% occurrence rate of encroachment activities over a period of 50 years from 1955 to 2005.
(5) Uniform distribution of the encroachment

Although not entirely accurate on the historical trend, the simulation retains similar value as the historical one at present day, as projected in Fig. 11. One reason for the behaviour of the historical trend is due to planning. The model assumes uniform distribution of the encroachment, but in reality it had two stages of encroachment before and after the establishment of the protected area. The protected area was established with the purpose to curb the encroachment. The results from the simulation are presented in Fig. 11. Assuming that the establishment of the protected area had an effect on the encroachment, the encroachment rate was simulated in two steps, the period between 1955 and 1974 and the period after 1974. Sensitivity analysis was used to find the approximate values for the periods. The value 31% was used for the early period and 15% for the latter. Fig. 11 shows the simulated encroachment with the two stage setup. With the instalment of the protection zone the success rate of encroachment on the field was reduced by a factor of two. In the Örby field case the size of the Tolerance Zone is assumed to be 1% of the Core Zone. For Örby that translates into an approximate 8 meter wide Tolerance Zone that extends inwards into the recharge zone. In that zone, individuals have been able to obtain permits for different activities. The good fit between the simulated TYST model and the field observations, are a strong indication that this model behaviour is really at work here in the formulation we have suggested.

Considering the good correlation between historical and modelled values for encroachment on the Örby field, a simple model based on the TYST behavior was used to predict the behaviour of the Örby system within a span of 100 years from today. The first scenario is concerned with the business as usual development in the field (Fig. 12). The loop R1 (Fig. 10) is activated, simulating an increase of encroachment activities following an increase in the Encroached Zone. This reflects the hypothesis that further encroachment activities are encouraged when previous ones have been successful, resulting in an increase of the encroachment rate, and therefore the encroached area as well. The regulatory detection property of the sys-

tem remains unchanged, meaning that the steps of the encroachment activities are not allowed to be larger, only the rate of these independent steps increases. As suggested by the CLD in Fig. 10, depletion of the recharge zone would be expected to occur faster in the future.

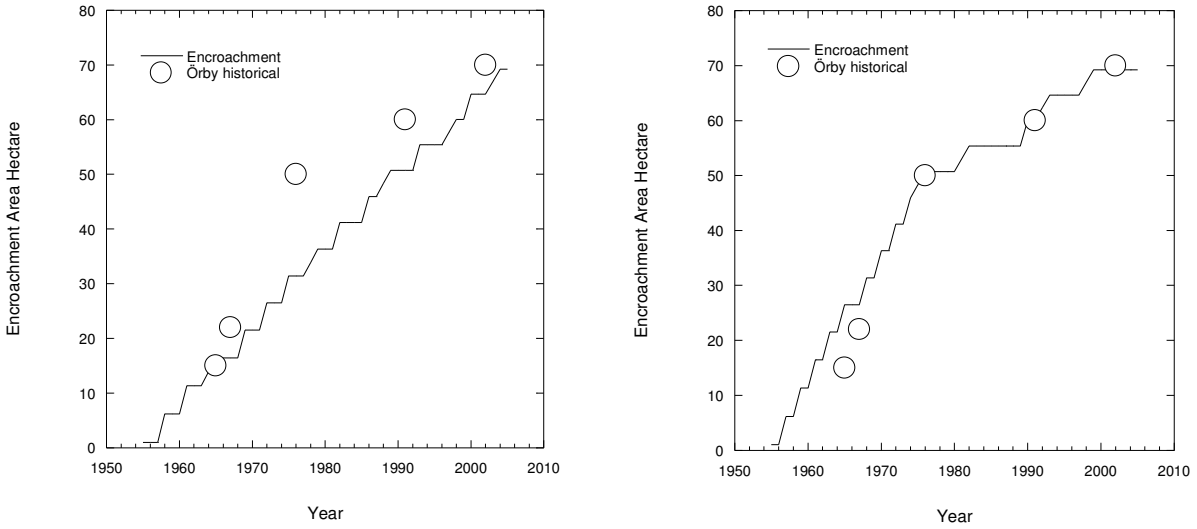

Fig. 11: Generating the present encroachment area in Örby resulted in simulating a 30% success rate of encroachment through out the period from 1955 to 2005. : Encroachment simulated in two stages, before and after the establishment of the protection boundaries (31% and 15% respectively).

