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Editors' Remarks

Under a spreading apple tree,
The village genius stands;
His mind conceives of wondrous things,
He writes them with his hands;
His fame goes forth to all the world--
He's known in many lands.

* *

In one chapter in his story
(though apocryphal, it's said),
An apple, falling from a tree
impacted on his head,
Which drew his thoughts to gravity,
and we all know where *that* led.

He wondered if, by any chance,
the self-same gravitation
That pulls an apple to the ground,
affected all creation:
The moon, the planets, and the sun. . .
Thus went his cogitation.

* *

He discovered that the math you need
to show the laws of nature,
Surpassed the knowledge of that day;
the cosmos' legislature
Required *new* math, so Newton wrote
his "fluxions" nomenclature.

He talked of falling bodies
and his famous Laws of Motion,
And of colors seen in bubbles
and the tides upon the ocean.
And his crowning jewel, "Principia,"
created *great* commotion.

Yes, Newton's brilliant mind, it was
a trunk with many twigs--
His mind branched out in every way
(right through his powdered wigs).
His greatest contribution, though,
was cookies made from figs.

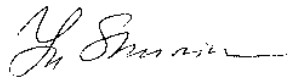
David Arns, from **'Sir Isaac Newton'** , 1997

This 13th volume No.3 is devoted to various questions of **Education Technologies, Applied Statistics and Transport&Logistics**. In particular, we present actual papers from Israel, India, Lithuania and Latvia.

Our journal policy is directed on the fundamental and applied sciences researches, which are the basement of a full-scale modelling in practice.

This edition is the continuation of our publishing activities. We hope our journal will be interesting for research community, and we are open for collaboration both in research and publishing. This number continues our publishing work in the year of 2009. We hope that journal's contributors will consider the collaboration with the Editorial Board as useful and constructive.

EDITORS



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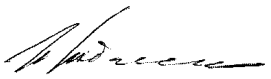

I.V. Kabashkin

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A CASE STUDY OF TWO HIERARCHICAL RECURSIVE METAPHORS FOR INFORMATION ORGANIZATION: THE CABINET METAPHOR VERSUS THE TREE METAPHOR

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Metaphors are commonly used in our every day language. They structure our perceptions and understanding and are known to be very useful for educating new concepts. Metaphoric-based interfaces are considered in the HCI field as usable and easy to learn, because metaphors relate user actions in computerized systems to already familiar concepts.

The general idea of metaphors is to transfer knowledge from the familiar and usually more concrete world to the unfamiliar and more abstract world. A suitable metaphor enables the user to function effectively in the new system, even without perfect understanding. Visual metaphors not only make a new system easier and simpler to learn, but also have a considerable effect on user experience. Although the intent of the metaphor at the beginning is to aid understanding and usability, metaphors are used also as a motivator, at first to get the user to use the system, then to make him productive and keep his interest. Information organization is a very important aspect in today computerized environments. Metaphorically speaking, searching information is often described as looking for a needle in a haystack. Designing interfaces for young children is a very challenging activity.

The aim of this research is to design and then evaluate two hierarchical metaphoric-based systems suitable for children's educational programs for searching for information about animals and continents: the cabinet (object-container, nested) metaphor and the tree (parent-child) metaphor. We first seek to find which metaphor is more suitable for the design of children's interfaces. We also are interested in examining whether children transfer hierarchical organization of one kind to the other. In a laboratory experiment, participants interacted with two metaphoric-based systems for educating children. Our children participants used the systems to find answers for questions regarding animals and continents. We measured performance in the tasks, and subjective aspects such as experience and user satisfaction. We tested the hypotheses that children cognitively transfer hierarchical organizations.

Keywords: *hierarchical recursive metaphors, information organization*

1. Motivation

When my firstborn son was 5 years old, I had a conversation with him about places we live in. We were speaking about addresses and I explained to him the relationships between concepts such as continents, countries, cities, neighbourhoods, streets, buildings and apartments using an object-container metaphor. Specifically I spoke about boxes in different sizes, which you can put one inside the other (for example "Think of a box called city, that has several smaller neighbourhood boxes inside it, and then each neighbourhood box has even smaller street boxes inside …"). When I finished, my son said "oh, it's like a family tree; the streets are the kids of the neighbourhood, neighbourhoods are the kids of the city…" and he went on and on ending with the father of all, planet earth.

This conversation prompted the undertaking of this research to investigate whether children transfer hierarchical organization of one kind to the other. Further motivation was to test the effectiveness of different hierarchical metaphor-based interfaces.

2. Introduction

2.1. Designing for Children

Children always used a wide variety of tools to explore and learn about their world. Today, more than ever, children are exposed to computers in their early development years. In both the European Union and the U.S., households with children are more likely to have more access to both computers and Internet than households without children do. Around the world, children use the Internet for schoolwork, to play games, and to communicate with each other. These activities often require searching and browsing, accomplished with interface tools such as search engines and digital libraries [10].

Computer systems offer children with new tools that allow for exploration, understanding and creation. A computer used with young children is found to be "a powerful learning device that facilitates cognitive development and positive social interaction without harm to young children" ([2], p. 338). It is obvious

that an important requirement in a learning process is to foster a positive attitude. The benefits of effective learning are so vast, that it is clear that it is most important to make a smooth entrance into this technological environment, and that they be provided with a suitable interface that would make their learning process easy and enjoyable.

Creating interfaces for young children presents particular challenges. Not only is there the constraint of limited literacy and numeracy to contend with but young children may not be aware of conventions used in common computer interfaces. The designer is thus compelled to avoid reliance on skills traditionally expected of the average user. Metaphors have a particularly important function in interfaces for young children, as other standard methods of communicating the purpose of an activity are not suitable for them [4]. A successful user interface paradigm is to design the human-computer interaction based on metaphors of real life situations and objects.

2.2. Metaphor Based Interfaces

A user interface that is based on direct manipulation is portrayed as an extension of the real world. It is assumed that a person is already familiar with the objects and actions in his or her environment of interest. The system simply replicates them and portrays them on a different medium, i.e. the screen. The user is allowed to work in a familiar environment and in a familiar way, focusing on the data, not the application and tools [5]. The above-described advantages of direct manipulation are also advantages of metaphor-based interfaces, in which the user can intuitively manipulate objects and work in a familiar environment and in a familiar way. The general idea of metaphors is to transfer knowledge from the familiar, usually more concrete world to the unfamiliar and more abstract world. A suitable metaphor enables the user to function effectively in the new system, even without perfect understanding ([29], p. 212).

A metaphor is a cognitive process in which an experience is related to an already familiar concept. Metaphors and mental models are forms of highly organized knowledge that help us overcome cognitive limitations in complex tasks ([29], p. 90). People develop new cognitive structures by using metaphors to cognitive structures they have already learned. Metaphors when used in computer systems are generally used to enable people rapidly and easily to build a mental model of how the system works. Building user interfaces using everyday concepts helps to make computers seem more a part of our everyday world and thus enhances their acceptability. Also using common concepts in user interfaces tends to speed up the learning process, thus reducing the need for training [13].

As a cognitive process, a metaphor is a model, structure, or conceptual framework, which helps bridge the gap between what a person knows and what he needs to learn. Norman's well known model of the *Seven Stages of Action* is widely applied in the HCI (Human Computer Interaction) field to bridge the gap between what a user wants to achieve using an interactive system (goals), and the possible actions he must learn to actually achieve his goals (system's physical requirements). Specifically, the difference between the user's intentions and the allowable actions is the *Gulf of Execution* [20]. Since user interface metaphors have a potential to achieve a good mapping between the interactive system and some reference systems already known to the user from the real world, it can serve as a special design strategy to bridge the execution gulf.

The perceptual psychologist, James Gibson [7] coined the term *affordances* to refer to the properties of an environment that allow creatures to function in that environment. Affordances are "the perceived and actual properties of the thing, primarily those fundamental properties that determine how the thing could possibly be used" [20]. When a metaphor is applied to a system, it gives the system a particular *set of affordances*. The book metaphor includes a set of affordances, including those for page turning, reading text, book marking, and so on [15]. Metaphorically treating a metaphor as a container for a particular set of affordances, we can conclude that appropriately designed metaphor-based interfaces can reduce the demands on the cognitive resources of the user. Utilizing familiar knowledge, metaphors make objects and actions much more intuitive and natural.

Following the idea of minimizing the demands on the limited cognitive resources of the user, metaphors can indeed minimize cognitive complexity by dramatically reducing memory requirements and system learning requirements. When cognitive resources are unnecessarily devoted to mental activities as memorizing and retrieving from memory, and to learning new processes and objects, it may be at the expense of performance. Furthermore, as performance is often also a function of time (not only of accuracy), the time devoted to those activities may directly decrease performance without potential benefits to accuracy [11]. Metaphors serve as a retrieval cue for interpreting symbols and actions. For example, when presented with an ambiguous icon, the user can quickly learn what it represents, as the metaphor helps him tie the symbol to the right association. While a kitchen-based metaphor in a recipes web site implies that an icon

of a round object with small circles is a chocolate-chip cookie, the exact same icon will be interpreted as a ball when used in the context of a playground-based metaphor in a children's web site for fun and games.

It is important to find and to use appropriate metaphors in teaching the naive user a computer system. A useful metaphor must have a suitable domain for a given system and given user population. This is in line with an important usability heuristic proposed by Nielsen [18]: match between the system and the real world. The system should speak in the user's language, with words and concepts that are familiar to the user, and should follow real-world conventions, making information appear in a natural and logical order.

2.3. Hierarchical Organization of Information

In order to cope with the overwhelming diversity of objects and properties in the world, people must mentally group objects, treating them as instances of a category instead of as unique individuals. Many natural categories are hierarchical organized – that is – they are organized into nested class-inclusion relations, with some classes being super-ordinate or subordinate to others. There has been a great focus of much development research on how children establish and come to use a taxonomic organization [12].

The importance of hierarchy organization was elaborated in Simon's famous article 'The Architecture of Complexity', showing that 'Hierarchy ... is one of the central structural schemes that the architect of complexity uses…Hierarchy is ... a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem' [28].

Collins and Quillian's [3] Hierarchical Network Model states that concepts are stored and represented within a hierarchical structure in our long-term memory, with meaningful associations between super-ordinate and subordinate concepts. Concepts are represented as nodes that are interconnected to other nodes. The 'IS A' link is the most common link in this semantic network model. The nodes within the network that are connected by this link have a specific type of relationship that is hierarchical in nature. Therefore, a concept at the lower level node is a type of the concept at the higher-level node. One criticism towards the model is the fact that not all categories can be represented in a hierarchical form. However, while the process becomes challenging when it comes to abstract concepts, the structure of the model is well suited for itemizing words in naturally occurring categories, i.e., animals, food, etc., [9]. This kind of knowledge is in the focus of our current research.

Reuter and Druin [23] found that elementary-age children were able to navigate in a hierarchy while browsing. Baek and Lee [1] found that children do not think as logically as adults do and their searching pattern is very diverse. Information architecture, which is designed from an adult's logical level, may result in inefficient searching due to relatively deeper hierarchy than the one in a child's mental model. As the comparison of information architecture by a child and an adult shows, a hierarchy with high logicalness tends to have more sub-categories and therefore, deeper level. In order to increase the efficiency of search, it is important to find the optimum depth of categories.

Considering children's short-term memory span, 5 ± 2 is an appropriate number of the first hierarchy keywords in the structure. As one way of enhancing search, the number of the first hierarchy keywords is set to 7 ± 2 (Miller's magical number seven; Miller [14]). By putting the main keywords within the boundary of a child's short-term memory span, the child is able to search information more efficiently. Whereas the short-term memory span of an adult is seven units, an elementary school student has only 5 units, and a kindergarten student $3 \sim 4$ units. This implies that the number of directories of a website for children should be set to 5 ± 2 (Baek & Lee [1]).

Organizing information to reach the goal of getting to what you are looking for, leads to the notion of "Find-ability". According to Morville [17], Find-ability is as follows:

a. the quality of being locatable or navigable;
b. the degree to which a particular object is easy to discover or locate;
c. the degree to which a system or environment supports navigation and retrieval.

We seek to examine which of the two hierarchical metaphoric-based interfaces, cabinet versus tree, is characterized by a higher level of find-ability.

2.4. Object-Container Nested Metaphor Versus Tree Metaphor

The file/folder metaphor for organizing content on our computing devices has been around since the advent of Unix-like command-line interfaces and shells. It became more visually oriented with the releases of the Canon Cat, Xerox Star, and of course, the Macintosh (Sherman, [28]). The file/folder organization embodies two well known hierarchical metaphoric-based interfaces for file access and file

management; one is the desktop interface, which is based on a nested object-container metaphor, and the other is the file manager interface, which reflects the tree metaphor.

An object-container metaphor for hierarchical organization expresses the relationship of "object-within-object". This metaphor allows recursion to be visualized in an intuitively nested "Russian doll" fashion, the Matryoshka (often known as the Babooshka doll), that has a principle named after it, which refers to the action of placing an object into another. The nested Russian doll and it's similar version, the Chinese boxes metaphor, is widely used in recursive problem solving and in programming and mathematic education to explain recursive models (Schiemenz, [25]). Human cognition, whether biologically or culturally determined, is a myriad composite of representations, metaphorically a hall of mirrors, and a set of nested Chinese boxes or Russian dolls (Gessler, [6]). Perhaps the most obvious example of the nested doll principle is Microsoft Windows. Windows is simply windows inside windows inside windows. There are multiple screens displayed, each "nested" within another. Looking at information organization through the nested doll lens raises the question of "Inside which object should one place another object for best find-ability".

A specific variation of the object-container metaphor, which we borrowed from children's playrooms, is the Cabinet metaphor. The cabinet metaphor to organize information follows the way children organize their stuff in their playrooms, which is in chests or closets of drawers. The choice of a metaphor that matches a mental model that young children had already formed follows the aforementioned usability heuristic of matching between the system and the real world (Nielsen, [18]).

The alternative tree metaphor for organizing content uses a navigation mode of hierarchal tree layout visualization. The most obvious way to organize a collection of elements is by explicit arrangement into a hierarchical tree, using the well-known metaphor of folders and files. The graphical version of this layout originates from the very first instantiations of computer desktop environments, and has come out so pervasive that is firmly embedded into our intuitive ways of dealing with 'items', be it images, videos or generally speaking any type of information that can be defined as 'files' (Villegas, [30]). Users navigate by clicking on little structural elements (plus and minus symbols) that opens and closes various directories.

Objectives. The objectives for this research are as follows:

1. Decide on the main design features of two prototypes for a computer program that educates children about animals and continents, a prototype for each hierarchical recursive metaphor: the cabinet metaphor and the tree metaphor.
2. Implement the two prototypes of the educational computer program that meets the design criteria.
3. Test the prototypes by using several methods: such as subjective measures of satisfaction and acceptance, objective performance measures, and using the think aloud technique. We concentrate on investigating whether children transfer hierarchical organization of one kind to another, by examining whether the exposure to one program improves performance in the other.

