
Climate Change: Innovative Approaches for Modeling and Simulation of Water Resources and Socioeconomic Dynamics

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1. Introduction

This chapter shows an innovative approach for handling the rising scarcity of water resources caused by climate change. It introduces a new way of the modeling and simulation of socioeconomic adaptation and mitigation to water scarcity. But the model can be used for all the resources that humans have to share on planet earth.

It tries to find an explanation for the reactions of different societies to water availability problems caused by climatic change. For that purpose a Knowledge Attributed Petri Net based discrete simulation model is used modeling these different reactions. The model is based on integrated psychosocial development theories.

The Knowledge Attributed Petri Net model is implemented in the CASSANDRA (Cognizant Adaptive Simulation System for Applications in Numerous Different Relevant Areas) system developed by the McLeod Institute of Simulation Sciences Hungarian Center at the Budapest University of Technology and Economics.

2. Climate change, water availability and socioeconomic problems

2.1. Climate change and water resources

Many climate scenarios, socioeconomic models and digitized river networks show that water stress is already high in many parts of the world.

Latest edition of the UN World Water Development Report, Managing Water under Uncertainty and Risk (WWAP, 2012) launched at the World Water Forum in Marseille on 12 March 2012 warns that unprecedented growth in demands for water are threatening all

major development goals. The growing pressure on global water resources comes from rising food demand, urbanization and climate change. According to the Report climate change will alter rainfall patterns, soil humidity, glacier-melt and river-flow and also causes changes to underground water sources. Floods or droughts are already rising in frequency and intensity.

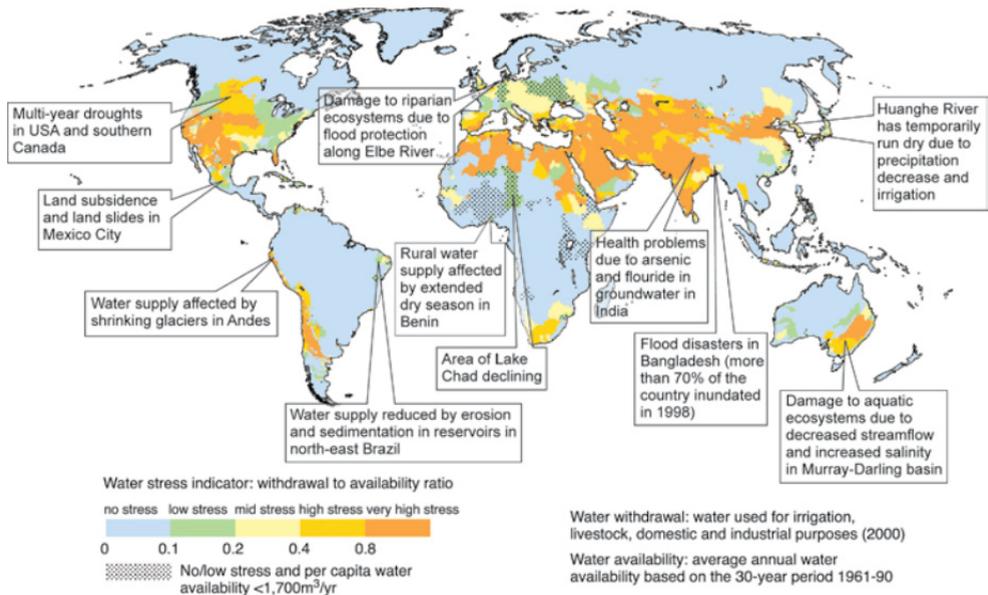


Figure 1. Examples of current vulnerabilities of freshwater resources and their management (Alcamo et al., 2003)

2.2. Climate change and water conflicts

The Report (WWAP, 2012) says that by the middle of the century 70 per cent more food will be needed. It means at least 19 per cent increase in the water required for agriculture. Many countries have already started to respond to water scarcity by acquiring fertile land outside their jurisdiction. Transnational land acquisition has risen from 15-20 million hectares in 2009 to more than 70 million hectares today. This is a problematic new tendency, a new kind of agro imperialism particularly happening in Africa by water scarce richer Arabian and western countries. Also as about 40 per cent of the world's population is living in river basins shared by many countries the risk rises that global climate change and the anticipated alteration of precipitation patterns will very likely lead to water-based conflicts in these regions.

2.3. Climate change, water and related socioeconomic challenges

According to the Report (WWAP, 2012) climate change will drastically affect food production in South Asia and Southern Africa between 2012 and 2030. By 2070, water-stress will also be felt in central and southern Europe, affecting up to 44 million people. These pressures will exacerbate economic disparities between countries, sectors or regions within countries. Better governance of water resources is required including investments in infrastructure from both private and public sectors (as for instance more than 80 per cent of the world's waste water is neither collected nor treated).

According to Intergovernmental Panel on Climate Change Technical Paper on Climate Change and Water (IPCC, 2008) the amount of water available for withdrawal is a function of runoff, groundwater recharge, aquifer conditions, water quality and water supply infrastructure. Safe access to drinking water depends more on the level of water supply infrastructure than on the quantity of runoff. However, the goal of improved safe access to drinking water will be harder to achieve in regions where runoff and/or groundwater recharge decreases as a result of climate change. In addition, climate change leads to additional costs for the water supply sector, e.g., due to changing water levels affecting water supply infrastructure, which might hamper the extension of water supply services to more people. This leads, in turn, to higher socio-economic impacts and follow-up costs (IPCC, 2008).

2.4. Environmental problems or social problems?

Researches show that current levels of human consumption, in combination with growing population are contributing to climate change (Dietz & Rosa, 1994; Myers & Kent, 2003; Stern, Dietz, Ruttan, Socolow, & Sweeney, 1997). Population growth will increase the global emissions anyway but a much larger increase would result if per capita emissions from energy consumption in developing countries increased to the developed countries level.

This makes it more imperative to understand how people make decisions that influence climate change through their behaviors (e.g. consumption) and to examine the values underlying that behavior. Consumption patterns represent classes of behaviors that explain the ways that human behavior contributes to climate change. In order to understand and address the links between consumption and climate change, it is useful to understand psychological, social, and cultural drivers of consumption and to understand what it is about consumption that influences climate change (APA, 2011).