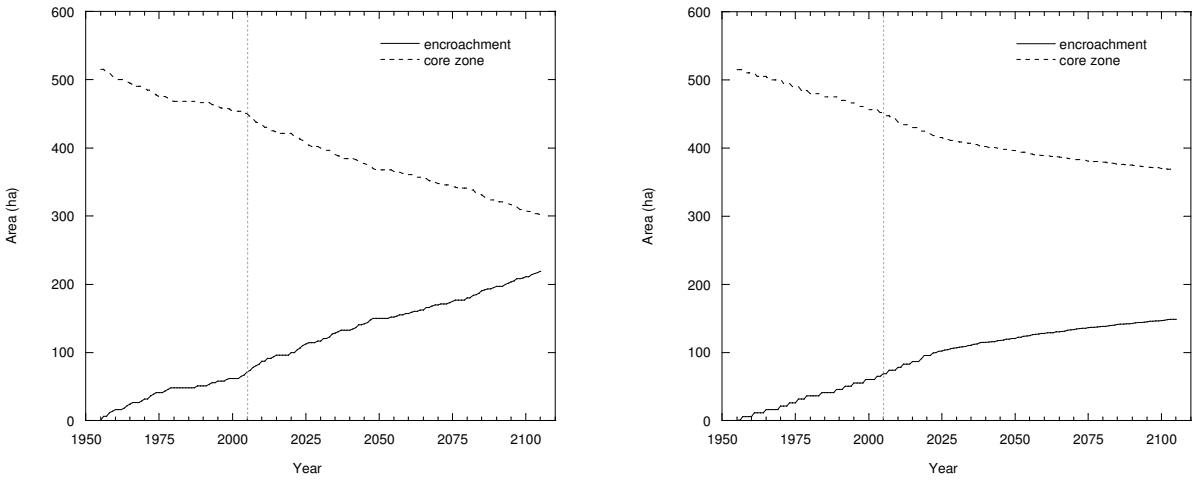

Fig. 12: The encroachment continues as the natural state of the system remains unchanged. Ultimately, the Core Zone would be depleted. Activating a higher vigilance of the system results in a reduction of the encroachment activities.

An alternative scenario was investigated where the link through "system vigilance" in Fig. 10 is activated. An increase in the system vigilance implies a reduction or elimination of the encroachment rate as well as the adjustment rate. The assumption behind this scenario is that as the urbanized zone increases and the Core Zone decreases, more care is given to the preservation of the remaining Core Zone. This does not require the elimination of already established encroachments, but prevents the appearance of any new ones. Fig. 12 shows the expected system behaviour following an exponential increase of system vigilance with the increase of the urbanized zone (equivalent to the decline of the Core Zone). The encroachment rate slows

down considerably, and would decline further if the system vigilance is set to respond more sharply to the increase of the urbanised zone.

6 Discussions

6.1 TYST and System Scales

Understanding the behaviour of TYST and when it occurs is important for understanding how to handle many critical situations, prevent adverse conflicts or succeed in preserving important resources and assets. The fundamental elements of TYST can be considered as following: The TYST itself is independent from the origin of the encroachment. What is interesting in the system is the erosion of the Core Zone as an effect of an encroachment. What often obscures the TYST element of a system is the occurrence of overstepping of the Tolerance Zone, converting it to a system dominated by other types of systemic behaviours. The TYST behaviour is likely to be inherent in systems that have a large dependence on spatial distribution, such as urbanisation or population diffusion into a new territory. One clear example is the Israeli gradual settlement in Palestinian territories occurring since the 1920ies until the present. Another example is the haggling over a price in the market between merchant and his customer. One common problem with archetypes and how they have been used is the mistake of describing the problem as well as providing a solution in the same variables (Wolstenholme, 2004). This stems perhaps from the lack of observing system scales. For a TYST system, the encroachment prevention option exists only on the overarching level. It cannot exist on the lower level since the communicative variables for detection reside on the higher level. Therefore the remedy for countering the behaviour is on the overarching level by introducing the System vigilance variable. System vigilance is the 'surveillance' within the system that 'keeps an eye on' the activities on the lower level. The discovery of the TYST behaviour was only possible due to the clear definition of the system boundaries, which enabled the necessary transparency to place the behaviour on two level scales, i.e. the overarching and the lower system scale. Furthermore, the TYST behaviour can strengthen the assertion that system boundaries and how they are defined in relation to the problem domain is central for generating the necessary overview for dealing with the problem and finding useful solutions.