2.5. Metaphoric Interfaces Design

In the current study, the two metaphoric-based systems for educating children about animals and continents will be aimed at the age group between the ages of seven and eleven. This age range fits to the *concrete operational* stage of development, according to the Swiss psychologist Piaget [22], who divided children's development into a series of changes. The concrete operational stage is characterized by an appropriate use of logic, and by important processes such as *Seriation*, *Classification* and *Reversibility*. Seriation is the ability to sort objects in an order according to one common property. Classification is the ability to structure objects hierarchically. Children at this stage identify sets of objects according to appearance, size or other characteristic. Classification includes the notion of class inclusion, e.g. understanding that an object is a part of a subset included within a parent set. Reversibility is the comprehension that objects can be changed, and then returned to their original state. Children in this stage can only solve problems that apply to actual (concrete) objects or events, and not abstract concepts or hypothetical tasks.

We classify the participants as *knowledgeable intermittent* users, in terms of Shneiderman's generic classification of users (Shneiderman, [27]). They already possess the semantic knowledge of hierarchical classification, and computer concepts as files and folders, but lack the specific syntactic knowledge of the metaphoric applications designed for this research. They are already exposed to windows and therefore are familiar with the file/folder organization which embodies the two hierarchical metaphoric-based interfaces for file access and file management; the desktop interface, which is based on a nested object-container metaphor, and the file manager interface, which reflects the tree metaphor.

We designed the cabinet metaphor as a wooden cabinet with two main drawers: animals and continents. As aforementioned, as in children's playrooms, cabinets are useful for organizing toys, clothes

and other objects. Ideally, when neatly arranged, drawers contain objects that belong to the same category. The cabinet metaphor endows a set of two affordances that are relevant to searching information: opening and closing drawers to reveal and conceal the stored objects. We designed the tree metaphor as a folding tree with two main branches: animals and continents. The tree metaphor endows the affordance of following paths from one branch to another. These paths are familiar to children, mostly from drawing or viewing family trees.

Considering Piaget's [22] concepts of classification and reversibility as processes that characterize the concrete operational stage, we assume that children in our research are able to classify, that is to structure objects hierarchically, or to identify sets of objects according to certain characteristics. Classification includes the notion of class inclusion, e.g. understanding that objects (for instance turtles) are a part of a subset included within a parent set (reptiles). Reversibility is the comprehension that objects can be changed, and then returned to their original state. This comprehension would help children to intuitively search for information in both applications; they will easily open and then close drawers in the cabinet-based metaphoric application, and will easily unfold and then fold branches in the tree-based metaphoric application, according to the information required by the task.

In both metaphoric applications, we used identical icons to represent categories of objects. The images we chose are good representations of a category, to activate prototypes that are already stored in the children's long-term memory. The prototype theory that refers to graded categorization in cognitive science (Rosch, [24]) claims that some members of a category are more central or more representative of that category. For instance, in our applications, a *kangaroo* image is more prototypical of the *marsupial* category than, say a *wombat.* To meet possible situations in which prototypes may not be stored in long-term memory yet, and to promote recognition, we attached a textual label alongside each image.

After implementing the two prototypes to meet the design criteria of the two hierarchical metaphors, we pilot tested both applications with four children at their home to identify usability problems and to obtain feedback from our potential users. By doing so, our application design follows Gould and Lewis [8] approach of a user-centred, iterative methodology. Similar to other researchers using the user centred design (UCD) approach, our aim was broadly to find out what characteristics of our design were working well, which features were easy and intuitive to use, what was difficult to use, what caused confusion and how children reacted to the application as whole. This information would be fed back directly into the design loop (Moll-Carrillo et al., [17]).

All children used both prototypes, two of them interacting with the cabinet metaphor first and the other two interacting with the tree metaphor first. The children carried out a series of search tasks, to answer questions such as "how much does a mature polar bear weight?" We observed the children's interaction with both applications and adjusted the design accordingly. During our observations, we were sensitive to the children's gestures and encouraged them to think aloud their thoughts, problems, indecisions, impressions, etc. After interacting with each application, we asked the children whether they were satisfied with the application, what they liked or disliked about each application, whether it was easy or hard to find what they were looking for, and what they would have preferred to be different.

We approved, omitted or improved features and interface ideas based on feedback we received from the children. Overall, the observations helped us validate the applicability of the two metaphors as a way to access information about animals and continents. We found that searching for objects in drawers of a hierarchical cabinet and drilling down through a tree-based hierarchy was an experience familiar to the children.

Since describing the phases of our iterative design process at length is outside the scope of the current work, in the next section we briefly provide examples of improvements in the design to illustrate how and why specific design decisions were made.

2.6. Apparatus

Since the research was conducted in Israel, the language of the interfaces at the two educational programs is Hebrew. The two educational programs are identical in the types and amount of information available. The hierarchical categorization and levels of hierarchies are also the same, with a number of levels and categories at each level adjusted to Baek and Lee's recommendation referring to 5 ± 2 categories in children's applications [1]. In both metaphoric applications, we used identical icons and labels to represent categories of objects.

Figure 1 presents two matching screens of the hierarchical metaphors: the cabinet (object-container) metaphor and the tree (child-parent) metaphor, respectively. The hierarchical classes that appear in both representations refer to the animal theme with the following hierarchical levels: Animals/mammals/predators/bears (by using a diagonal line we express an additional hierarchical metaphor, which is a popular navigation aid in web sites, the path metaphor). Figure 2 presents two additional matching screens of the two hierarchical metaphors, but this time the hierarchical classes refer

to the continents theme, with only two hierarchical levels: Continents theme/list of continents. A comparison between Figures 1 and 2 shows that when designing both applications, we strictly followed one of the most important usability heuristic proposed by Nielsen [18]: consistency, so that both systems would work in a predictable way.

The upper part of figure 1 presents the cabinet metaphor. The screenshot of the cabinet is currently at a stage that reveals two drawers: polar bears and panda bears. At the upper right side of the screen, is a navigation aid that expresses the nested drawers visually in an intuitively nested 'Russian doll' fashion: My Cabinet/Animals/mammals/predators/ bears (from the biggest drawer to the smallest and most nested, respectively). An additional navigation aid is the blue header of each window, currently presenting 'the bears' drawer'. For prominence, the currently opened category of drawers is displayed in white in both the cabinet and the navigation aid. We added this feature when we realized that the children did not make our intended relation between the cabinet and its mapping in the form of the navigation aid. Opening a drawer is accomplished by intuitively clicking on its handle, and closing an opened drawer is accomplished by clicking on an icon at the upper left side of the screen, of a drawer with an arrow directed at the cabinet, with the label 'close the *bears*' drawer'. We had previous versions for this icon that we had changed twice until its functionality was clear.

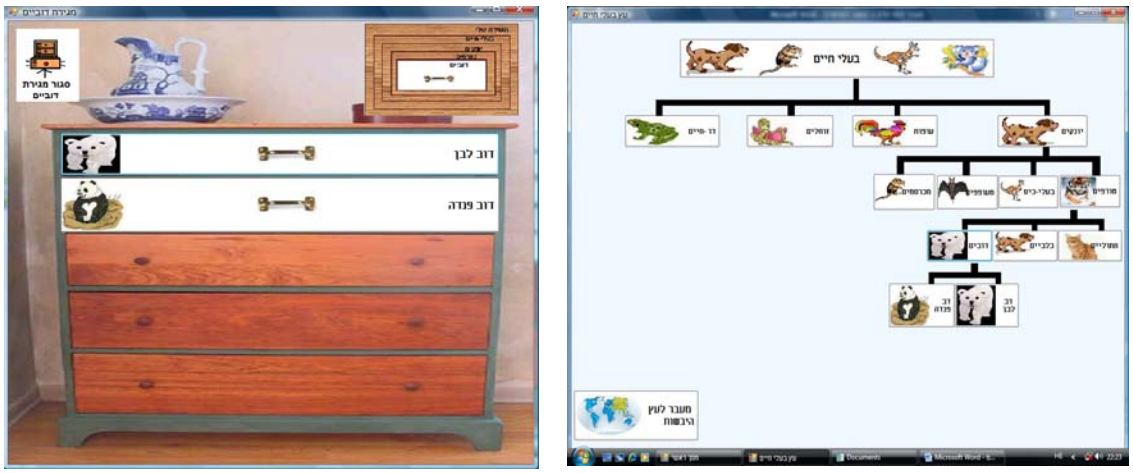


Figure 1. The cabinet metaphor versus the tree metaphor: screen shots from the animals theme

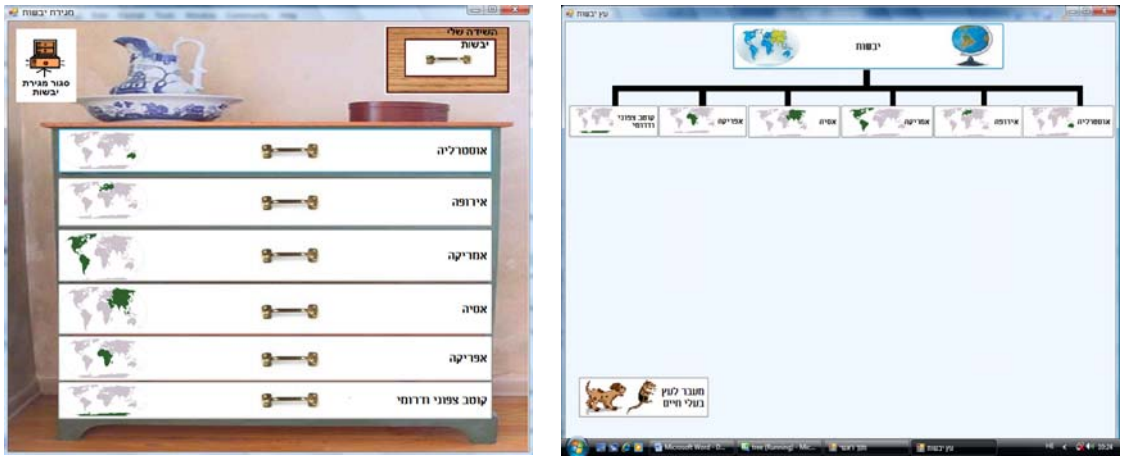


Figure 2. The cabinet metaphor versus the tree metaphor: screen shots from the continents theme

The lower part of Figure 1 presents the tree metaphor. The tree is currently at a stage that reveals the following branches: Animals/categories of animals (including mammals)/categories of mammals (including predators)/categories of predators (including bears)/categories of bears (polar bears and panda bears), (from the tree's root to the branch most distant from it, respectively). A navigation aid to highlight the last branch that was unfolded is a blue border around the rectangle presenting that tree branch. The tree metaphor endows the affordance of following paths from one branch to another. Unfolding a tree branch is accomplished by clicking on a branch that one wishes to unfold (expand). When clicking on

another branch, at the same level in the hierarchy or at an upper level, the already unfolded branch folds back. This will fold the tree up to the level of the branch that was clicked. The reason for folding a branch when the user wishes to unfold another is to prevent a cognitive load that is likely to occur when too much information is exposed. For this concern and for physical limitations of the screen, the animal tree and the continents tree (the two educational themes in both applications) were separated, that is, the two trees cannot be simultaneously unfolded. Users can simply switch from one tree to another by clicking on the root of the tree that is currently folded, always appearing at the lower left side of the screen.

The hierarchical "path" is manifest in the cabinet metaphor by the navigation aid of nested drawers ("Russian doll" fashion), and is manifest in the tree metaphor by the unfolded tree branches.

Finally, reaching and clicking on the most nested level of drawers or on a branch that is most distant from the tree's root (the leaf level) opens an information window displaying educational description of animal or continent items, e.g. information about the panda bear.

In both metaphoric interfaces, we used icons alongside textual labels. HCI research shows that children are able to recognize and remember icons more easily than commands. Many of the general design principles are encapsulated by the use of icons. They focus attention, and especially prompt recognition rather than recall. Preferring recognition over recall is one of Nielsen's [18] ten heuristics for designing usable interfaces. Icons must be designed to allow the user to match between the system and the real world, another previously mentioned usability heuristic (Gala, [5]).

3. Method

We tested our prototypes with 10 children, all within the target audience of seven to eleven years old. In total, there were six girls and four boys. All children participants interacted with both computer applications at their homes, to find answers for twelve search tasks, using both prototypes. Five children interacted with the cabinet prototype first and the other five interacted with the tree prototype first (there were 3 girls and 2 boys in each group). The number of users in each group in prototype testing follows Nielsen's finding that the best results come from testing no more than five users. According to Nielsen, after the fifth user, you are wasting your time by observing the same findings repeatedly but not learning much new (Nielsen, [19]).

We asked the children to carry out a series of 12 search tasks to answer questions regarding animals and continents, using the educational program. Examples for questions are "how does a bat navigate to locate prey?" and "what is special in the skin of a toad?" There were 12 different questions for each program, therefore 24 questions for each participant. In each set of search tasks, there were corresponding questions in terms of the depth of the hierarchical path, to remove potential differences that derive from task complexity. In each set of search tasks, we mixed up questions regarding continents with questions regarding animals for better examination of the children's ability to switch drawers/trees. Both groups of children received the sets of search tasks at the same order. As in the pilot, we used the think aloud technique to gather direct information about the children's attitudes, feelings and thoughts. We observed the children's interaction with the programs, paying attention to their gestures and their verbal expressions of thoughts, difficulties, indecisions, impressions, etc. We examined subjective evaluations of satisfaction and acceptance, and several objective performance measures: the time to complete the search task, the number of overall successful answers, and the number of erroneous clicks at each task. We also examined the type of mistakes that occurred at each program.

We designed a questionnaire to elicit information about the children's attitudes and opinions about each metaphoric program, without overloading them with too many questions. The questions were short, and worded in simple Hebrew, so that the children would understand what they were being asked. We asked whether they were satisfied with the application, what they liked or disliked about the application, whether it was easy or hard to find what they were looking for, whether they would like to have the application, what they would have preferred to be different, and finally asked them to give an explanation of individual components. At the end of the experiment, after interacting with both applications, we asked each child which application he prefers.

4. Results

Overall, the children who participated in the pilot and those who used the experimental systems wanted to explore both applications and were satisfied with them. All children had at least some previous experience with computers. Only two of the ten children were unfamiliar with the opening and closing of hierarchical folders to search or to access content. We found that all children had somewhat trouble with following the right hierarchical paths to answer the questions. For example, for answering the question "how does a bat navigate to locate prey?" four children mistakenly opened the birds or the reptiles' drawers/branches.

Most of the children were confused when asked a question that referred to both themes, for example: 'Which animals are common in Australia?' Although they were aware of the continents drawer/branch, they first started their search using the animals' drawer/branch. The youngest children at the age of seven and eight encountered somewhat reading problems and needed some help from the observer.

Figures 3–4 present the average time to complete a search task and the overall number of mistakes during the tasks for each participant in the group that experienced the cabinet metaphor first and in the group that experienced the tree metaphor first, respectively. Axis X in both figures presents the children who participated.