Consumption is influenced strongly by social and cultural context. Cultural norms identify appropriate and desirable behaviors. It is important to see to which extent cultures value consumerism. Whereas environmental consumption is the use of resources and energy and economic consumption is spending money to acquire goods, consumerism is "a belief and value system in which consumption and acquisition rituals (e.g., shopping) are naturalized as sources of self-identity and meaning in life, goods are avidly desired for non-utilitarian

reasons such as envy provocation and status seeking, and consuming replaces producing as a key determinant of social relations" (p. 231; Zhao & Belk, 2008).

Disciplines ranging from hydrology, politics, and international relations to law have in the recent past been tempted by the idea of „war over water“. This is a common belief or a projection that if a country runs out of water it will start a war (Ijjas, Valkó, 2011). However this belief is just a belief and as such it is the product of a certain belief system (also called value system). Such beliefs change automatically when the value system changes. Value systems mostly change when life conditions change. Climate change will definitely indicate changing life conditions. As a result conflicting water scarce countries of shared river basins will escape water deficit by economically invisible and politically silent processes just as likely as they will start a war over water.

2.5. Climate challenge vs. psychosocial challenge

It seems that there is a strong cross-coupling between climate change, population growth, economic development, and social development. Therefore the relevance of these subsystems and links between them cannot be neglected.

The way how people manage their resources that their environment provides them with is strongly determined by the thinking of these people. Both individual and social acts are triggered by the set of values and thinking modes that those individuals and social groups have. Let it be acts as consumption behavior (energy consumption, water consumption, food consumption or buying consumer goods) or developing strategies and programs by companies or by the government, decisions are always based on certain set of values and cognitive structures. By missing the qualities or levels of these subjective realms of decision making, resources management cannot fully be understood and finding solutions for environmental-social-economical problems will easily be dismissed. The question is how to link the subjective with the objective - how to understand why people are handling conflicts related to rising water, food or energy demand in a certain way.

In our case in order to have a more complete view of real water availability it is necessary to consider interactions among climate change, integrated water management and human systems including societal adaptations to water scarcity.

Grumbine (1994) states that management scenarios for climate change, water and economical, human systems should make the role of human values explicit because people base their commitments on values rather than on facts and on logic. People having different value systems want to fulfill different needs. This applies to scenario development concerning river management in developing, and particularly in developed areas, where the landscape is largely man-made. There are already cases where values systems have been taken into account by managing water resources. The psychosocial evolution model of river management is a good example for that. The model has been created within the cooperation of the Utrecht University and another research institution in order to have a guide for

selecting and positioning specific landscaping measures within a changing climatic, human and economical surrounding (Straatsma *et al.*, 2009).

3. Psychosocial development

By social development we mean human activities organized at ever higher levels achieving greater results. Psychosocial development further integrates patterns of psycho development analogous to social development resulting in an integrated development model of both individual and collective human structures. Psychosocial development takes place when life conditions change in time. For example when water resources become scarce - different societies react differently according to their value systems and they may organize themselves at a higher level (regression to lower levels is also possible).

3.1. Models of psychosocial development

Water related problems are human related problems and for that they are not to be solved without showing and understanding the human factor that is behind them. In order to understand the role of value systems in forming different adaptation and mitigation techniques - according to water scarcity issues caused by climate change - several psychosocial developmental model can be used.

Psychosocial models relevant for our issue have been developed by Hamilton M. (Doctor of Philosophy in Administration and Management, Columbia Pacific University) Graves C. W. (Prof. Dr. Emeritus in Psychology, New York Union College) Cook-Greuter S. (doctorate for Postautonomous Ego Development, Harvard University) Maslow A. (Prof. Dr. Head of American Psychological Association) the psychologist Piaget J. or the developmental psychologist Erick Erickson (Harvard Medical School).

We've found that these models are based on the same principles and they are following similar dynamics. What we have done was synthetizing these models to get an integrated model. The most focus was given to Graves' model as it proved to be the most applicable in practical questions and most applicable for modeling and simulation.

The psychosocial development model of Graves (1970) is also called an emergent, cyclical, double-helix model of adult psychosocial systems development. Graves identified (1974) eight levels of existence that can be described by life conditions and the brain's coping conditions with those certain life conditions. The eight levels are: A-N *Automatic*; B-O *Autistic*, C-P *Egocentric*, D-Q *Absolutistic*, E-R *Multiplistic*, F-S *Relativistic*, G-T *Systemic*, and the H-U *Differential* levels. 'A' stands for the neurological system in the brain upon which the psychological system is based. 'N' stands for the existential problems that can be coped with the 'A' neurological system. In the 'A-N' *Automatic* state 'N' problems of existence arise and the 'A' neurological system is switched on in the brain. This is the first existential state (A-N state) when the human being is living in conditions where it is only focusing on satisfying its physiological needs. In B-O *Autistic* state man must assure the continuance of his first established way of life, in C-P *Egocentric* state he must survive as an individual, in D-Q

Absolutistic state he must obtain lasting security in his existence, in *E-R Multiplistic* state he must assert his independence as a person, in *F-S Relativistic* state he must live in a non-competitive way together with other humans in community, in *G-T Systemic* state he must truly learn life is interdependent, and in *H-U Differential* state he must learn to fashion a life that honors and respects all the different levels of human being. The different states arise and come to stage center in man's mind as each successive set of human problems are resolved.

The model was later transformed by Wilber (1997); Beck and Cowen (1996) to be applicable in conflict resolution. (The result is called *Spiral Dynamics Integral (SDI)*.) By further integrating the work of other researchers (e.g. Kohlberg, Armon, Mumford, Howe, Rawls, Piaget, Erikson, Maslow, Loevinger, Fromm) and inspired by the *Book of Changes* (Blofeld, 1965) we have formed a developmental model of ethical values in social systems which is useable to simulate optional adaptation strategies to the water challenges of our times.

3.2. Model of psychosocial complexity evolution

This chapter describes the eight value systems that are forming society's value systems and behaviors such as climate change mitigation and adaptation strategies according to shared and shrinking resources. The next chapter maps these behaviors into a Knowledge Attributed Petri Net model that simulates a case study taking river basins shared by many countries with different value-memes.