The Örby field case study illustrates a real life manifestation of the TYST behaviour. The conditions for the rise of TYST are fulfilled, namely that the system domain is fixed, and that change is unwanted, driven by external activities, and irreversible. The presence of the Tolerance Zone, central for the TYST behaviour, is made possible by the permissiveness of the planning authorities to allow small independent encroachments on the recharge field. The presence of two governing systems, a wider one and a local authority, splits the decision making authority into two levels which do not have continuous communication. As a result, the encroachments allowed by the local authority are not known by the planning authority on the higher level above until it is too late. The fact that the encroached areas cannot be reclaimed closes the TYST cycle. However, the Örby case presents an opportunity where fixes to the TYST behaviour could be tested. Setting up apparent communication between the local system and the overarching system, through the establishment of a system vigilance would allow for a continuous alteration of the master plan rules and the reduction of the encroachment on the recharge field.

6.2 Different examples of TYST

In this paper, the authors have shown in the Örby case how the TYST behaviour is manifested on an overarching scale as well as at a local one (Fig. 13). This simple overview is important since it illustrates the combined behaviour of the variables over a period of time that is manifested through TYST. Each variable in the CLD represents a simplification of a sub system and is at the same time a simplification of a system that is much more complex. The concept of Core Zone and Tolerance Zone can be observed in many situations that are not necessarily connected to physical systems. For instance, negotiations can be viewed through the TYST process.

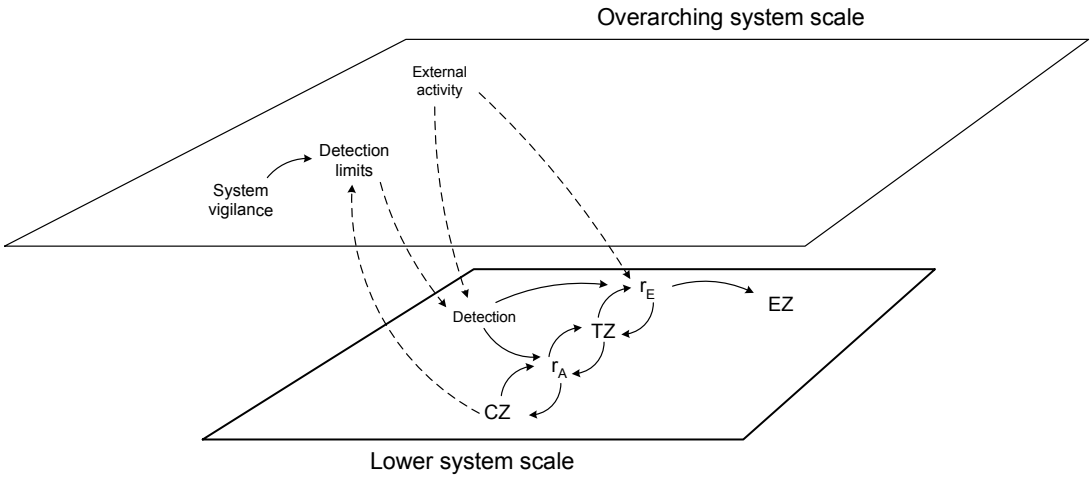

Fig. 13. The TYST behaviour works on two different hierarchal system levels, a local scale that is fast paced and an overarching level that is slower.

Each party prepares a proposal of main goals (Core Zone) which they intend to reach. Each party prepares also a list of lesser objectives (Tolerance Zone) that can be used in the negotiation process in order to reach consensus. Any compromises on the main goals are encroachment on the Core Zone. One party can cleverly reformulate a proposal in which the other party's goal is compromised. The key for each party is to have a complete overview of its goals and understand what the other party's proposal will do to their goals. This is the system vigilance in the process. If a negotiator is not well prepared, he/she may not detect the erosion of the main goals during the negotiation process. The Kyoto protocol is an example of such a process. The initial main goals were much higher than the compromise that was agreed upon. Lobbyism is an example of purposeful encroachment onto a Core Zone with the aim to alter the other party's main goals.