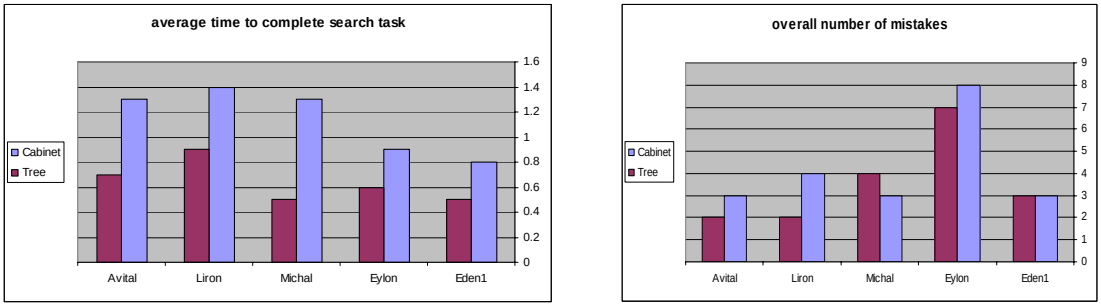


Figure 3. Average time to complete the search tasks and the overall number of mistakes during the tasks in the group that experienced the cabinet metaphor first

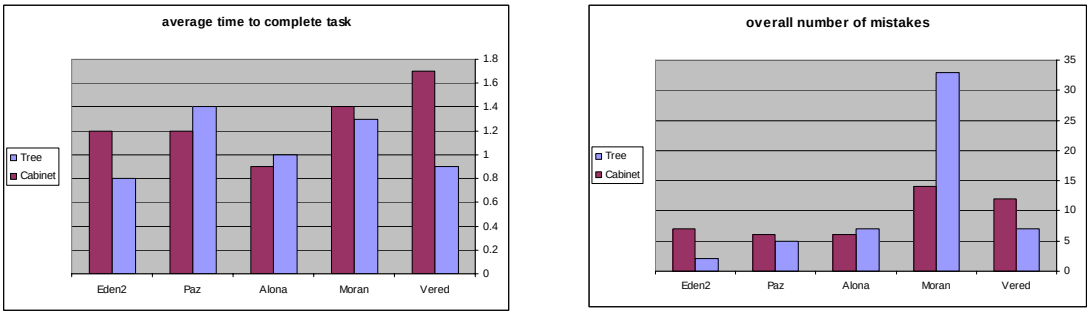
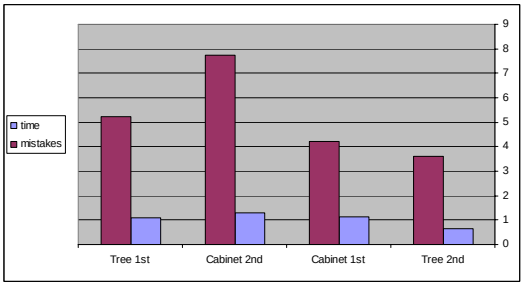


Figure 4. Average time to complete the search tasks and the overall number of mistakes during the tasks in the group that experienced the tree metaphor first

Figure 5 presents the average time to complete a search task and the overall number of mistakes during the tasks, beyond participants. One child participant in the second group was omitted at this stage because the number of mistakes she exhibited was exceptional (see overall number of mistakes for Moran in Figure 4).



		Application experienced first	
		Tree	Cabinet
Performance	Tree	Tree 1st	Tree 2nd
	Cabinet	Cabinet 2nd	Cabinet 1st

Figure 5. Average time to complete the search tasks and the overall number of mistakes during the tasks for each group

When observing Figure 3, it is clear that the average time to complete a search task has declined from one application to the other in the group who started using the cabinet metaphor and then used the tree metaphor. Figure 4 reveals that only two of 5 children who started using the tree metaphor and then used the cabinet metaphor improved their performance in terms of time to complete the tasks, when they used the cabinet metaphor. Figure 3 reveals an improvement in terms of mistakes made during the task, in the group that experienced the cabinet metaphor first (except for one girl that made more mistakes when using the tree

metaphor), and figure 4 shows a partial improvement in the group that experienced the tree metaphor first (for only two children, the number of mistakes decreased). In the next section, we will address these results when we discuss whether learning and transferring knowledge of hierarchical organization occurred. The average time to complete a search task using the cabinet metaphor program is similar for both experimental groups (1.28 minutes for the group that experienced the tree metaphor first and 1.14 for the group that experienced the cabinet metaphor first). The average time to complete a search task using the tree metaphor program is 1.08 minutes for the group that experienced the tree metaphor first and 0.64 for the group that experienced the cabinet metaphor first. Overall, performance in terms of time to complete a search task was higher when using the tree metaphor.

As expected, comparing performance when using the tree metaphor shows that the group that experienced the tree metaphor second did better than the group that experienced it first. Surprisingly, comparing performance of experimental groups when using the cabinet metaphor shows that the group that experienced the cabinet metaphor first did better than the group that experienced it second.

The measurement of the overall number of correct answers was relatively homogenous. Almost all participants succeeded in all search tasks. The reason for this is that we did not set a time limit for the tasks. Therefore, most children finished each task only when they found the answer for the questions.

Nine out of the ten children participants preferred the tree metaphor application, and claimed that it was easier, more understandable and more fun to use. Only one child, who belonged to the group that experienced the tree metaphor first, preferred the cabinet metaphor, stating that it was prettier. This was surprising, since three out of the four pilot participants preferred the cabinet metaphor application, and claimed that it was more fun to use, and more interesting.

The think aloud technique revealed that in the cabinet metaphor, the navigation aid that expressed the nested drawers visually in a nested "Russian doll" fashion was difficult to understand. Therefore, the children hardly used this feature. Comparing the children's reactions to the educational applications, we found a better flow of interaction in the tree based metaphor with a higher degree of comprehension and effective transitions between hierarchical levels. This distinction was salient in situations on which a child was trying to withdraw from a certain level in the hierarchy that he mistakenly had accessed. In the cabinet metaphor, many children expressed confusion and disorientation ('now how do I get back?'). In the following section we discuss our results.

5. Discussion

We were interested in determining whether one of two hierarchical metaphors, the cabinet (object-container) or the tree (parent-child) is more suitable for the design of children's interfaces. We were also interested in examining whether children transfer hierarchical organization of one kind to the other.

We designed the cabinet metaphor to resemble the natural environment of a children's playroom. We were surprised to find that the children less preferred the cabinet metaphor, which we expected to be more fun and interesting. We ascribe the higher level of satisfaction with the tree metaphor application to the more smooth interaction that the children experienced. The cabinet metaphor that was found to be less comprehensible was more demanding on the cognitive resources of the children, and the relatively higher cognitive complexity sensed, resulted in a lower sense of pleasure and enjoyment.

We found that the tree metaphor was better for transitioning between various levels of a hierarchy. One reason is the ability to unfold all relevant levels of the tree, in a way that made the relevant hierarchical structure fully visual. On the other hand, the cabinet metaphor showed less information about the hierarchy, since hierarchy at each level was presented via a navigation aid that revealed the relevant upper level drawers (upper level containers) and the nested drawers of a current opened drawer (the current drawer's nested objects) but not the nested drawers of the upper level drawers. In addition, we already mentioned that the children were confused by the navigational aid that expressed the nested drawers visually. The second reason for better transitioning among levels of hierarchy in the tree metaphor is the ability to efficiently withdraw from a certain level in the hierarchy. The cabinet metaphor required the user to close each drawer by using the icon "close drawer". For example, to reach back to a drawer that is three levels higher in the hierarchy, the user needs to click on the "close drawer" icon twice. In the tree metaphor, the user clicks only once on the target branch and the tree folds back up to that level.

The group that first used the cabinet metaphor showed a more significant improvement in performance when transferring to the second application (tree metaphor), in terms of number of mistakes made during the tasks and in terms of time to complete the tasks. In the group that first used the tree metaphor, improvement was only partial. Given that there was some improvement in both groups, we can on one hand assume that the children did transfer the hierarchical organization of concepts from one

metaphoric application to the other. On the other hand, we cannot be certain of whether there was a significant transfer of hierarchical knowledge, given the fact that the improvement was significant only for the group that first used the cabinet metaphor. An alternative explanation for the significant improvement in the group that first experienced the cabinet metaphor is the better visualization of the hierarchical organization that made the tree application more usable and more comprehensible. Therefore, the improvement in performance may be explained by differences in design features and not only by a learning process of the hierarchical structures.

When comparing performance in the cabinet metaphor program, we were surprised to find that the group which experienced the cabinet metaphor first preformed better than the group that experienced the cabinet metaphor secondly, after experiencing the tree metaphor. Given the fact that there were few participants in each group, one possible explanation is that the children who were first exposed to the cabinet metaphor were characterized by a higher level of cognitive abilities. Another explanation can be a higher sensation of cognitive complexity in the group that experienced the cabinet metaphor after a much more satisfying interaction with the tree metaphor. Experiencing the cabinet metaphor after the tree metaphor may have put the children in that group in a state of a negative affect (frustration for example), while experiencing the tree metaphor after the cabinet metaphor may have put the children in the other group in a state of a positive affect. According to Norman, our affective state, whether positive or negative changes how we think. Negative and positive affects play a major role in our ability to concentrate. Positive affects arouse curiosity, engages creativity, and makes the brain into an effective learning organism. When one is relaxed and in a pleasant mood, he is more able to cope with minor problems with a device (Norman, [21], pp. 25–26).

The results of our study make it difficult to determine whether one of the two hierarchical metaphors is more suitable for the design of children's interfaces and whether children transfer hierarchical organization of one kind to the other. On the one hand the tree metaphor seems more preferable, but on the other the predominance of the tree metaphor in our research may be due to specific design elements of each metaphoric interface and not to the hierarchical organization of information. Our main recommendation is to conduct further research with the same hierarchical metaphors, only the design of the cabinet metaphor will take into account the flaws found in the current research. Future design should especially improve navigation between levels of hierarchy in a way, that the closing and opening of levels of hierarchies would be accomplished in the same amount of clicks, and that the visualization of hierarchical information would not give an advantage of one metaphoric design over another.

In addition, future studies should be conducted with larger groups of children to gain information that is more systematic. The performance measurement of overall correct answers (number of successful tasks) would be more usable in future study if a time limit is set for each task.

We also suggest that educational applications should have an additional feature of auditorial output along with a visual highlight of pronounced words to overcome reading problems which are displayed by younger children. For example, a reading aid for textual information about an animal or a continent, can be a visual indicator of the word that is currently read in the form of a "jumping ball" (karaoke style) or a highlight around that word. Serving as an attention focusing feature, it would gain not only help in coping with the current text, but also advance the process of obtaining one's reading skills.

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ASYMPTOTIC DISTRIBUTION OF MANN-WHITNEY TYPE STATISTICS FOR NONPARAMETRIC CHANGE POINT PROBLEMS

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The literature displays change point detection problems in the context of one of key issues that belong to testing statistical hypotheses. The main focus in this article is to review shortly nonparametric retrospective change point policies, proposing new relevant tests based on Mann-Whitney type statistics. Asymptotic approximations for the significance level of the suggested tests are obtained analytically. Monte Carlo experiments show that the rate of convergence of our asymptotic is fast, and provide accurate results for a level of significance of the suggested tests for sample sizes commonly observed in practice.

Keywords: *change point; nonparametric tests; Mann-Whitney statistics; threshold limit value*

1. Introduction

We assume that $X_1, X_2,..., X_n$ are independent random variables and consider the following problem of hypothesis testing:

H_0, the null: $X_1, X_2,..., X_n \sim F_1$ versus (1)

H_1, the alternative: $X_i \sim F_1$, $X_j \sim F_2$, $i = 1,..., \nu$, $j = \nu + 1,..., n$,

where F_1 and F_2 are distribution functions with corresponding density functions f_1 and f_2, respectively. The distribution functions F_1 and F_2 are not necessary known. The unknown parameter $\nu + 1$, $1 \le \nu \le n-1$ is called a change point.

There is already a rich literature dealing with this problem (c.f., [1–4, 7–11]), divided into parametric and nonparametric cases. In the parametric case it is assumed that the distribution functions F_1 and F_2 have known forms that can contain certain unknown parameters (e.g., [4, 9, 10]). In the nonparametric case of (1) the functions F_1 and F_2 are unknown (e.g., [3, 5, 6, 13]). In this paper we concentrate on the nonparametric approach to the problem (1).

When the problem (1) is stated nonparametrically, there is no a universal powerful methodology for this subject. However, common components of nonparametric change point detection policies have been proposed to be based on signs and/or ranks and / or U-statistics (e.g., [2, 3, 8, 12]. Sen and Srivastava [12] focused on the problem (1) with the unknown distributions $F_1(x)$, $F_2(x) = F_1(x - \beta)$, $\beta > 0$. The authors suggested to reject H_0, for large values of the statistic

$$D_1 = \max_{1 \le k \le n-1} \left\{ \left[U_{k,n-k} - k(n-k)/2 \right] / \left[k(n-k)(n+1)/12 \right]^{\frac{1}{2}} \right\}, \quad (2)$$

where $U_{k,n} = \sum_{i=1}^{k} \sum_{j=k+1}^{n} I\left(X_i \le X_j\right)$, ($I(\cdot)$ is the indicator function) is the Mann-Whitney statistic for two samples of size k and $n-k$. (Sen and Srivastava [12] did not analyse analytical properties of the statistic (2).) Setting the problem (1) in a similar manner to Sen and Srivastava [12], Pettitt [11] used the statistic

$$\max_{1 \le k \le n-1} \left\{ -\sum_{i=1}^{k} \sum_{j=k+1}^{n} Q_{ij} \right\}, \; Q_{ij} = sign\left(X_i - X_j\right) = \begin{cases} 1 & X_i > X_j \\ 0 & X_i = X_j \\ -1 & X_i < X_j \end{cases}$$

to propose a change point detection policy. Wolfe and Schechtman [13] showed that this statistic can be presented as

$$K = 2 \max_{1\le k\le n-1} \left\{ U_{k,n-k} - k(n-k)/2 \right\}. \tag{3}$$

Thus, the statistics K and D_1 have a similar structure. In this case, Csorgo and Horvath [2] modified the statistic D_1 to have the form of

$$D_2 = \sqrt{3} \max_{1\le k\le n-1} \frac{U_k}{\left(k(n-k+1)n\right)^{\frac{1}{2}}}, \tag{4}$$

where $U_k = -\sum_{i=1}^{k}\sum_{j=k+1}^{n} sign(X_i - X_j)$. This modification was introduced to evaluate asymptotically $(n \to \infty)$ the type I error of the corresponding to the statistic (4) test that requires to reject H_0, if $D_2 > C_{D_2}$, where C_{D_2} is a test-threshold. They obtained the following asymptotic result:

$$\lim_{n\to\infty} P_{H_0}\left\{ D_2 \le a(y, \log n) \right\} = \exp\left(-\exp(-y)\right), \tag{5}$$

where $a(y,\log n) = \left(y + 2\log\log n + \frac{1}{2}\log\log\log n - \frac{1}{2}\log\pi \right)\left(2\log\log n\right)^{-\frac{1}{2}}$, $-\infty < y < \infty$, P_{H_0} denotes the distribution of the observations $X_1,...,X_n$ under H_0.