Following table shows these major value systems we have formed with the referring levels of other researchers such as Graves, Beck and Cowen and the main life conditions, with the mind/culture coping conditions and main needs of each level:

Für-Ijjas levels	Graves-Beck-Cowan levels	Main needs	Life conditions	Coping tools
Surviving individuals	A-N Beige	biophysical needs	N - State of nature and biological urges and drives: physical senses dictate the state of being	A - Instinctive: as natural instincts and reflexes direct; automatic existence
Superstitious clans/tribes	B-O Purple	temporary security within group	O - Threatening and full of mysterious powers and spirits that must be placated and appeased	B - Animistic: according to tradition and ritual ways of the group/tribe
Egocentric warriors	C-P Red	individual security	P - The world is a jungle where the strong prevail and the weak serve. Nature is to be conquered.	C - Egocentric Ego wants dominance, conquest and power; exploitive, aggressive

Conformist groups	D-Q Blue	long term safety within group	Q - Higher authority punishes bad behavior but rewards good work.	D- Absolutistic Obedient, conforming; conservative, hierarchic, driven by guilt
Creative hedonists	E-R Orange	long term individual safety, mental, behavioral independence	R - The environment is full of resources; the world is full of possibilities.	E - Multiplistic Pragmatic to achieve results; testing options, rational, modern, effective, selfish, arrogant, creative
Communities of human beings	F-S Green	long term individual safety within group, emotional freedom	S - Humanity is living in a habitat wherein people can find love and purpose through affiliation and sharing.	F - Relativistic Responding to human needs, affiliative, consensual, fluid, accepting, less efficient
System-thinking humans	G-T Yellow	finding and realizing Self-worth	T - The world is a chaotic organism where change is the norm and uncertainty is an acceptable state of being.	G - Systemic Functional, integrative, interdependent, existential, flexible, questioning, needs more time for complexity
Holistic communities of human beings	H-U Turquoise	finding and realizing self-worth within holistic system	U - Turquoise A delicately balanced system of interlocking forces in jeopardy at humanities hands	H - Holistic: experiential: transpersonal; collective consciousness; collaborative; interconnected

Table 1. Levels of psychosocial development 1

The defined levels represent also eight forms of behaviors that are related to the outer manifestation of an entity (group of human beings) in the environmental space. This relation is not easy to identify therefore oracles from different cultures have to be adopted and composed in such way that the common representatives can be examined within scientific frames. In order to understand how it can become possible to analyze a social action (e.g. regarding environmental resources) based on its internal level of psychosocial development

linear independent types of attributes has to be found. These types of attributes should give the most elementary common description to each level regardless of their actions taken.

The elementary types of attributes that aim to the description of the connection between the level and its environment are following:

- set of needs (N)
- way of the actions taken to suffice needs by acquiring resources (A)
- set of resources that are handled by the entity (R)

Fig. 2. highlights the direction of materialism of the three main model elements from the inner (soft) aim to the outer (sharp) result.

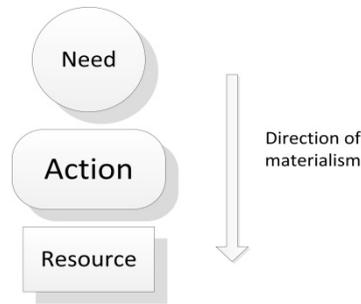


Figure 2. The 3-tuple of the basic psychosocial-environmental relation

After determining the elements of the basic psychosocial-environmental relation the domain of analysis should be appointed. This question is of great importance and also of enormous complexity. The needs can be ordered to clusters in many different ways and can also own different relevance in space and time regarding the environment. The set of actions, interventions taken by a social entity can also be infinite consequently the exact description and fragmented clustering of these elements is not suggestible at that level of examination. In point of the resources we face the same situation therefore the complicated formal descriptions can be replaced by binary qualities.

These binary qualities give relevant information about the elements of the 3-tuple of the basic psychosocial-environmental relation:

- Needs can have two subsets:
 - Inner needs (e.g. need for express the existence, need for belonging to, need for freedom, need for “happiness” etc.)
 - Outer needs (e.g. need for nutriment, need for heat, need for space, etc.)
- Resources can have also two subsets:
 - Inner resources (e.g. religion, art, education, social institutes, etc.)
 - Outer resources (e.g. water, soil, flora, fauna, fossil fuels, etc.)
- Actions can be taken in two different ways:
 - Actively (the psychosocial entity makes effort to achieve the expected state in case of presence of need). This phenomenon is also called “need-driven” action.

- Passively (the psychosocial entity is awaiting the optimal circumstances for its needs to be sufficed independently from the presence of need). This way of acting is marked as “resource-driven” action.

Fig. 3. highlights the possible behaviors through 8 different interconnections between needs and resources.

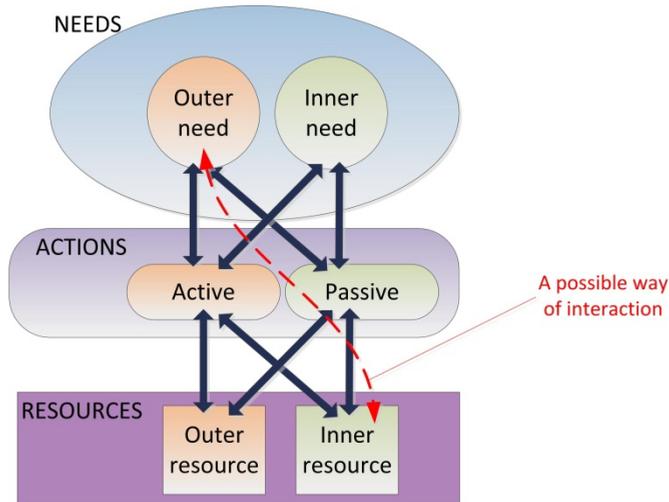


Figure 3. Interconnections between needs and resources

The actions – as transitions from the physical world to the psychical world – have a special role in the model through aiming to the maximization of the simultaneous occurrences of needs and resources over a given period of time or the maximization of collecting resources for sufficing further needs expectable in the future (buffering). Actions – in that explanation – are experiments on sufficing special type of needs by special type of resources. The number of the mentioned synchronism can be regarded as the indicator of “success” (S). The *S-indicator* is the key of surviving of a given social structure under the changing boundary conditions in the environment.