There are several additional examples where the authors think the TYST mechanism may be at work. Such areas are:

- The gradual encroachment of one language upon another in a country; Latinization of the Mediterranean, The eradication of Celtic in the British isles, the encroachment of English in Europe (Renfrew and Rowlett, 1990).
- Negotiations and bargaining in conflicts and markets between actors (Kahn 1966)
- Competition for market share of products

- Encroachment of pollution or larger and larger areas, the rise and fall of acidification 1900-2000.
- The gradual building up of conflicts and tension before wars, such as the prelude to world war I (Willmott, 2003) or World War II (Churchill, 1948; Frankson and Zetterling, 2002; Willmott *et al.*, 2004)

One such example is the post-WW1/pre-WW2 German National policies. During that time, Germany was moved forward by small steps (Churchill, 1948; Guderian, 1952). Eruption in the system (the war) arose when the tolerance limit was overstepped by accident or purpose. These were not exclusively Nazi policies, therefore it can be seen that the preparations for war started long before the Nazis came to power:

(1) Rearming Germany
    a. Army (1921-34)
        i. Recreation of the General staff and army (1921)
        ii. Go above the 100,000 army size limit (1929)
        iii. Develop tank divisions (1932)
        iv. Demands of Army "equality" with France (1933)
        v. Introducing the Army draft (1934)
    b. Navy (1926-1939)
        i. Marine General staff organized (1926)
        ii. Submarine construction commenced (1930)
        iii. Versailles treaty oversized battleships constructed (1934)
    c. Air force (1926) in violation of the post-WW1 settlements
(2) Establishment of dictatorship rule in 1933 and abolition of democracy
(3) Reoccupied the Rhineland and Saar in March 1936
(4) Annexed Austria in the infamous Anschluss in March 1938
(5) Annexed the Sudetenland in September 1938
(6) Occupation of Bohemia and Moravia in March 1939
(7) Annexed the Memel territory in March 1939
(8) The military conquest of Poland in September 1939

When the attack on Poland was initiated in September 1939, the German state leadership firmly believed they would succeed, believing they were slowly enlarging the tolerance of their adversaries (Churchill, 1948). With the attack on Poland the Tolerance Zone was overstepped, the alarm sounded and the armed conflict phase of the second world war (WW2) was initiated (Churchill, 1948).

6.1 Is TYST an archetype ?

A reoccurring systemic behaviour, created by the same type of components set in defined set of feedbacks, constitutes an archetype. The components and system settings may vary, but as long as they retain their functional characteristics and mutual system of feedbacks, there exists an archetype. Senge (1990; 1994) originally describes 11 different system structures that can be classified as archetypes. Some archetypes, such as: "fixes that fail", "Floating goals" or "the tragedy of the commons", are frequently seen. In his recent work, Woltstenholme (2003) argues for reducing the number of archetypes in order to make them more generically applicable. He suggests 4 generic structures in which all current archetypes should be placed within, either of (1) Underachievement, (2) Out of control, (3) Relative achievement or (4) Relative control. These archetype structures can generally be identified with two loop struc-

tures that are first represented as problem archetypes and secondly as solution archetypes. Solution archetypes involve a 'solution link' for breaking the 'problem' behaviour of the archetype. In its current form, the TYST behaviour does not appear to fall within Wolstenholme (2004) definition since the encroachment on the Core Zone is through the Tolerance Zone and therefore creates a three-loop interaction. The authors argue that the Tolerance Zone cannot be excluded from the Core Zone in the definition of TYST. Actually, it is possible to argue that there are archetypes with one, two, three, four and more loops. Each number of loops constitutes one archetype dimension, connected to hierarchal levels. However, with increasing number of loops, the generality of the archetype becomes more and more difficult to determine and define. On the one loop dimension we have two archetypes known to any systems analyst: The accelerating loop (R) and the balancing loop (B). On the two-loop level we have 4 according to Wolstenholme (2004), on the three-loop dimension the final maximum number is not yet determined. With increasing number of dimensions, the archetype behaviour will become more and more complex and multifaceted, making archetype recognition much more challenging.

7 Conclusions

Having an overview of any system or process is vital to hold system vigilance in place and keeping the Core Zone intact. The TYST behaviour illustrates the necessity for total transparency in any systems in order to avoid unintended effects. It is possible to reverse the TYST, but only if the process is halted completely. The authors think that the TYST is common enough as a behaviour in interactions between systems that it may be regarded as a fundamental behaviour. We make the following conclusions.

(1) TYST is a reoccurring behaviour which each time show the same type of components and mutual feedbacks
(2) The good fit between the simulated TYST model and the field observations, are a strong indication that this model behaviour is at work in Helsingborg in the formulation we have suggested
(3) The TYST behaviour maybe frequently appearing in human systems
(4) The authors think that TYST might fulfil the definition of an archetype based on a three loop dimension discussed above.

The TYST process may be regarded as a part of wide range of complex systems but depending on the conditions, it can remain dormant, and only become active when the conditions for lack of transparency are fulfilled.

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