Ferger [3] suggested a number of tests based on U-statistics. He evaluates the asymptotic significance level and compares the asymptotic power for some of these tests. In particular, following Csorgo and Horvath [2] he evaluated the asymptotic distribution of the statistic K under H_0:

$$\lim_{n\to\infty} P_{H_0}\left\{ \sqrt{3} n^{-\frac{3}{2}} K \le x \right\} = 1 - \exp\left(-2x^2\right). \tag{6}$$

Gombay [5, 6] studied the asymptotic behaviour of U-statistics. Wolfe and Schechtman [13] compared the powers of the tests based on the statistics K and D_1 for several specific distributions and different change points by Monte Carlo methods. Their conclusion is that there isn't a globally preferable test. For $\nu \approx \frac{n}{2}$ it seems that the test based on the statistic K is preferable; and for ν that is close to edges, the test based on the statistic D_1 is preferable.

When the two-sided statement $F_2(x) = F_1(x-\beta)$, $\beta \ne 0$ is assumed, the absolute values of the statistics (2)–(4) should be considered to construct the tests for the two-sided alternative.

In this paper we suggest two new tests for the considered change point problem (1) based on modifications of Mann-Whitney type test-statistics (2) and (3). We present approximations for the level of significance of the suggested tests based on asymptotic analysis. We find that the rate of convergence of our asymptotics is fast and yields accurate results for sample sizes commonly observed in practice. We present Monte Carlo comparisons of the power of the suggested tests with the power of tests based on widely used statistics (3) and (4). We compare also the rate of convergence of our asymptotic results with that of Csorgo and Horvath [2] and Ferger [3]. The Monte Carlo investigation results confirm the preference of the suggested tests from the application perspective. The paper is organized as follows. In Section 2 the proposed tests are formulated and approximations for their significance level are presented. In Section 3 we report a simulation study. We state our conclusions in Section 4.

2. Suggested Tests and Asymptotic Results for Their Level of Significance

Let $X_1, X_2,..., X_n$ be independent random observations. We consider the hypotheses (1) where unknown distribution functions F_1 and F_2 such that for all x, $F_2(x) \le F_1(x)$ (that is, we assume after a possible change the observations are stochastically larger than before the change). In accordance with (2) and (3), we suggest following new modifications of Mann-Whitney type statistics K and D_1 for the problem (1):

$$MK = \sum_{k=1}^{n-1} \left(U_{k,n-k} - k(n-k)/2 \right), \tag{7}$$

$$MD_1 = \sum_{k=1}^{n-1} \frac{U_{k,n-k} - k(n-k)/2}{\sqrt{k(n-k)(n+1)/12}}. \tag{8}$$

Note that consideration the sum instead of the max in definition of statistics (7) and (8) allow evaluating an accurate asymptotic behaviour of these statistics under the null hypothesis H_0. We propose two following tests for the change point problem (1). The first test is: reject the null hypothesis H_0 if

$$MK > C_{MK}, \tag{9}$$

where C_{MK} is a test-threshold. The second test is: reject the null hypothesis H_0 if

$$MD_1 > C_{MD_1}, \tag{10}$$

where C_{MD_1} is a test-threshold.

The following Theorem 1 states limit distributions of test-statistics MK and MD_1.

Theorem 1. For all $-\infty < x < \infty$

$$\lim_{n\to\infty} P_{H_0}\left(\frac{MK}{S1_n} > x \right) = 1 - \Phi(x), \tag{11}$$

$$\lim_{n\to\infty} P_{H_0}\left(\frac{MD_1}{S2_n} > x \right) = 1 - \Phi(x), \tag{12}$$

where

$$S1_n = \sqrt{\frac{n+1}{12}\left(\sum_{k=1}^{n-1} k(n-k) \right) + 2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k} k(n-k-r)}\ ,\ S2_n = \sqrt{(n-1) + 2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k} \sqrt{\frac{k(n-k-r)}{(n-k)(k+r)}}}\ ,$$

$\Phi(x)$ is the cumulative distribution function of the standard normal distribution.

Proof. See the Appendix.

Remark. For the two-sided alternative ($F_2(x) \le F_1(x)$ or $F_2(x) \ge F_1(x)$, $-\infty < x < \infty$) one can consider the absolute values of the statistics (7) and (8), and use the Theorem 1 for evaluating threshold limit values for corresponding tests.

In Section 3 we check approximations for the significance level of the suggested tests (9) and (10) following from the Theorem 1. We compare the power of the suggested test with that of widely accepted nonparametric tests based on statistics K and D_2. We compare also the rate of convergence of the asymptotic results (11) and (12) with that of Csorgo and Horvath [2] and Ferger [3] ((5) and (6), respectively).

3. Monte Carlo Results

Denote the following:

TK – The test based on the statistic K (defined by (3)): reject H_0 if $K > C_K$,

TD_2 – The test based on the statistic D_2 (defined by (4)): reject H_0 if $D_2 > C_{D_2}$,

TMK – The suggested test (9).

TMD_1 – The suggested test (10).

To conduct the Monte Carlo simulations below, for each distribution set with different sample sizes, we generated 10,000 times corresponding data. The Monte Carlo powers of the nonparametric tests TK, TD_2, TMK, TMD_1 were evaluated at the level of significance 0.05 that was fixed experimentally by choosing special values of the test-thresholds. (Since, under the null hypothesis of (1), the baseline

distribution functions of the nonparametric test-statistics K, D_2, MK, MD_1 do not depend on data distributions, only tables of critical values of the tests are required for their implementation.) In Table 1, we report a Monte Carlo comparison of powers of the tests TK, TD_2, TMK, TMD_1 when the real pre-change and post-change distributions are $N(\mu,\sigma^2)$ and $N(\mu+\beta\sigma,\sigma^2)$, respectively. None of the four statistics depend on the parameters μ and σ. Therefore, for our simulations we used $\mu=0$ and $\sigma=1$.

Table 1. Simulated powers of the tests TK, TD_2, TMK, TMD_1 when the real pre-change and post-change distributions are $N(\mu,\sigma^2)$ and $N(\mu+\beta\sigma,\sigma^2)$. The size of the sample is n. The observation ν is the last observation before the change. The significance level is $\alpha=0.05$

n	β	ν	TK	TMK	TD_2	TMD_1
	0.8	10	0.427	0.408	0.381	0.392
		5	0.258	0.267	0.295 (0.258^{+})	0.272
		3	0.136	0.162	0.190 (0.145^{++})	0.171
	1.0	10	0.579	0.544	0.518	0.527
20		5	0.350	0.348	0.404 (0.358^{+})	0.355
		3	0.165	0.200	0.255 (0.186^{++})	0.213
	1.2	10	0.718	0.679	0.655	0.652
		5	0.458	0.439	0.518 (0.472^{+})	0.443
		3	0.195	0.233	0.333 (0.231^{++})	0.253
Test-threshold			$C_K=57.000$	$C_{MK}=1.671\sqrt{S1_{20}}$, $S1_{20}=23275.000$	$C_{D_2}=2.302$	$C_{MK}=1.662\sqrt{S2_{20}}$, $S2_{20}=182.520$
	0.8	20	0.693	0.664	0.619	0.643
		10	0.471	0.445	0.502 (0.462*)	0.451
		5	0.180	0.208	0.299 (0.235**)	0.228
	1.0	20	0.856	0.825	0.800	0.803
40		10	0.641	0.590	0.674 (0.634*)	0.598
		5	0.235	0.263	0.413 (0.332**)	0.291
	1.2	20	0.949	0.925	0.915	0.910
		10	0.793	0.718	0.819 (0.791*)	0.727
		5	0.301	0.325	0.542 (0.445**)	0.362
Test-threshold			$C_K=166.000$	$C_{MK}=1.653\sqrt{S1_{40}}$, $S1_{40}=728433.333$	$C_{D_2}=2.488$	$C_{MK}=1.634\sqrt{S2_{40}}$, $S2_{40}=741.102$

$^{+}$ indicates simulated powers of the test TD_2 for $\nu=15$; * indicates simulated powers of the test TD_2 for $\nu=30$;
$^{++}$ indicates simulated powers of the test TD_2 for $\nu=17$; ** indicates simulated powers of the test TD_2 for $\nu=35$.

The power functions of the statistics K, MK and MD_1 as functions of ν are symmetric around the middle points $\nu=10$ for $n=20$ and $\nu=20$ for $n=40$. The power function of the statistic D_2 as a function of ν is not symmetric. Therefore, to compare the test TD_2 with other presented tests, we evaluated as well the simulated powers of this test for additional values of ν.

From the analysis of the Table 1, it turns out that there are no essential differences between powers of all considered tests. However, the test TD_2 is slightly preferable to the test TMD_1 when $n=40$. Moreover, for the considered examples, the tests TD_2 and TMD_1 are preferable to the tests TK and TMK if the real change in the distribution occurs near the edges ($\nu\approx 1$ or $\nu\approx n$), and the tests TK and TMK are preferable if the real change occurs in the middle ($\nu\approx n/2$).

Note that the result (5) of Csorgo and Horvath [2] provides asymptotically ($n\to\infty$) the distribution free type I error of the test TD_2; the result (6) of Ferger [3] provides asymptotically the distribution free type I error of the test TK; and results (11) and (12) of the Theorem 1 provide asymptotically distribution free type I errors of the tests TMK and TMD_1, respectively. To examine the accuracy of these results, we determine critical values C_{D_2}, C_K, C_{MK}, C_{MD_1} of the tests TD_2, TK, TMK, TMD_1, taking into account the results (5), (6), (11), (12), respectively, expecting to obtain the nominal significance levels $\alpha=0.05$.

For the test TD_2 we determine the critical value C_{D_2} that corresponds to level of significance $\alpha = 0.05$ through an asymptotic distribution of the statistic D_2 as given by (5):

$$C_{D_2} = \left(y + 2\log\log n + \frac{1}{2}\log\log\log n - \frac{1}{2}\log\pi \right)\left(2\log\log n\right)^{-\frac{1}{2}}, \quad (13)$$

where $y = 2.970$ (then, $\exp(-\exp(-y)) = 0.95$).

For the test TK we determine the critical value C_K that corresponds to level of significance $\alpha = 0.05$ through an asymptotic distribution of the statistic K as given by (6):

$$C_K = \left(x/\sqrt{3}\right)n^{1.5}, \quad (14)$$

where $y = 1.224$ (then, $1 - \exp\left(-2x^2\right) = 0.95$).

For the test TMK we determine the critical value C_{MK} that corresponds to level of significance $\alpha = 0.05$ through an asymptotic distribution of the statistic MK as given by (11):

$$C_{MK} = xS1_n, \quad (15)$$

where $S1_n$ is defined by (11), $x = 1.645$ (then, $1 - \Phi(x) = 0.05$).

For the test TMD_1 we determine the critical value C_{MD_1} that corresponds to level of significance $\alpha = 0.05$ through an asymptotic distribution of the statistic MD_1 as given by (12):

$$C_{MD_1} = xS2_n, \quad (16)$$

where $S2_n$ is defined by (12), $x = 1.645$.

We present in Table 2 the actual Monte Carlo type I errors of the tests TD_2, TK, TMK, TMD_1 with the test-thresholds (13), (14), (15), (16), respectively, expecting to obtain the nominal type I errors $\alpha = 0.05$.

Table 2. The actual Monte Carlo type I errors of the tests TD_2, TK, TMK, TMD_1 with the test- thresholds (13), (14), (15), (16), respectively, for different sample sizes n.

$n = 20$				
Test	TD_2	TK	TMK	TMD_1
Test-threshold	$C_{D_2} = 3.131$	$C_K = 63.207$	$C_{MK} = 1.645S1_n$, $S1_n = 23275.000$	$C_{MD_1} = 1.645S2_n$, $S2_n = 182.520$
Type I error	**0.002**	**0.026**	**0.053**	**0.052**
$n = 40$				
Test	TD_2	TK	TMK	TMD_1
Test-threshold	$C_{D_2} = 3.182$	$C_K = 178.777$	$C_{MK} = 1.645S1_n$, $S1_n = 728433.333$	$C_{MD_1} = 1.645S2_n$, $S2_n = 741.102$
Type I error	**0.006**	**0.034**	**0.051**	**0.049**
$n = 100$				
Test	TD_2	TK	TMK	TMD_1
Test-threshold	$C_{D_2} = 3.241$	$C_K = 706.677$	$C_{MK} = 1.645S1_n$, $S1_n = 70131875.000$	$C_{MD_1} = 1.645S2_n$, $S2_n = 4662.628$
Type I error	**0.007**	**0.036**	**0.049**	**0.048**
$n = 200$				
Test	TD_2	TK	TMK	TMD_1
Test-threshold	$C_{D_2} = 3.279$	$C_K = 1998.784$	$C_{MK} = 1.645S1_n$, $S1_n = 2233277500.000$	$C_{MD_1} = 1.645S2_n$, $S2_n = 18679.369$
Type I error	**0.009**	**0.042**	**0.050**	**0.050**

Table 3 presents simulated powers of the tests TK, TD_2, TMK, TMD_1 with the test- thresholds (13), (14), (15), (16), respectively, when the real pre-change and post-change distributions are identical to that of Table 1.

Table 3. Simulated powers of the tests TD_2, TK, TMK, TMD_1 with the test- thresholds (13), (14), (15), (16), respectively, when the real pre-change and post-change distributions are $N(\mu,\sigma^2)$ and $N(\mu+\beta\sigma,\sigma^2)$. The size of the sample is n. The observation ν is the last observation before the change.

n	β	ν	TK	TMK	TD_2	TMD_1
	0.8	10	0.309	0.419	<0.05	0.400
		5	0.161	0.277	<0.05 (<0.05^{+})	0.279
		3	0.075	0.170	<0.05 (<0.05^{++})	0.175
	1.0	10	0.452	0.556	0.095	0.532
20		5	0.228	0.357	<0.05 (<0.05^{+})	0.362
		3	0.090	0.208	<0.05 (<0.05^{++})	0.218
	1.2	10	0.602	0.688	0.161	0.658
		5	0.310	0.451	0.063 (0.028^{+})	0.451
		3	0.107	0.248	<0.05 (<0.05^{++})	0.259
Test-threshold			$C_K = 63.207$	$C_{MK} = 1.645\sqrt{S1_{20}}$, $S1_{20} = 23275.000$	$C_{D_2} = 3.131$	$C_{MK} = 1.645\sqrt{S2_{20}}$, $S2_{20} = 182.520$
	0.8	20	0.621	0.667	0.261	0.639
		10	0.386	0.448	0.158 (0.134*)	0.447
		5	0.124	0.211	<0.05 (<0.05**)	0.225
	1.0	20	0.808	0.827	0.454	0.800
40		10	0.551	0.594	0.0292 (0.252*)	0.594
		5	0.162	0.267	0.079 (0.051**)	0.286
	1.2	20	0.923	0.926	0.666	0.907
		10	0.718	0.722	0.464 (0.407*)	0.723
		5	0.207	0.327	0.133 (0.076**)	0.356
Test-threshold			$C_K = 178.777$	$C_{MK} = 1.645\sqrt{S1_{40}}$, $S1_{40} = 728433.333$	$C_{D_2} = 3.182.$	$C_{MK} = 1.645\sqrt{S2_{40}}$, $S2_{40} = 741.102$

$^{+}$ indicates simulated powers of the test TD_2 for $\nu = 15$; * indicates simulated powers of the test TD_2 for $\nu = 30$;
$^{++}$ indicates simulated powers of the test TD_2 for $\nu = 17$; ** indicates simulated powers of the test TD_2 for $\nu = 35$.