The *S-indicator* has two types:

- Success of sufficing inner needs (*INS*)
- Success of sufficing outer needs (*ONS*)

Both of the success indicators have to be of high value in order to gain balanced and stable state of the psychosocial entity.

During the process of model synthesis a very important analogy cannot be left out of consideration. The eight value system defined in Table 1 and the 3-tuple structure of the basic psychosocial-environmental relation assuming the binary values of the tuple-elements indicates the $2^3=8$ decomposition of the Fúr-Ijjas levels. That kind of

interpretation is well-known in the philosophy of TaijiQuan. Fig. 4. shows the development of behaviors. In the first column the whole system of balanced psychosocial entities is represented therefore this system can be regarded as neutral from the outside. In the second column the system is split into two main parts causing the stress and giving the base of model. Two main qualities of the psychosocial entities can be differentiated that is analogous with the two main forces of TaijiQuan: Yin is the acceptor and Yang is the donor. This is called the base binary value.

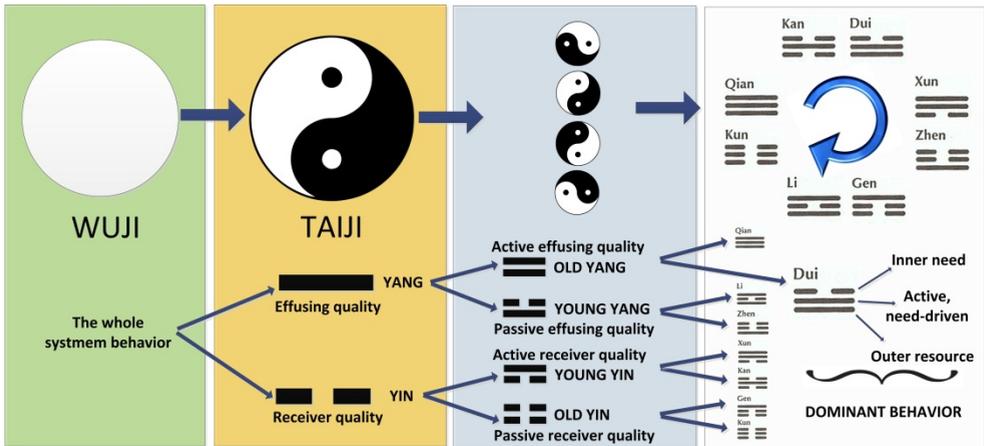


Figure 4. Interpretation of the TaijiQuan philosophy within the Fūr-Ijjas model

The base binary value (second column of Fig. 4.) represents the direction how the psychosocial entity relates to the environment (effusing or receiving quality). The second binary value has a comprehensive meaning of purity of the base behavior in the dual interpretation (third column of Fig. 4.). Young psychosocial entity does not own a clear self-concept includes disturbances from the other behavior, contrarily the old entity is cleared perfectly and it can show well defined functioning.

The most complex interpretation (fourth column of Fig. 4.) is based on the Trigrams that are combinations of three independent elements given by the base binary values. The bottom binary value represents the resources (outer resource=Yang, inner resource=Yin). The middle binary value represents the action (active, need-driven behavior=Yang, passive, resource-driven behavior=Yin). The top binary value means the type of needs (outer need=Yang, inner need=Yin)

The next table shows these levels linked to the corresponding binary values we have adopted from the Book of changes. These binary values designate different biopsychophysical qualities, forces and movements. The lowest line in the Trigram represents the aimed resources by the psychosocial entity (inner/outer resources) the line in the middle determinates the way of acquiring the resource (actively or passively) and the top line stands for the prevailing needs of the psychosocial entity (inner/outer needs).

Fúr-Ijjas levels	Book of changes - binary value	Book of changes - image in nature	Gender quality	Outer/inner needs the active/passive way outer/inner resources
Surviving individuals	☰	The Creative, heaven	male individual	outer needs active outer resources
Superstitious clans/tribes	☷	The Abysmal, water	female collective	inner needs active inner resources
Egocentric warriors	☰	The Joyous, lake	male individual	inner needs active outer resources
Conformist groups	☷	The Gentle, flood	female collective	outer needs active inner resources
Creative hedonists	☷	The Arousing, earthquake	male individual	inner needs passive outer resources
Communities of human beings	☷	The Keeping Still, mountain	female collective	outer needs passive inner resources
System-thinking humans	☰	The Clinging, fire	male individual	outer needs passive outer resources
Holistic communities of human beings	☷	The Receptive, earth	female collective	inner needs passive inner resources

Table 2. Levels of psychosocial development 2

4. Knowledge attributed petri net based discrete simulation model

In this chapter a Knowledge Attributed Petri Net based discrete simulation model is described that is suited to map the previously highlighted eight value systems into reasonable experimental frames. The model aims the examination of struggling of entities for resources based on the level of psychosocial development.

4.1. The methodology and tool used

Proper describing of the physical reality in general has always been standing amongst the relevant questions of science. Several methodologies were developed based on classical mathematics, or statistics and also new disciplines – such as soft-computing techniques – appeared (Russel, S.J. – Norvig, P., 2002). Each methodology owns advantages in some fields of modeling, but none of them is adequate to describe complex processes in general. Multi-facetted problems require methodologies that are able to integrate high-level mathematical concepts in a natural way. An obvious solution of mapping reality to a well-structured form is given by the concept of Petri Nets (Petri, C.A. 1962).

Petri Nets follow an elementary abstraction of physical reality by describing containers as places, mobile entities representing temporal states as tokens, and rules – transitions – that determine the generation and elimination of tokens in space and time. These basic elements correspond to real or virtual elements: e.g. tokens to information, money, materials, living beings, and places to physical locations, or virtual containers – such as bank accounts, data storages or indicators – transitions can represent the static knowledge or rules of physical laws, economic or legal regulations.