It is evident from the Tables 2 and 3 that our asymptotic results for the significance level of tests TMK and TMD_1 are valid even for small sample sizes. In contrast, the asymptotic results of Ferger [3] and especially of Csorgo and Horvath [2] for the significance level of the test TK and TD_2, respectively, yield incorrect results for sample size commonly observed in practice. Thus, we do not recommend to utilize asymptotic formulas (5) and (6) for obtaining the critical values of the tests TD_2 and TK, respectively. The results (11), (12) can be used in practice.

4. Conclusions

In this article we have reviewed nonparametric techniques applied to create decision rules for the retrospective change point detection issue. We concentrated to present two new relevant procedures based on Mann-Whitney type statistics. We have derived an asymptotic distribution of the suggested statistics under the null hypothesis H_0 and presented approximations for the level of significance of the suggested tests. We conducted a broad Monte Carlo study for judging the accuracy of our asymptotic results and powers of the suggested tests. Simulation results confirm the preference of the proposed tests from the application perspective.

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Appendix

Proof of the Theorem 1. Firstly, we show that for each $n \geq 2$: $E_{H_0}\left(\frac{MK}{S1_n}\right)=0$, $E_{H_0}\left(\frac{MD_1}{S2_n}\right)=0$, $V_{H_0}\left(\frac{MK}{S1_n}\right)=1$, $V_{H_0}\left(\frac{MD_1}{S2_n}\right)=1$, where E_{H_0} and V_{H_0} denote the expectation and the variance under P_{H_0}.

Since, under H_0, the expectation and the variance of the Mann-Whitney statistic for two samples of size k and $n-k$, $E_{H_0}\left(U_{k,n-k}\right)=\frac{k(n-k)}{2}$, $V_{H_0}\left(U_{k,n-k}\right)=\frac{k(n-k)(n+1)}{12}$, we have

$$E_{H_0}\left(MK\right)=\sum_{k=1}^{n-1}\left(E_{H_0}\left(U_{k,n-k}\right)-\frac{k(n-k)}{2}\right)=0, \tag{A1}$$

$$E_{H_0}\left(MD_1\right)=\sum_{k=1}^{n-1}\frac{E_{H_0}\left(U_{k,n-k}\right)-k(n-k)/2}{\sqrt{k(n-k)(n+1)/12}}=0. \tag{A2}$$

$$V_{H_0}\left(MK\right)=V_{H_0}\left(\sum_{k=1}^{n-1}U_{k,n-k}\right)=\sum_{k=1}^{n-1}V_{H_0}\left(U_{k,n-k}\right)+2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k}\mathrm{cov}_{H_0}\left(U_{k,n-k},U_{k+r,n-(k+r)}\right), \tag{A3}$$

where $U_{n,0}=U_{0,n}=0$.

Note that for all $r=1,...,n-k$

$U_{k,n-k}=\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i \leq X_j\right)+\tilde{U}_{k,n-(k+r)}$, where $\tilde{U}_{k,n-(k+r)}=\sum_{i=1}^{k}\sum_{j=k+r+1}^{n}I\left(X_i \leq X_j\right)$ is the Mann-Whitney statistic for two samples $\left\{X_1,...,X_k\right\}$ and $\left\{X_{k+r+1},...,X_n\right\}$,

$U_{k+r,n-(k+r)}=\tilde{U}_{k,n-(k+r)}+\sum_{i=k+1}^{k+r}\sum_{j=k+r+1}^{n}I\left(X_i \leq X_j\right)$. Therefore,

$$\operatorname{cov}_{H_0}\left(U_{k,n-k},U_{k+r,n-(k+r)}\right)=V_{H_0}\left(\tilde{U}_{k,n-(k+r)}\right)+\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\tilde{U}_{k,n-(k+r)}\right) \tag{A4}$$

$$+\operatorname{cov}_{H_0}\left(\sum_{i=k+1}^{k+r}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right),\tilde{U}_{k,n-(k+r)}\right)+\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\sum_{i=k+1}^{k+r}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right)\right).$$

$$\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\tilde{U}_{k,n-(k+r)}\right)=\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\sum_{i=1}^{k}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right)\right) \tag{A5}$$

$$=\sum_{i=1}^{k}\operatorname{cov}_{H_0}\left(\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right)\right)=\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}\sum_{l=1}^{n-(k+r)}\operatorname{cov}_{H_0}\left(I\left(X_i\le X_j\right),I\left(X_i\le X_{k+r+l}\right)\right).$$

Note that, for all $k=1,\ldots,n-1$, $r=1,\ldots,n-k$, $i=1,\ldots,k$, $j=k+1,\ldots,k+r$, $l=1,\ldots,n-(k+r)$ we have

$$\operatorname{cov}_{H_0}\left(I\left(X_i\le X_j\right),I\left(X_i\le X_{k+r+l}\right)\right) \tag{A6}$$

$$=P_{H_0}\left(X_i\le X_j,X_i\le X_{k+r+l}\right)-P_{H_0}\left(X_i\le X_j\right)P_{H_0}\left(X_i\le X_{k+r+l}\right)=1/3-1/4=1/12.$$

By (A5), (A6) we get

$$\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\tilde{U}_{k,n-(k+r)}\right)=\frac{kr(n-(k+r))}{12}. \tag{A7}$$

By the similar way as (A5)-(A7), we have

$$\operatorname{cov}_{H_0}\left(\sum_{i=k+1}^{k+r}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right),\tilde{U}_{k,n-(k+r)}\right)=\operatorname{cov}_{H_0}\left(\sum_{i=k+1}^{k+r}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right),\sum_{i=1}^{k}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right)\right) \tag{A8}$$

$$=\sum_{j=1}^{n-(k+r)}\operatorname{cov}_{H_0}\left(\sum_{l=1}^{r}I\left(X_{k+l}\le X_{k+r+j}\right),\sum_{i=1}^{k}I\left(X_i\le X_{k+r+j}\right)\right)$$

$$=\sum_{j=1}^{n-(k+r)}\sum_{l=1}^{r}\sum_{i=1}^{k}\operatorname{cov}_{H_0}\left(I\left(X_{k+l}\le X_{k+r+j}\right),I\left(X_i\le X_{k+r+j}\right)\right)=\frac{(n-(k+r))rk}{12}.$$

$$\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\sum_{i=k+1}^{k+r}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right)\right) \tag{A9}$$

$$=\sum_{l=1}^{r}\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}I\left(X_i\le X_{k+l}\right),\sum_{j=1}^{n-(k+r)}I\left(X_{k+l}\le X_{k+r+j}\right)\right)$$

$$=\sum_{l=1}^{r}\sum_{i=1}^{k}\sum_{j=1}^{n-(k+r)}\operatorname{cov}_{H_0}\left(I\left(X_i\le X_{k+l}\right),I\left(X_{k+l}\le X_{k+r+j}\right)\right).$$

Note that, for all $k=1,\ldots,n-1$, $r=1,\ldots,n-k$, $l=1,\ldots,r$, $i=1,\ldots,k$, $j=1,\ldots,n-k-r$, we have

$$\operatorname{cov}_{H_0}\left(I\left(X_i\le X_{k+l}\right),I\left(X_{k+l}\le X_{k+r+j}\right)\right) \tag{A10}$$

$$=P_{H_0}\left(X_i\le X_{k+l}\le X_{k+r+j}\right)-P_{H_0}\left(X_i\le X_{k+l}\right)P_{H_0}\left(X_{k+l}\le X_{k+r+j}\right)=1/6-1/4=-1/12.$$

Then, by (A9), (A10)

$$\operatorname{cov}_{H_0}\left(\sum_{i=1}^{k}\sum_{j=k+1}^{k+r}I\left(X_i\le X_j\right),\sum_{i=k+1}^{k+r}\sum_{j=k+r+1}^{n}I\left(X_i\le X_j\right)\right)=-\frac{rk(n-(k+r))}{12}. \tag{A11}$$

By (A3), (A4), (A7), (A8), A11) we get

$$V_{H_0}(MK)=\sum_{k=1}^{n-1}\frac{k(n-k)(n+1)}{12} \tag{A12}$$
$$+2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k}\left(\left(\frac{k(n-(k+r))(n-r+1)}{12}\right)+2\frac{kr(n-(k+r))}{12}-\frac{kr(n-(k+r))}{12}\right)$$
$$=\sum_{k=1}^{n-1}\frac{k(n-k)(n+1)}{12}+2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k}\left(\frac{k(n-(k+r))(n+1)}{12}\right)$$
$$=\frac{n+1}{12}\left(\sum_{k=1}^{n-1}k(n-k)+2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k}k(n-k-r)\right)=S1_n{}^2.$$

$$V_{H_0}(MD_1)=V_{H_0}\left(\sum_{k=1}^{n-1}\frac{U_{k,n-k}}{\sqrt{k(n-k)(n+1)/12}}\right) \tag{A13}$$
$$=\sum_{k=1}^{n-1}V_{H_0}\left(\frac{U_{k,n-k}}{\sqrt{k(n-k)(n+1)/12}}\right)+2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k}\mathrm{cov}_{H_0}\left(\frac{U_{k,n-k}}{\sqrt{k(n-k)(n+1)/12}},\frac{U_{k+r,n-(k+r)}}{\sqrt{(k+r)(n-k-r)(n+1)/12}}\right).$$

By $(A.4)$, $(A.7)$, $(A.8)$, $(A.11)$, for all $k=1,...,n-1$, $r=1,...,n-k$, we have

$$\mathrm{cov}_{H_0}\left(U_{k,n-k},U_{k+r,n-(k+r)}\right)=\frac{k(n-k-r)(n-r+1)}{12}+\frac{kr(n-k-r)}{12}=\frac{k(n-k-r)(n+1)}{12}.$$

Therefore, for all $k=1,...,n-1$, $r=1,...,n-k$,

$$\mathrm{cov}_{H_0}\left(\frac{U_{k,n-k}}{\sqrt{k(n-k)(n+1)/12}},\frac{U_{k+r,n-(k+r)}}{\sqrt{(k+r)(n-k-r)(n+1)/12}}\right) \tag{A14}$$
$$=\frac{k(n-k-r)(n+1)/12}{\sqrt{k(n-k)(n+1)/12}\sqrt{(k+r)(n-k-r)(n+1)/12}}$$
$$=\frac{k(n-k-r)}{\sqrt{k(n-k)}\sqrt{(k+r)(n-k-r)}}=\sqrt{\frac{k(n-k-r)}{(n-k)(k+r)}}.$$

Thus, by $(A.13)$, $(A.14)$, we have

$$V_{H_0}(MD_1)=(n-1)+2\sum_{k=1}^{n-1}\sum_{r=1}^{n-k}\sqrt{\frac{k(n-k-r)}{(n-k)(k+r)}}=S2_n{}^2 \tag{A15}$$

Thus, by (A1), (A2), (A12), (A15), we have

$E_{H_0}\left(\frac{MK}{S1_n}\right)=0$, $E_{H_0}\left(\frac{MD_1}{S2_n}\right)=0$, $V_{H_0}\left(\frac{MK}{S1_n}\right)=1$, $V_{H_0}\left(\frac{MD_1}{S2_n}\right)=1$. The rest of the proof follows from the central limit theorem.

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COMPARATIVE EFFICIENCY ASSESSMENT AND RANKING OF PUBLIC DEFENSE AUTHORITY IN ISRAEL

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Checking comparative efficiency of public services becomes nowadays an ever growing demand. In developed countries, relative assessment of such services is carried out on a timely basis, to facilitate the process of continuous improvement. In many cases, information regarding comparative efficiency of structural units within a public service causes employees to compete for better achievements, thus enabling mutual improvement of all units involved.

Setting up efficiency targets for public service units necessarily causes employees to maintain awareness of their duties both to the employer, namely the government, as well as to improve and upgrade the quality of service provided to the citizen.

In this course, we witness comparative efficiency assessment of public schools, hospitals, police stations, academic institutions, etc.; the common grounds for all these organizations is their dedication to serve the general public for non-profit purposes, as well as the great number of measurable inputs and outputs to be assessed. In this paper, we will demonstrate efficiency assessment of structural units within the public defense authority in Israel, by means of the Data Envelopment Analysis (DEA) and subject to two ranking methods: Super Efficiency and Cross Efficiency. The efficiency assessment has been carried out among 5 counties (80 units in total) between 2001–2004 on a quarterly basis.

In the given research 3 different inputs and 2 outputs have been investigated. Efficiency ranking and assessment of public defense authority units, to our best knowledge, was never investigated before in scientific literature, which contributes to the novelty of our research.

Keywords*: Data Envelopment Analysis (DEA); Ranking; Super Efficiency; Cross Efficiency; Public defense.*

1. Introduction

The Data Envelopment Analysis (DEA) firstly introduced by Charnes et al. in 1978 [6] enables efficiency comparison between structural units (the so-called Decision-Making Units – DMUs) standing for assessment. The philosophy of the method boils down to determining optimal weights that are different for each unit causing its relative efficiency criterion to obtain the maximal value. The DEA method enables to the organization in general to measure the relative efficiency of each DMU, subject to its input and output values. The DMUs may represent: public schools (when the efficiency relation is carried out between different schools), or various classes within the same school, hospitals, different units of the same hospital, academic branches in a specific area (like comparing between Departments of Economics from a number of universities), local municipal councils, branches of a bank, factories, etc. The comparison between the DMUs may be taken along the time axis as well, namely by comparing the efficiency of each DMU at various time periods. The DMUs have to meet the criterion of similarity, e.g. characterized by the same set of inputs and outputs, as well as belonging to a homogenous group of DMUs in terms of internal structure and targets; the latter supposes providing similar services or selling similar products. In other words, relative efficiency between DMUs may be measured only when the latter perform similar tasks (same outputs) and consume for this purpose similar resources (same inputs). As a matter of fact, such DMUs may belong to the public sector (various not-for-profit organizations) or to the private sector (business).

Practical examples are given by a number of authors, among them: Doyle and Green [7] who ranked 20 universities in the UK; Sinuany-Stern et al. [18] ranked 22 academic departments in a university; Friedman and Sinuany-Stern [8] ranked industrial branches in Israel; Sinuany-Stern and Friedman [17] ranked towns in Israel; Sueyoshi and Kirihara [19] use linear discriminant analysis for classification of Japanese Banking Institutes, and they extended the method in 2001; Sueyoshi [20], ranked Japanese agriculture cooperatives.

There is major importance in relative efficiency estimation of governmental bodies regarded as DMUs, since every efficiency improvement of such bodies will necessarily cause the government to save part of the assigned budgets which might be re-rooted to other useful purposes, as well as improve quality of service provided to the public customer. Pierce [10] argues that setting up an efficiency scale to evaluate governmental public services stimulates employees to greater awareness as to their obligations to the employer (the government), on one hand, and their duties to further strengthen the weak points of providing services to the customers within their organization, on the other one. It can be well-recognized that in an even broader sense, providing business efficiency targets for an organization enhances its efficiency and that of the structural DMUs it is comprised of.

In our study we will carry out comparative efficiency assessment of DMUs belonging to the Israeli public defense authority, by means of the DEA methodology and two alternative ranking approaches for the units: the Super Efficiency method versus the Cross Efficiency method. The efficiency assessment was carried out within 2001–2004 on a quarterly basis and included 5 counties (altogether 80 DMUs). 3 types of inputs and 2 types of outputs have been singled out.