During the last decades several extensions have been suggested to the original concept of Petri Nets in order to raise its describing power. Inhibitor arcs (Inhibitor Petri Nets, IPN), colored tokens (Colored Petri Nets, CPN), stochastic delayed streaming of mobile entities (Stochastic Petri Nets, SPN), object oriented architecture (Object Oriented Petri Nets, OOPN), numerical (Numerical Petri Nets, NPN) and linguistic attributes (Fuzzy Petri Nets, FPN) (Peterson, J.L., 1981, Jensen, K. Rosenberg, G., 1991, Balbo, G., 2002, Carl G. Looney 1994) broaden the range of capabilities.

In some fields of problem solving usage of static and mobile knowledge bases is needed: e.g. modeling of flexible manufacturing systems (Jávor, A., 1993), routing and treatment of patients in hospitals (Jávor, A. Benkó, M., Leitereg, A., Moré, G., 1994), or intelligent traffic simulation (Jávor, A., Szűcs, G., 1998). These problems to be investigated involved new conceptual developments of Petri Nets and led to the introduction of Knowledge Attributed Petri Nets (KAPN) (Jávor, A. 1993–2). At the same time artificial intelligence (AI) and distributed control in simulation appeared, intelligent demons (agents) (Jávor, A. 1992, 2006) supported the connection of mobile knowledge bases and static inference engines in an effective way.

In our research we decided to use the KAPN methodology that owns all the properties of High Level Petri Nets mentioned before and that is also able to host AI within the model. As simulation tool CASSANDRA (Cognizant Adaptive Simulation System for Application in Numerous Different Relevant Areas) simulation system was chosen. CASSANDRA is a KAPN based system with the accomplishment of the methodology of model identification by reconstruction (Fűr, A., Jávor, A., 2007). CASSANDRA was developed by the McLeod Institute of Simulation Sciences Hungarian Center where the authors contribute to the methodological research.

4.2. Model identification by reconstruction

During the process of model synthesis there are several cases where simulation experts can face incomplete knowledge on structure, parameters or the algorithms describing the operation of the system to be investigated. Sometimes even the behavior of the system itself is not strictly defined. In these cases the usage of model identification by reconstruction can be suggested. This methodology is based on a special simulation entity (agent) that aims to the modification of the model based on observing the trajectory of its behavior. Fig. 5. illustrates the closed-loop controlled like modification of the simulation model by an intelligent agent.

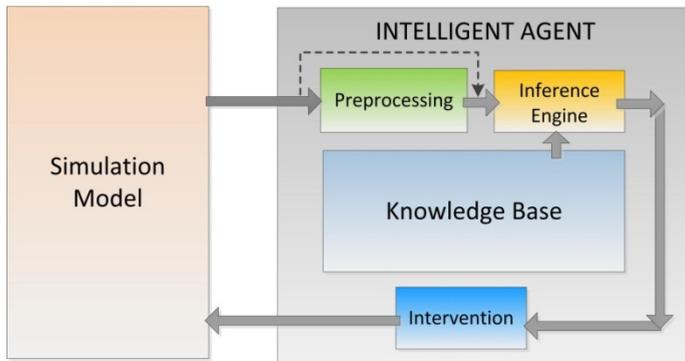


Figure 5. Agent controlled simulation

The identification process starts with the definition of the initial model that gives a soft delineation of the system based on the available theories and assumptions. The initial model – often built as a network of objects – should give a rough, but functionally approximating description.

The next step is triggering the model input by historical data and monitoring the output by the agent that compares it with the historical behavior of the system. In case when the agent finds significant deviations it may change the model until acceptable correspondence between reality and the model is achieved. The changes which the intelligent agent can execute are the following (Fűr, A., Jávora, A. 2007):

- Change the topology of the model network
- Change the parameters of the model elements
- Change the functions describing the effects of one model element on an other

There are several strategies how model reconstruction can be carried out, and also the complexity of the iterating algorithms can vary in a wide range from the multi-criteria estimation of parameters to the structure synthesis. After having reconstructed the initial model in such way that the output behavior corresponds to the reality the model can be used for further virtual experiments (e.g. prediction, or analysis) affording acceptable reliability regarding the simulation results (see Fig.6.).

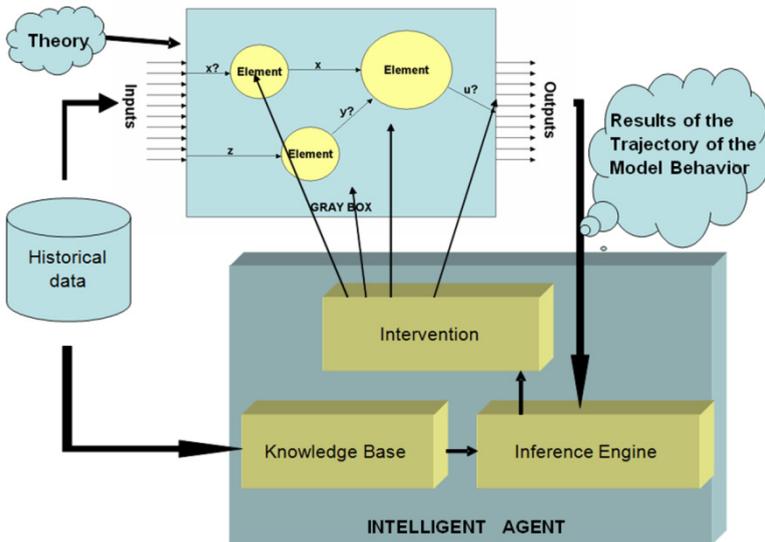


Figure 6. Identification by reconstruction using an intelligent agent (Fúr, A., Jávora, A. 2007)

4.3. The KAPN model of the Fúr-Ijjas levels

The basic concept of the model is based on two natural phenomena of the Petri Nets. The first one is the way of resource allocation. If there are two places given (the one representing the container of needs, the other the container of resources) and these are assigned to a transition object that has a place (container of results, state or success) at the output, the whole structure can be interpreted as a simple Petri Net model of resource allocation. In that case both input places (needs, and resources) has to contain tokens (representing the presence of need and resource at the same time) in order to trigger the event (this is called firing). After the process of resource allocation (firing) is finished the next state of the Petri Net model is that the resource (token) is destroyed in order to eliminate the need (token) and a result state (satisfaction, success) is generated (in also form of a token).