Our paper is presented as follows: *Section 2* introduces the DEA methodology, the Super Efficiency (SE) and the Cross Efficiency (CE) method, *Section 3* describes the case study, *Section 4* outlines the research results, while *Section 5* summarizes the conclusions and suggests future research opportunities.

2. The DEA Methodology and Ranking Methods

2.1. Data Envelopment Analysis

DEA is a procedure designed to measure the relative efficiency in situations when there are multiple inputs and multiple outputs and no obvious method how to aggregate both inputs and outputs into a meaningful index of productive efficiency. DEA was developed by Charnes, Cooper and Rhodes (CCR) [6]. The DEA provides a mechanism for measuring a Decision-Making Unit (DMU) Pareto efficiency compared with other DMUs. The mechanism is extensively employed in diverse industries and environments (an extensive review of DEA applications is provided by Seiford (1996)). In the service sector, applications of DEA include education (Sexton et al. [11]), recreation and health care management (Sherman [15]) to name just a few.

The efficiency in DEA is termed Technical and Scale Efficiency (TSE) and the relative efficiency of a DMU is defined as the ratio of its total weighted output to its total weighted input. The question is how to select the weights if no standard unit of measure can be assigned to the inputs and outputs? Here lies the seed of DEA procedure. DEA permits each DMU to select any desirable weight for each input and output, provided that they satisfy certain reasonable conditions: first those weights can not be negative, and second that the weights must be universal, which means that the resulting ratio should not exceed 1.

The Technical and Scale Efficiency (TSE) with constant return to scale is computed according to the CCR model [6]. Consider n DMUs, where each DMU j ($j = 1,\ldots,n$) uses m inputs $\vec{X}_j = \left(X_{1j}, X_{2j}, \ldots, X_{mj}\right)^T > 0$ for producing S outputs $\vec{Y}_j = \left(Y_{1j}, Y_{2j}, \ldots, Y_{sj}\right)^T > 0$. The CCR model is: For each unit k we find the best weights $U_r^k \ (r = 1,2,..,S)$ and $V_i^k \ (i = 1,2,..,m)$ that maximize the ratio between the weighted output and weighted input:

$$
\begin{aligned}
& h_k = Max \sum_{r=1}^{s} U_r^k Y_{rk} \\
& s.t \\
& \sum_{i=1}^{m} V_i^k X_{ik} = 1 \\
& \sum_{r=1}^{s} U_r^k Y_{rj} - \sum_{i=1}^{m} V_i^k X_{ij} \le 0 \quad j = 1,\ldots, n \\
& U_r^k \ge 0 \quad r = 1,2,.., s \\
& V_i^k \ge 0 \quad i = 1,2,.., m
\end{aligned}
\tag{1}
$$

The weights are all positive and the ratios are bounded by 1 (100%). Each unit k is assigned the highest possible efficiency score by choosing the most optimal weights. If a unit reaches the maximum possible value of 100% it is efficient, otherwise it is inefficient.

Obviously, the values of the weights would differ from unit to unit, and they sometimes have great variability. Therefore, we cannot perform a full rank of all the units based on the DEA scores.

2.2. Ranking Methods

There are different methods for ranking units in the DEA context (see [1]). Ranking is a well established approach in social science (see [21]), historically much more established than the dichotomic classification of DEA for efficient and inefficient organizational units [21]. Also, economics applied the classical measurement of efficiency which rank-scales economic units. Rank scaling in the DEA context has become well established in the last decade. Sexton [11] was the first to introduce full rank scaling of organizational units in the DEA context, by utilizing the Cross-Efficiency Matrix. Anderson and Peterson [3] developed the super efficiency approach for rank-scaling that was followed by other researchers. The ranking in relation to rank-scaling has the advantage that it can be tested statistically by a nonparametric analysis (see, e.g., [8, 9, 16]).

2.2.1. The Super Efficiency Method (SE)

Anderson and Peterson (A&P) (1993) view the DEA score for the inefficient units as their rank scale. In order to rank scale the efficient units, they suggest allowing the efficient units to receive a score greater than 1 by dropping the constraint that bounds the score of the evaluated unit k; namely the primal problem of A&P of unit k will be formulated as follows:

$$h_k = \text{Max} \sum_{r=1}^{s} U_r^k Y_{rk}$$

s.t.

$$\sum_{r=1}^{s} U_r^k Y_{rj} - \sum_{i=1}^{m} V_i^k X_{ij} \le 0 \quad \text{for } j = 1,2,..,n,\ j \ne k \tag{2}$$

$$\sum_{i=1}^{m} V_i^k X_{ik} = 1$$

$$U_r^k \ge \varepsilon > 0 \qquad r = 1,2,..,s$$

$$V_i^k \ge \varepsilon > 0 \qquad i = 1,2,...,m$$

where $\varepsilon > 0$ is a non-Archimedean infinitesimal.

2.2.2. The Cross Efficiency Method (CE)

The Cross Efficiency (CE) rating was first introduced by Sexton et al. [11]. The results of all the CCR ratios can be summarized in matrix which is called the Cross Efficiency Matrix. Its elements are:

$$h_{kj} = \frac{\sum_{r=1}^{s} U_r^k Y_{rj}}{\sum_{i=}^{m} V_i^k X_{ij}} \qquad k = 1,2,...,n \quad j = 1,2,..,n \tag{3}$$

Thus, h_{kj} represents the ratio given to unit j in the CCR run of unit k. This score evaluates the efficiency of unit j by the optimal weights of unit k. The elements on the diagonal h_{kk} are the CCR efficiency score. Let us define $\bar{h}_k = \frac{\sum_{j=1}^{n} h_{kj}}{n}$ as the average cross- efficiency score given to unit k. The maximum value of $\bar{h}_k$ is 1, which occurs if unit k is efficient in all the runs i.e. all the units evaluate unit k as efficient. In order to rank the units, we can assign the unit with the highest score a rank of one and the unit with the lowest score a rank of n. For more details see [8].

3. The Case Study

The Israeli public defense authority is a governmentally funded body whose purpose is to provide in-court representation and legal assistance in judicial procedures to detainees and defendants, who are entitled to such assistance according to criterions as stated in law, including financial incapability. The process of developing the law responsible for the public defense authority inauguration started in 1993, when it was stated that the newly erected body should provide considerable and fair legal assistance to all suspects, detainees, defendants and convicts who are entitled to this in judicial procedures. The public defense authority is split to 5 counties according to their geographic spread. The counties (regarded further on as DMUs) are: Tel-Aviv and the Center, Jerusalem, Beer-Sheva and the South, Haifa, as well as Nazareth and the North.

3.1. Output and Input Measures

In order to utilize the DEA methodology, one has to establish on a preliminary stage the kind of inputs and outputs that the units would be judged according to. Belton and Vickers [4] mention that deciding on the inputs and outputs for each DMU may eventually become a problem by itself. There is sometimes difficulty in correctly deciding and even discriminating between an input and an output; as an example let us consider for a moment relative efficiency of academic units, in which case one of the basic parameters may be academic hours; such a parameter may be regarded to both as input and output. Anyway, defining the problem is not a scientific issue, and depends merely on the experience and concepts of the personnel involved. The question of singling out inputs and outputs may become especially acute in the case of not-for-profit organizations, as the two phenomena may be easily confused. Variable accepted as input in a particular research may be recognized as output in another study, e.g. Ahn et al. [2] defined the number of students in every academic department as output, while Bessent et al. [5] dealt with the very same variable as input.

The issue of efficiency assessment of the public defense authority has never been explored in literature; neither there was a source for us to rely upon. In order to define inputs and outputs for our specific study, we consulted ourselves with experts as well as chose measurable variables with available statistical data. The chosen variables are as listed below:

Outputs. Y_1 – the number of closed files, Y_2 – the number of treated files.

Inputs. X_1 – the number of external lawyers, X_2 – the number of internal lawyers, X_3 – the number of opened files.

The division in the inputs section into internal and external lawyers came up due to the self-explanatory assumption stating that the efficiency of the public defense might be significantly influenced by external employees, bringing us to the decision to adopt the appropriate approach regarding the two groups of lawyers in the public defense authority. The research was carried out for all applicable counties in 2001–2004 while each year was further sub-divided into 4 quarters. The numerical data for the inputs and outputs is presented in Table 1:

Table 1. The numerical data

Year	Quarter	County	DMU	INPUTS			OUTPUTS	
				X_1	X_2	X_3	Y_1	Y_2
2001	1	Tel-Aviv	1	224	26	5522	1356	1795
		Jerusalem	2	90	18	2129	752	1687
		South	3	97	20	2792	800	2151
		Haifa	4	97	19	1358	517	986
		North	5	90	10	2132	770	1987
	2	Tel-Aviv	6	186	20	5136	1370	4571
		Jerusalem	7	82	18	2148	777	1593
		South	8	93	20	3040	881	2680
		Haifa	9	90	19	1631	607	1400
		North	10	67	10	1810	660	1211
	3	Tel-Aviv	11	173	22	3902	660	3251
		Jerusalem	12	75	18	1722	614	1037
		South	13	91	21	2346	714	2025
		Haifa	14	89	17	1295	489	896
		North	15	73	10	1524	572	1239
	4	Tel-Aviv	16	232	23	5116	1400	4791
		Jerusalem	17	92	18	1912	677	1601
		South	18	98	23	2566	800	2079
		Haifa	19	86	19	1374	501	837
		North	20	66	10	1267	455	723

Year	Quarter	County	DMU	INPUTS			OUTPUTS	
				X_1	X_2	X_3	Y_1	Y_2
2002	1	Tel-Aviv	21	179	22	5478	1615	3975
		Jerusalem	22	84	18	2004	716	1692
		South	23	93	21	2360	759	1422
		Haifa	24	70	15	1394	508	987
		North	25	71	10	1507	533	965
	2	Tel-Aviv	26	175	22	5223	1534	3427
		Jerusalem	27	85	17	1968	667	1659
		South	28	92	20	2328	727	1422
		Haifa	29	45	10	1091	392	895
		North	30	59	11	1279	466	911
	3	Tel-Aviv	31	165	20	4544	1372	3971
		Jerusalem	32	83	20	2116	720	1953
		South	33	95	21	2355	745	1803
		Haifa	34	45	10	996	353	766
		North	35	60	11	1300	457	957
	4	Tel-Aviv	36	60	13	1300	457	979
		Jerusalem	37	97	19	2398	755	2001
		South	38	92	20	2540	863	2040
		Haifa	39	82	16	1729	616	1660
		North	40	60	9	1287	452	1009
2003	1	Tel-Aviv	41	216	24	6064	548	5493
		Jerusalem	42	88	17	2228	269	1850
		South	43	101	20	2635	317	2200
		Haifa	44	86	10	2095	468	1891
		North	45	72	7	1528	207	1006
	2	Tel-Aviv	46	183	22	5490	604	4957
		Jerusalem	47	86	18	2017	202	1800
		South	48	95	21	2566	265	2004
		Haifa	49	89	17	1995	433	1705
		North	50	63	13	1336	157	1010
	3	Tel-Aviv	51	169	19	4974	776	4000
		Jerusalem	52	82	19	2045	338	1401
		South	53	94	19	2256	335	1866
		Haifa	54	84	18	1899	454	1503
		North	55	58	9	1262	134	1003
	4	Tel-Aviv	56	220	25	6213	685	5739
		Jerusalem	57	84	19	2154	240	1793
		South	58	98	21	2698	441	2051
		Haifa	59	90	19	1960	417	1203
		North	60	49	9	1205	182	809
2004	1	Tel-Aviv	61	181	21	6682	2027	4293
		Jerusalem	62	87	16	2495	853	1221
		South	63	94	22	2851	1009	1815
		Haifa	64	60	18	2355	831	1319
		North	65	85	10	1721	661	1001
	2	Tel-Aviv	66	169	21	5811	2113	4393
		Jerusalem	67	85	17	2269	943	1792
		South	68	98	24	2681	375	951
		Haifa	69	69	15	2237	568	1292
		North	70	90	10	1540	368	1667
	3	Tel-Aviv	71	149	21	5396	1493	3153
		Jerusalem	72	71	17	2229	737	1235
		South	73	93	21	2492	682	1600
		Haifa	74	60	14	2174	680	1570
		North	75	69	10	1551	440	1000
	4	Tel-Aviv	76	172	20	6886	1652	4179
		Jerusalem	77	84	18	2570	644	1015
		South	78	93	21	2961	500	1013
		Haifa	79	67	14	2169	399	997
		North	80	56	9	1502	533	999

4. Results

We ran the DEA on all the 80 units, 7 units came out efficient in the CCR model. The DEA classifies the units into two groups; efficient and inefficient. In order to obtain a full ranking of the units we ran the Super Efficiency and the Cross Efficiency ranking methods, that ranked all the units from 1 (the most efficient DMU) to 80 (the most inefficient one).

Table 2 includes the scores and the ranking of all the units for all the ranking methods. The correlations between the ranking methods are 85.53%. The correlations are significantly (with p-value less then 0.01) correlated**.**

Table 2. The efficiency score and the ranking of the DMUs

Year	Quarter	County	DMU	DEA	Super Efficiency		Cross Efficiency	
					Score	Rank	Score	Rank
2001	1	Tel-Aviv	1	0.5717	0.5717	77	0.4792	78
		Jerusalem	2	0.8738	0.8738	33	0.8092	21
		South	3	0.8399	0.8399	45	0.7779	30
		Haifa	4	0.8187	0.8187	54	0.6459	60
		North	5	1	1.0843	3	0.9746	1
	2	Tel-Aviv	6	1	1.0250	5	0.8892	5
		Jerusalem	7	0.8772	0.8772	29	0.8068	23
		South	8	1	1.0199	6	0.8822	6
		Haifa	9	0.8828	0.8828	27	0.7673	33
		North	10	0.9282	0.9282	19	0.8244	16
	3	Tel-Aviv	11	0.8441	0.8441	43	0.7891	28
		Jerusalem	12	0.8119	0.8119	55	0.6752	52
		South	13	0.8724	0.8724	34	0.8019	25
		Haifa	14	0.8242	0.8242	50	0.6430	61
		North	15	0.9427	0.9427	14	0.8534	10
	4	Tel-Aviv	16	0.9608	0.9608	9	0.8654	8
		Jerusalem	17	0.8742	0.8742	31	0.7962	27
		South	18	0.8282	0.8282	49	0.7832	29
		Haifa	19	0.7887	0.7887	61	0.6014	66
		North	20	0.8413	0.8413	44	0.6689	56
2002	1	Tel-Aviv	21	0.8810	0.8810	28	0.8323	14
		Jerusalem	22	0.8949	0.8949	23	0.8345	13
		South	23	0.7503	0.7503	66	0.6734	54
		Haifa	24	0.8385	0.8385	47	0.7131	47
		North	25	0.8599	0.8599	38	0.7363	43
	2	Tel-Aviv	26	0.7991	0.7991	57	0.7766	31
		Jerusalem	27	0.8684	0.8684	35	0.8144	19
		South	28	0.7397	0.7397	67	0.6726	55
		Haifa	29	0.9112	0.9112	22	0.8236	17
		North	30	0.8676	0.8676	36	0.7598	36
	3	Tel-Aviv	31	0.9839	0.9839	8	0.9082	4
		Jerusalem	32	0.9325	0.9325	18	0.8628	9
		South	33	0.7944	0.7944	59	0.7544	38
		Haifa	34	0.8741	0.8741	32	0.7627	34
		North	35	0.8593	0.8593	39	0.7623	35
	4	Tel-Aviv	36	0.8528	0.8528	40	0.7484	40
		Jerusalem	37	0.8517	0.8517	41	0.8078	22
		South	38	0.8742	0.8742	30	0.8362	12
		Haifa	39	0.9500	0.9500	11	0.8669	7
		North	40	0.8916	0.8916	25	0.8099	20
2003	1	Tel-Aviv	41	0.9155	0.9155	21	0.6932	49
		Jerusalem	42	0.8203	0.8203	52	0.6049	65
		South	43	0.8206	0.8206	51	0.6123	64
		Haifa	44	0.9494	0.9494	12	0.8031	24
		North	45	0.6866	0.6866	73	0.5372	74
	2	Tel-Aviv	46	0.9564	0.9564	10	0.7249	45
		Jerusalem	47	0.8449	0.8449	42	0.5906	67
		South	48	0.7670	0.7670	64	0.5595	69
		Haifa	49	0.8290	0.8290	48	0.6905	50
		North	50	0.7141	0.7141	69	0.5117	76
	3	Tel-Aviv	51	0.8888	0.8888	26	0.7151	46
		Jerusalem	52	0.6720	0.6720	74	0.5483	71
		South	53	0.7954	0.7954	58	0.6146	63
		Haifa	54	0.7664	0.7664	65	0.6665	57
		North	55	0.7774	0.7774	62	0.5537	70
	4	Tel-Aviv	56	0.9369	0.9369	17	0.7275	44
		Jerusalem	57	0.8075	0.8075	56	0.5818	68
		South	58	0.7695	0.7695	63	0.6205	62
		Haifa	59	0.5913	0.5913	76	0.5381	73
		North	60	0.6887	0.6887	72	0.5449	72

Year	Quarter	County	DMU	DEA	Super Efficiency		Cross Efficiency	
					Score	Rank	Score	Rank
2004	1	Tel-Aviv	61	0.9389	0.9389	15	0.8383	11
		Jerusalem	62	0.8398	0.8398	46	0.6831	51
		South	63	0.8604	0.8604	37	0.7707	32
		Haifa	64	1	1.0003	7	0.7574	37
		North	65	0.9436	0.9436	13	0.7411	42
	2	Tel-Aviv	66	1	1.1429	1	0.9673	2
		Jerusalem	67	1	1.0410	4	0.9121	3
		South	68	0.3681	0.3681	80	0.3489	80
		Haifa	69	0.6920	0.6920	70	0.6470	59
		North	70	1	1.0854	2	0.8154	18
	3	Tel-Aviv	71	0.7903	0.7903	60	0.7439	41
		Jerusalem	72	0.8192	0.8192	53	0.7013	48
		South	73	0.6909	0.6909	71	0.6585	58
		Haifa	74	0.9389	0.9389	16	0.8272	15
		North	75	0.7295	0.7295	68	0.6744	53
	4	Tel-Aviv	76	0.9168	0.9168	20	0.7510	39
		Jerusalem	77	0.6183	0.6183	75	0.5217	75
		South	78	0.4222	0.4222	79	0.3994	79
		Haifa	79	0.5419	0.5419	78	0.4974	77
		North	80	0.8921	0.8921	24	0.8010	26

5. Summary and Conclusions

The following main conclusions can be drawn from the study:

In this paper, we have applied the DEA methodology (CCR model) and 2 ranking methods for ranking the Israeli public defense authority by efficiency. For the inefficient units, the DEA methodology recommends improvements needed in each input (reduce) and each output (increase) so that the unit will improve its efficiency. This property provides significant tools for managers and consultants and can be derived from any DEA supporting software (such as EMS). The rankings arrived at using the different models differ from each other in spite of the high correlation among some of the ranking models we used. The reason is that each ranking model has its own objective function, which is different from the others. In order to select the most appropriate model, the user (decision-maker) has to set the criterion (objective function) that is most suitable for his/her purpose (or to his/her opinion), and then decide on the model to be used. Note that there is a high correlation between the ranking methods.

In this article we investigated the efficiency and the ranking of the public defense authority based on quantitative parameters (inputs and outputs), which specific values were determined by experts in legal affairs. We suggest future research that will combine both quantitative and qualitative parameters, such as percentage of success at the court trial, division of the files into categories according to the nature of the offense committed, like severe crime, moderate and minor offenses, etc., as output parameters, to be used in the methodology presented in this paper.

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MODELLING OF FREIGHT FLOWS IN THE REGIONAL TRADE NETWORK

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The synthesis of regional road transport freight system's topological structure enables the assessment of impact exercised by various structural characteristics on the functioning of system. For this reason increases the quality of project solutions in the stage of system structural synthesis.

Models of optimisation and simulation (included into the simulation procedure of optimisation of topological structure) have other possibilities as well. For instance, simulation model enables the solution of such various objectives of functional analysis of systems as, for example, the efficiency comparison analysis of stability of structure undergoing the changes of meanings of system's parameters, the analysis of managing impacts of various types, loading technologies, etc.

Keywords: *road transport freight, the simulation procedure of optimising*

1. Introduction

Among other things, the technology of transportation involves the provision of services, i.e. freight haulage. Services embrace major operations (transportation or haulage) and minor procedures (loading, unloading, storage, control, documentation, etc.). The efficiency of technological operations may be defined in terms of the following factors: consumption of energy and materials per ton/km, and quality and intensity of hauls. Moreover, technological operations of haulage should ensure safety of goods and be environmentally friendly.

To improve the technology of transportation may seem as simple as to replace old transport facilities by the new ones. However, even the most advanced transport facilities may be not efficiently used. Therefore, overall technological process of transportation should be improved. To achieve this, numerous tests should be conducted, involving the determination of flows of goods, their constant control and forecasting, road network and traffic optimisation, etc. The problems of improving freight transportation in long hauls and carriage of 20–40 tons of goods were analysed in [1–4]. However, the analysis of carriage of goods of 50–1500 kg over small areas by transport facilities, say in the city, with the bottlenecks on the roads and ecological limitations in force, has not been practically made. In the present investigation, some solutions to the above problems are offered.

2. Synthesis of the Topological Structure of Road Freight Transport Regional System

In designing a logistics centre of transport distribution, the topological structure of the area which is serviced by this centre should be worked out. In the above structure, a number of the local warehouses, their capacity and location in the zone as well as the settlements (or the particular urban areas) which will be serviced by the particular warehouses, for instance, by those belonging to a commercial enterprise "MAXIMA", should be provided for.

For example, the network of the settlement (town) roads for freight transportation is expressed by the matrix $D = \| d_{ii'} \|$, where $d_{ii'}$ are the shortest routes in the road network between the i-th and the i'-th points; $d_{ii'} = d_{i'i}$. The amount of goods to be carried in the particular region serviced by the particular company is also determined by the matrix $A^K = \| a_{ii'} \|$, where $a_{ii'}$ is the flow of goods from point i to point i'. The purpose of the topological synthesis of freight road transport system embracing a set of commercial enterprises in the region E^n, the route between the points D and the flow of goods A^k, is to divide the settlements of a region into zones serviced by the warehouses $E_j \left(\bigcup_j E_j = E^n, \;\; E_j \bigcap E_{j'} = \emptyset \right)$

and to determine the location of warehouses within zones E_t, minimizing the costs of goods transportation in the region. This is expressed in the following way:

$$\sum_{j\in J}\sum_{i\in I}\sum_{i'\in I} c_1 d_{ii'} x_{ij} x_{i'j'} + \sum_{j\in J}\sum_{j'\in J}\sum_{k\in I}\sum_{k'\in I} c_2 d_{kk'} y_{kj} y_{k'j'} + \sum_{i\in I}\sum_{i'\in I} a_{ii'} x_{ij} x_{i'j'} + \\ + \sum_{j\in J}\sum_{j'\in J}\sum_{k\in I}\sum_{k'\in I_j} c_1 d_{kk'} y_{k'j} + \sum_{i\in I_j}\sum_{i'\in I_j} a_{ii'} x_{ij} x_{i'j'}, \quad (1)$$

here, $x_{ij} = 1$ if the point i enters zone j of the warehouse; in the opposite case $x_{ij} = 0$; $y_{ij} = 1$, if the warehouse is located at the point i; for the opposite case – $y_{ij} = 0$; c_1 – cost of goods transportation by low or medium functional capacity vehicles; c_2 – cost of transportation by high functional capacity lorries and trailers; J – a set of warehouse indices; I_j – a set of indices of settlements in the j-th warehouse zone; N – a set of indices of the region settlements where warehouses may be located.

The first term in the formula (1) expresses the cost of goods transportation within a zone, while the 2nd term denotes the cost of goods transportation from one warehouse to another and the 3rd – the cost of goods carriage to and from the warehouse.

The synthesis of the topological structure of freight road transport regional system is performed by solving two problems:

a) the distribution of a set of points supplying and receiving goods according to zones serviced by the particular warehouses, minimizing the total freight flows disbalance between the warehouses;

b) determining the location of the warehouse within a zone, minimizing the total volume of work of delivering goods to a warehouse and taking them out of it. The total disbalance of cross – hauls will be the optimisation criterion of the problem a, because this is the main cause why the functional capacity of vehicles and the hauls are not used to full advantage.

Let $P_i = \left\{E_{i/j} = \overline{1, 2^n}\right\}$ be a family of all E_j subsets of a region set of points $E^P = \{1, 2, ..., i, ..., n\}$. Here, n is the number of points in the region. In order to explain the k-th expansion of the set E^P, let us introduce the set J_k which is such a set with the index E_j that $\bigcup_{j\in J_k} = E^P$, $E_j \bigcap E_{j'} = \emptyset$, V_j, $j' \in J_K$. Then, the k-th expansion of the set E^P is such a subfamily $P_k(P_k \subset R)$ that $P_k = \{E_j / j \in J_k\}$, where J_k means a subset E_j of the expansion. The disbalance of cross – flows of goods of the warehouse of the zone serviced by the warehouse j will be as follows:

$$\alpha_j = \left| \sum_{i\in E_j}\sum_{i'=E_j} (a_{ii'} - a_{i'i}) \right|, \quad (2)$$

here, $a_{ii'}$ is the flow of goods from point i to point i'.

The total disbalance among the warehouses in the system for the k-th expansion is determined in the following way:

$$z = \sum_{j\in J} \alpha_j x_j, \quad (3)$$

here, $x = \begin{cases} 1, \text{if } j \in J_k, \\ 0, \text{if } j \notin J_k, \end{cases}$, where J is a set of indices of the subset E_j, the potential zones serviced by warehouses.

In formalizing the problem of the system's structure synthesis, the requirements to structural and functional KKTRS parameters are stated by the constraints of two types: 1) the constants of structural parameters of the system are commonly expressed by the analytical expression; 2) algorithmic expression

is mostly used for functional parameters requirements (the sophisticated relationships of these parameters can not be expressed analytically).

The following analytically expressed constraints can be suggested.

The requirements that the subsets do not cross each other and cover the whole sets of the region points:

$$\sum_{j\in J} t_{ij} x_j = 1, \quad i \in E^P, \tag{4}$$

here, $t_{ij} = \begin{cases} 1, \text{if } i \in E_j, \\ 0, \text{if } i \notin E_j. \end{cases}$

The number of the region warehouses serviced is:

$$Q^t_{\min} \le \sum_{j\in J} x_j \le Q^t_{\max}, \tag{5}$$

here, $Q^t_{\min}$, $Q^t_{\max}$ – permissible and maximum numbers of warehouse zones in the system for the warehouse number in each zone:

$$\sum_{i\in E^P} b_i t_{ij} \ge 1, \quad j \in J, \tag{6}$$

here, $b_i = \begin{cases} 1, \text{if a warehouse may be set up in point } i, \\ 0 \text{ - for the opposite case;} \end{cases}$

$$G^l_{\min} \le \sum_{i\in E^P} t_{ij} \le G^l_{\max}, \quad j \in J, \tag{7}$$

here, $G^l_{\min}$, $G^l_{\max}$ – permissible minimum and maximum numbers of points in a warehouse zone:

$$d_{ii'} t_{ij} t_{i'j} \le L^l, \ \forall i, i' \in E^P, \ j \in J, \tag{8}$$

for the length of the route between warehouse j and the points of its zone:

$$d_{ii'} \le L^l_T, \quad \forall i' : b_{i'j} = 1, \quad j \in J, \quad i \in E^P, \tag{9}$$

here, L^l_T is the permissible length of route between the warehouse j and the points of its zone; the total volume of goods in a flow handled in warehouse j:

$$\sum_{i\in E^P} \sum_{i\in E^P} \left(a_{ii'} + a_{i'i}\right) t_{ij} \left(1 - t_{ij}\right) \le \hat{P}_j, \quad j \in J, \tag{10}$$

where $\hat{P}_j$ is the capacity of the terminal j allowing to handle goods in the period of time τ_m.

Algorithmic restrictions identified for

– the coefficient of carrying capacity

$$k_k\left(P_k,\ N_A,\ A^g,\ D,\ N_j^{prm}\right) > k_k^n, \tag{11}$$

– the coefficient of run exploitation

$$k_r\left(P_k,\ N_A,\ A^g,\ D,\ N_j^{prm}\right) \ge k_r^n; \tag{12}$$

– for the term of goods delivery

$$T_m\left(P_k,\ N_A,\ A^g,\ D,\ N_j^{prm}\right)\le T^n; \tag{13}$$

– the time of goods' stay in the warehouse

$$\tau_{mj}\left(P_k,\ N_A,\ A^g,\ D,\ N_j^{prm}\right)\le \tau^n,\ \ \forall m\in M; \tag{14}$$

– average technical speed of road vehicles

$$V_{\text{tech.}}\left(P_k,\ N_A,\ A^g,\ D,\ N_j^{prm}\right)\le V_{\max}^n, \tag{15}$$

here K_k and K_k^n real and normative coefficients of carrying capacity; K_r and K_r^n real and normative coefficients of run exploitation; T_m and T_m^n real and normative terms of delivery of goods; M – set of indices of goods consignments; $V_{\text{tech.}}$ and $V_{\text{tech.}}^n$ real and normative average technical speed of road vehicles; τ_{mj} – real time of the consignment m goods stay in the j warehouse; τ^n normative time of stay of goods in the warehouse; N_A – set of vehicles' characteristics (number of vehicles, their owner dependence, etc.); A^g – the matrix of freight flows of the region, $A^g=\left\| a_{i'}\right\|$; D – the matrix of distances between the points in the region, $D=\left\| d_{ii'}\right\|$; N_j^{prm} – the number of handling places in the warehouse j.