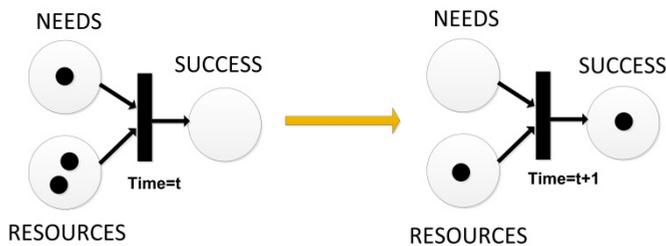


Figure 7. Basic Petri Net model of the process of resource allocation

The model delineated in Fig.7. shows deterministic functioning. In order to turn the model behavior more realistic an extension to the transition firing condition can be suggested. At

each simulation step to each transition a random number can be generated (of a given distribution, within the range of $[0,1]$) and it has to be compared with the threshold of the transition (constant $\in [0,1] \cup \{-1\}$) and the firing is executed depending on the result of this comparison. The threshold parameter (TRP) controls the permeability of the transition regarding the tokens during a given time interval. $TRP=-1$ “closes” the transition (see Fig.8).

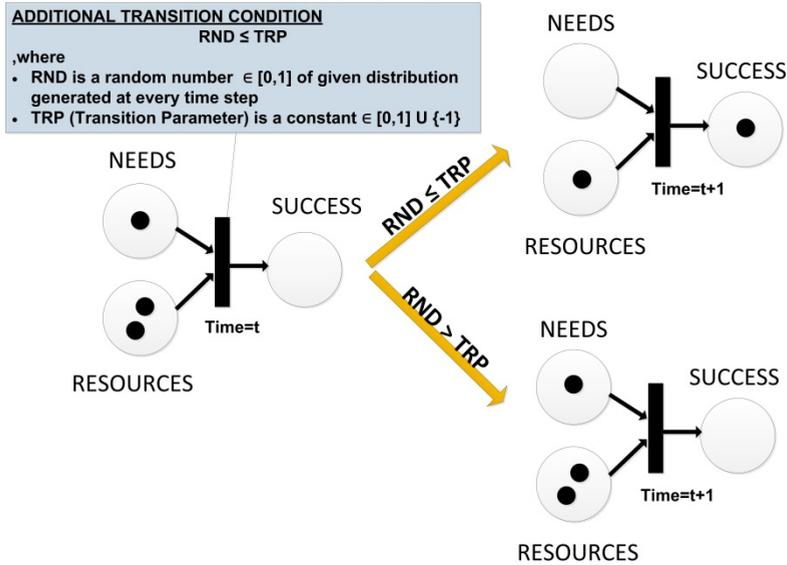


Figure 8. Knowledge Attributed Petri Net model of the process of resource allocation

The other main advantage of the Petri Net (or KAPN) based description lays in the power of handling the conflict situations (see Fig.9.). In the case when e.g. needs of two different entities require the same type of resource and in the container of the common resources there is only one resource (token) present – although both of the competitors are marked to be satisfied – in reality only one of them can access the resource (the one who fires before).

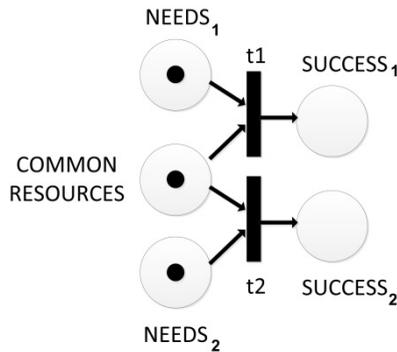


Figure 9. The common resource conflict situation

The firing order can be random or can follow priority considerations. (In our model the firing order is chosen to be random.)

In the following part a short description is given about the basic processes and their KAPN models that are subnets of the Fúr-Ijjas model. The basic consumption chain of a psychosocial entity (according to Fig.3.) can be need-driven (active) or resource-driven (passive). The main difference between the two approaches is the interpretation of the state of “success”.

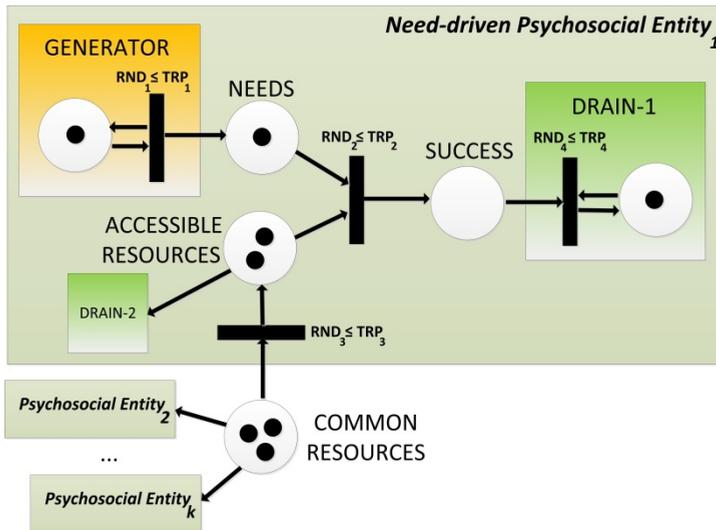


Figure 10. The model of a Need-driven Psychosocial Entity (NPE)

In the case of the Need-driven Psychosocial Entity (NPE) the success is defined as the simultaneous occurrences of needs and resources at a given time instant. The detailed network (see Fig. 10.) shows that the NPE collects tokens from the place of common resources transforming them into accessible resources (that can be utilized at any time instant by the NPE). This can correspond to the transportation or the exploitation of the resource. Each NPE possesses its own efficiency (TRP_3) on accessing the common resources consequently the available base of sufficing needs is different for each of them. The accessible resources have natural diminution (represented by DRAIN-2) that is independent of the consumption intents of NPE. Reasons for the diminution can follow from the nature of the resource (if it is hard to store over a long period of time – e.g. food, electricity, water under given conditions, etc.) or can be caused by disasters, epidemics, or the unforeseen annihilation of the already acquired resource. The generator of needs awakes necessities during simulation run with given intensity (TRP_1). The simultaneous occurrence of needs and resources triggers the transition causing the generation of a token in the place of SUCCESS. The efficiency of resource allocation can be adjusted by the parameter TRP_2 . If efficiency is low (e.g. thanks to backward governmental systems or infrastructure) then generated needs cannot be sufficed in time and thereunder natural diminution can happen. DRAIN-1 is responsible for not to get stuck the simulation because of the finite capacity of

SUCCESS place (infinite number of tokens in a place is not acceptable therefore each place possess given capacity – that corresponds to natural behavior).

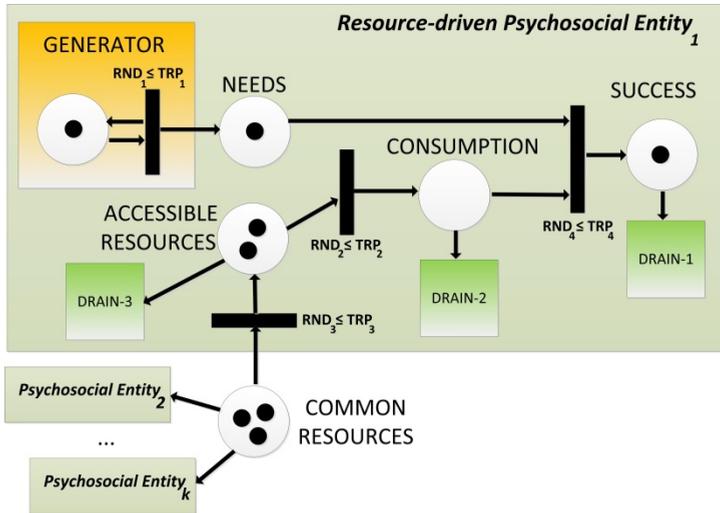


Figure 11. The model of a Resource-driven Psychosocial Entity (RPE)

Resource-driven Psychosocial Entities (RPE) appear to be different in their behavior. In the resource allocation process of these entities the annihilation of the accessible resources is independent of the presence of need. The consumption happens anyway hoping that in the future upcoming needs will be sufficed. That kind of buffering has a great advantage. This preventing behavior can possibly lower the number of cases when needs cannot be sufficed, but as a main disadvantage a new drain (see. Fig. 11. DRAIN-2) can appear that destroys that pre-buffered consumptions. Success is interpreted as simultaneous occurrence of needs and consumed resources. The main difference between NPEs and RPEs can be highlighted by the following metaphor: *“Need-driven Psychosocial Entities eat WHEN THEY ARE hungry, Resource-driven Psychosocial Entities eat NOT TO BE hungry”*.

As previously delineated the Fúr-Ijjas levels consider eight value systems with eight dominant behavior and relation to environmental resources. The given basic networks representing NPE and RPE (Fig. 10 and Fig. 11.) have to be integrated into a general KAPN model to ensure the possibility of modeling transitional (fuzzy) behavior between the clearly defined, dominant functioning of NPE and RPE. Also the two different types of needs and resources (inner/outer) have to be visualized in the model therefore the possible ways of resource allocation increases due to the different cross-couplings.

The following figure (see Fig.12.) outlines a possible KAPN implementation of the eight levels integrated into one psychosocial entity (PE). The aim of this general purpose entity is – beyond reproducing the original eight levels – the possibility of combination of the crisp behaviors. That corresponds to natural behavior of PEs because there are several cases when subdominant properties become also noticeable.

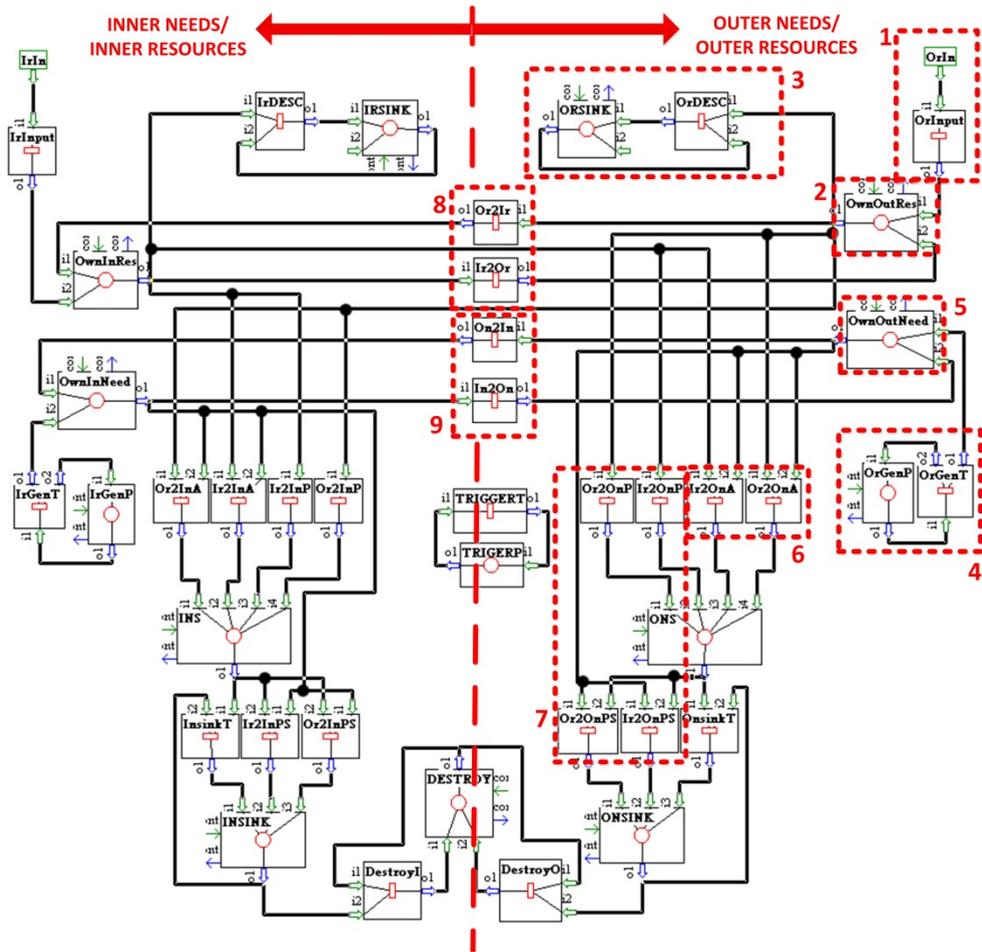


Figure 12. KAPN model of the Fúr-Ijjas levels (screenshot from the CASSANDRA system)

In the figure it can be seen that the model owns symmetric configuration with processes of inner needs and resources on the left side and outer needs and resources on the right side. The subnets marked by numbers on the picture correspond to the followings:

1. Input from the outer world for outer resources (connected to the place of common outer resources outside the PE)
2. Place of accessible (own) outer resources
3. Natural diminution of accessible resources (drain)
4. Generator of outer needs
5. Place of outer needs
6. Need-driven functioning (Or2OnA=Actively destroying outer resource on demand of outer need, Ir2OnA=Actively destroying inner resource on demand of outer need)

7. Resource-driven functioning (Or2OnP=Destroying outer resource anyway, consumption gets into buffer, then buffer is emptied when outer need is present, Ir2OnP=Destroying inner resource anyway, consumption gets into buffer, then buffer is emptied when outer need is present)
8. Cross-coupling between outer and inner resources. We assume that there are some cases possible when the resources of different types can be converted into each other. Outer resources can be converted into inner resources (e.g. the amount of water can have influence on the social, economic system) and inner resources can be converted into outer resources (with faith or a different approach inaccessible water resources can be accessed or even accessible water resources can be saved).
9. Cross-coupling between outer and inner needs. Several observations can give the ground to the assumption that inner and outer needs can substitute each other (within reasonable frames). In countries where the outer needs (e.g. need for nutriment) are hard to suffice PEs often turn to inner needs (e.g. need for family, need for express the existence by music, dance, art, etc.) in order to deflect attention from the real situation. In contrast developed countries often forget about their natural inner needs concentrating on sufficing their outer needs.

The figure below represents a possible test environment with different PEs accessing common outer and inner resource bases.

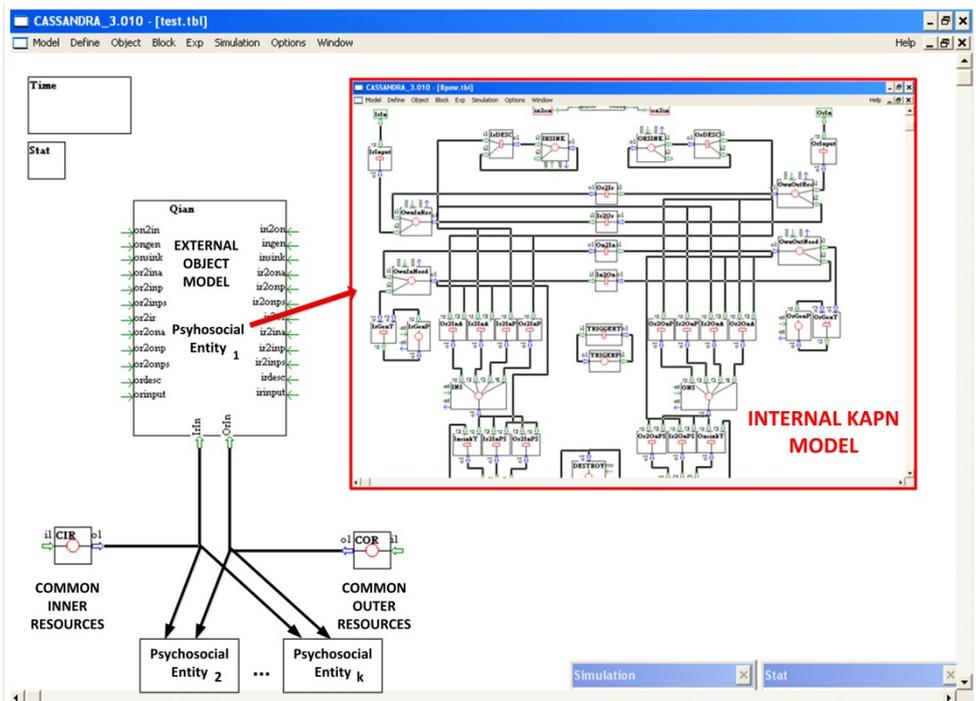


Figure 13. Conflict situation between Psychosocial Entities (PEs)

The KAPN model of the PE can be encapsulated into another object that hides the inner functioning from the higher level (see. Fig. 13.). Based on these hierarchical models multiple PEs and their conflicts can be examined under different boundary conditions.

Our aim is to simulate the behavior of different psychosocial entities living along e.g. Jordan River Basin, facing the growing water scarcity. In order to do that the parameters of the models have to be fine-tuned by the methodology of model identification by reconstruction.

After achieving the correct internal parameters of those countries that are involved in a resource allocation conflict we intent to forecast water usage at different climate scenarios. That should be our future work.

5. Conclusion

In this paper we identified eight levels of psychosocial development based on integrated theories. By the aid of TaijiQuan philosophy we found a way how to map these complex and fuzzy defined levels into concrete actions taken by an entity. The elaborated model gives well defined relation between the entity and the environmental resource considering the needs. This model is also able to combine the eight different levels with different intensity into a contemporary complex entity. Based on agent controlled simulation by the CASSANDRA system the changing behavior of entities during simulation run can become also possible. This ensures the simulation of the adaptation process of a psychosocial entity.

We believe that in the future cross-coupling between inner and outer needs and resources explored by the model become more important and narrowing outer resources or growing outer needs should be partially substituted by inner resources and inner needs. That is the key to successful adaption of future generations.

We also have a vision of our model in policy applications, especially in the identification of dominant psychosocial behavior patterns of different countries aiming to the recognition of adequate response in their adaptation process. We do hope that the model helps to understand – beyond the frequently communicated materialized problems – the inner aspects of the upcoming environmental-social-economical challenge caused by climate change.

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