Thus the problem a – the distribution of points of the regional set into the servicing zones of the warehouses – is solved by the minimisation of the final function (3), when there are constraints (4)–(15). For the formalisation of the problem b the term *overall freight operation* is introduced for the incoming and outgoing goods into the zone of the warehouse j established in the point i. It is defined as follows:

$$\beta_{ij}=\sum_{i^*\in E^p}\sum_{i'\in E^p}\left(a_{i^*i'}+a_{i'i^*}\right)d_{ii'}t_{i'j}\left(1-t_{i^*j}\right),\quad j\in J_k,\ \ i:b_i=1. \tag{16}$$

The problem b is formulated as follows:

$$\sum_{j\in J_k}\sum_{i\in E_j}\beta_{ij}y_{ij}\to\min,$$

$$y_{ij}=\begin{cases}1, & \text{if the warehouse } j \text{ is established in the point } i;\\ 0 & \text{for the opposite case;}\end{cases}$$

when there are constraints of:

– the number of warehouses in each zone

$$\sum_{i:b_i=1}y_{ij}=1,\ \ j\in J_k; \tag{17}$$

– permissible rout distance between the warehouses in the region

$$L_{\min}\le d_{ii'}y_{ij}y_{i'j'}\le L_{\max},\ \ i\in E_j,\ \ i'\in E_{j'},\ \ j,\ \ j'\in J_k. \tag{18}$$

As mentioned before, the model of the synthesis of the topological structure (3)–(15), besides the constraints (4)–(10), (17)–(18), which are the analytical functions of the structural elements of the system, comprises also the constraints (11)–(15), which are complex functions of structural and functional characteristics and are defined in the algorithmic form. These constraints indicate essential dynamic aspects of the projected systems and its elements functioning and they can be defined by the way of simulation modelling of discrete developments.

Thus the model of the analysed structure synthesis will be as follows:

$$F\left(\overline{X}\right) \to \text{extr}\,,\ \overline{X} \in \sigma\,,$$

here $\sigma = \overline{\sigma} \bigcap \overline{\overline{\sigma}}$, $\overline{\sigma}$, $\overline{\overline{\sigma}}$ the set of structure variants allowed according to the analytical and algorithmic constraints.

There was developed the optimising simulation procedure enabling the use of optimisation and simulation models jointly for the search of analytical variants of the structure.

Below certain data of modelling results are presented.

The results obtained by the way of modelling are presented in Table 1 and Table 2 and on the Figure 1a, b, c, and d.

Table 1. Distribution laws of stochastic variable meanings

Stochastic variable	**Distribution law**	**Parameters of distribution law**			
		Average	**Least meaning**	**Highest meaning**	**Standard digression**
Type of goods	Uniform	2.5	1.0	4.0	–
Size of goods' consignment	Puasson's	7.0	1.0	25.0	–
Time of delivery of goods' consignment	Puasson's	12.0	0	24.0	–
Duration of vehicle handling	Normal	1.0	0.8	1.15	0.15
Vehicle traffic speed	Normal	50.0	45.0	55.0	5.0
Number of goods' consignment delivered to the warehouse No 1	Puasson's	80.0	40.0	200.0	–
Number of goods' consignment delivered to the warehouse No 2	Puasson's	60.0	30.0	140.0	–
Number of goods' consignment delivered to the warehouse No 3	Puasson's	60.0	30.0	140.0	–
Number of goods' consignment delivered to the warehouse No 4	Puasson's	130.0	90.0	350.0	–

Table 2. RESULTS obtained by modelling

Variables	**Names of locations of warehouses**			
	Vilnius	**Kaunas**	**Klaipėda**	**Šiauliai**
Quantity of consigned goods, thousand t	62.4	40.0	52.7	56.2
Quantity of outgoing goods, thousand t	58.7	38.1	56.1	58.8
Amount of loaded vehicles	694	557	460	640
Amount of consigned vehicles without goods	71	118	120	54
Amount of unloaded vehicles	563	441	487	564
Average loading coefficient	0.64	0.54	0.72	0.65
Average time of goods stay in warehouse, h	64.2	45.8	44.8	109.2
Average time of vehicle queuing, h	0	0	0.53	0.09
Average number of queuing vehicles	0	0	0.42	0.04
Maximum number of queuing vehicles	0	0	3.0	1.0

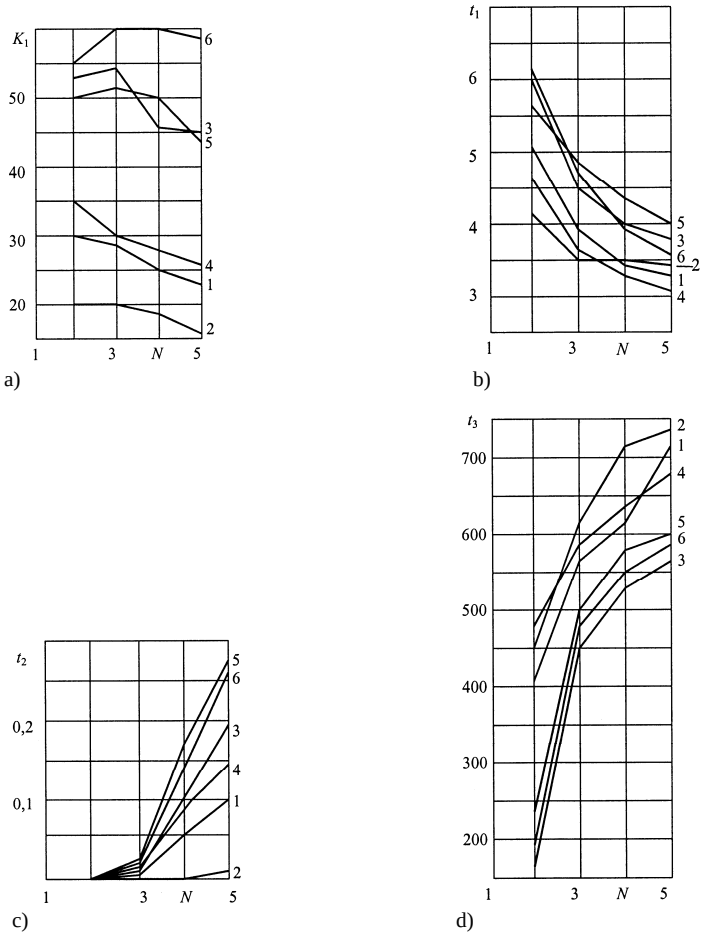

Figure 1. Results obtained by modelling

These data enable to gauge the impact of different structural characteristics of the system on its functioning, thus improving the quality of the project solutions in the stage of the synthesis of the system's structure.

The size of goods' consignment is a random quantity distributed according to the law with mathematic probability of 0.5 t and with a standard digression of 0.1 t. Average speed of the vehicle is a normal random quantity with the mathematic probability of 50 km/h and with a standard digression of 1.7 km/h.

The formulated problem model concerning the distribution of freight flows in the transport terminal to the consumers enables gauging the vehicle's possibilities (dimensions, carrying capacity), limitations of delivery time, and the time resources of vehicle and general costs.

3. The Simulation Procedure of Optimising the Topological Structure of Freight Road Transport Regional System (KKTRS)

In general, the simulation procedure of optimising KKTRS topological structure consists of the following major steps:

1) generation of the particular variant of the structure;
2) checking the compliance of the variant with the stated analytical constraints;
3) computer – aided experiment with the simulation model of the structural variant with permissible analytical constraints.

The optimisation algorithm of the simulation procedure consists of two optimisation models.

A special algorithm generates the initial family of the subset $R_D = \{E_j / E_i ,\ j \in J\}$ and selects all $E_j \in R$. Then, the algorithm is implemented in the following blocks:

The 1st block – the initiation of the simulation procedure of optimisation. Let $S_j = \{i / l_{ij} = 1\}$ be a set of the separate elements of the *j*-th column indices of T matrix; $R_i = \{j / t_{ij} = 1\}$ be a set of the separate elements of the *i*-th row of T matrix; $W = \left\{ j \middle/ x_j = 1,\ v_j : t_{ij} = 1 \to \sum_{j \in w} t_{ij} = 1 \right\}$ – a set of the indices of variables of a partial solution; $S_w + \left\{ i \middle/ \sum_{j=w} t_{ij} = 1 \right\} = \bigcup_{j \in w} S_j$ – a lot point; $V = Q - S_w$; $X_m = \{S_j / x_j = 1\}$ – a set of points of solution of problem *a* (the *m*-th variant of the division of the points serviced by a warehouse into zones); $V = Q - S_w$; $Y_m = \{i / y_{ij} = 1\}$ – optimal solution of the problem *b* of the variant X_m expansion; $\overline{X}_m = \{ X_m Y_m \}$ – the *m*-th variant of the system topological structure; $x = \{ \overline{X}_m \}$ – a family of the obtained variants of the topological structure; H – the current value of the efficiency function maximum; $F(w) = \sum_{j \in w} a_j$ – the current value of partial solution of the efficiency function; $F(X_m)$ – the value of the complete solution of the efficiency function. First, $W = S_w = \varnothing$, $v = Q$, $X = \varnothing$ are determined. Then, the 2nd block is handled.

The 2nd block. Generation of the family R_D. The matrix $T = \| l_{ij} \|$ is generated, with every *j*-th column corresponding to the set $E_j \in E$ and being *n* the componential cortege $< l_{ij}, \ldots, l_{nj} >$ above the set $\{0,1\}$.

Then all lexicographically arranged *i* componential corteges $\left(i = \overline{1, n}\right)$ satisfying the specified constraints are generated. All the corteges are checked for satisfying the constraints. If so, the value α_j of the cortege is calculated and included into the matrix T. In the opposite case, another cortege is generated. Then, we go on to the 3-d block.

The 3rd block. The matrix B is transformed. The columns S_j are included into the lists L_i. S_j is included into the list L_i then and only then, when $t_{1j} = t_{2j} = \ldots = t_{(i-1)j} = 0$, while $t_{ij} = 1$. S_j of each *j*-th list is transformed according to α_j. Thus *n* lists are formed, while every set S_j is included in only one list and some lists may be blank. Then, we go on to the 4-th block.

The 4th block. It is aimed to make a list L_{i*} and column $S_{j*} \in L_{i*}$. The number of the list is chosen as $i^* = \min\{ i / i \in v \}$. The column S_{j*}, to which $\min\{\alpha_j / j \in L_{i*}\}$ corresponds, is chosen from the list L_{i*}. Then, we may go on to the 5-th block.

The 5th block. A variable to be introduced into the partial solution is determined. In the list L_{i*} α_j, such $S_n \in L_{i*}$ is sought (beginning with S_{j*} in an ascending order) that $S_w \cap S_n = \varnothing$ and $F(w) + \alpha_j \le H$. If such S_n exists, the 7-th block is considered, if not, the 6-th block is handled.

The 6th block. If $w = \varnothing$, we may go on to the 14-th block. If $w \ne \varnothing$ and S_k is the last column in S_w, then *k* is taken out of *W* and S_k out of S_w. As a result, the following changes take place: $F(w): w = w / \{ k \}$, $F(w) = F(w) - \alpha_k$ and $S_w = S_w / \{ i / i \in S_k \}$. Let i^* be an index of the list containing S_k. Then we go on to the 5-th block.

The 7th block. A new variable x_n is introduced into the partial solution $w = w \cup \{ n \}$, $S_w = S_w \cup \{ i / i \in S_n \}$, $F(w) = F(w) + \alpha_n$. If $S_w \ne Q$, we may go on to the 4-th block. If $S_w = Q$, the 8-th block is handled.

The 8th block. A new expansion variant $\{w, S_{\overline{w}}\}$ should be replaced. Then $H = F(w)$, $\overline{X}_m = \{S_j / j \in w\}$, we may go on to the 9-th block.

The 9th block. The optimal arrangement of Y_m variant for the obtained X_m expansion version is determined. In this way, the variant $\overline{X}_m$ of the topological structure KKTRS, permissible within analytical constraints $\overline{X}_m = \sigma$, is formed. Then, we go on to the 10-th block.

The 10th block. The initiation of simulation. Changing of the values of structural parameters of simulation according the structural variant $\overline{X}_m$. Then, we go on to the 11th block.

The 11th block. Simulation. The values k_k, k_r, T_m, τ_{mj} and v_t of the structural variant $\overline{X}_m$ are obtained. Then we go on to the 12-th block.

The 12th block. The variant $\overline{X}_m$ of the structure may be tested as to its correspondence with algorithmically determined constraints. If $\overline{X}_n \in \overline{\overline{\sigma}}$, then we go on to the 13th block. If $\overline{X}_n \notin \overline{\overline{\sigma}}$, we go on to the 4-th block.

The 13th block. The variant of the structure $\overline{X}_m : X = X \bigcup \{\overline{X}_m\}$ permissible according to all constraints is fixed and the maximum $H = F(\overline{X}_m)$ is changed. Then, we go on to the 5-th block.

The 14th block. Printing of the results. If $X = \varnothing$, then the suitable variants of the topological structure KKTRS have not been found. In the opposite case, the variants of the structure are such that $F(\overline{X}_{opt.}) = H$. The work with the algorithm is over.

Optimisation and simulation models used in the procedure may have more applications. For example, the simulation model allows us to solve various problems of functional analysis of the systems, such as the study of the stability of the structure under the condition of varying system parameters, investigation of the effects of the most important factors, the analysis of the efficiency of various loading technologies, etc.

4. Conclusions

1. In big cities (Vilnius, Kaunas, etc.), large chains of stores should constantly study the flows of goods belonging to them as well as the flows of transport facilities delivering these goods to trade outlets and warehouses. Institutions of local government should control it and stimulate their interest in rational solution of these problems.

2. The synthesis of the topological structure of the road freight transport regional system enables evaluation of impact on the functioning of the system, which is exercised by various structural system's characteristics, thus improving the quality of project solutions in the stage of synthesis of the system's structure.

3. Optimisation and simulation models included into the simulation procedure of topological structure's optimisation have other possibilities as well. For example, the simulation model enables solution of different problems related to the analysis of the system's functioning, such as the investigation of system's stability under the changes of its parametric meanings, also the comparative analysis of efficiency of different types of ruling impacts, of carrying, loading, handling technologies, etc.

4. There has been developed the algorithm for the optimal definition by the carrying capacity of the structure of the vehicle fleet, which enables the carrier to find a required average listing number of vehicles according to the carrying capacity.

5. There have been proposed the methods of definition of optimal size of the consignment of goods and selection of transportation type, when the general storage and transportation costs are selected as the optimum criterion.

6. There has been developed the algorithm for the optimisation of the local road network among the trade points. Testing of the algorithm proved that in the case when the density of the distribution of target functions' meanings in the extreme zone is sufficiently large, the independent random search is sufficiently efficient even if compared with regular methods. Firstly, the number of the variants analysed is 200–500. Secondly, many variants close to the global extreme are found out, which in most cases can be interpreted as an indeterminacy zone after later evaluation of incomprehensive initial information. Generally such a zone is found out by the way of multi-critical optimisation with the application of regular methods.

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REVIEW OF CURRENT STATE OF EUROPEAN 3PL MARKET AND IT'S MAIN CHALLENGES

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This article examines basic reasons behind the use of 3PL, i.e. the main drivers of outsourcing (Part 2) as well as explains the essence of 3PL service (Part 3). Part 4 is dedicated to the analysis of current state of 3PL market in Europe. Finally, Part 5 gives an overview of main challenges that European 3PL service providers currently are facing.

Keywords: *3PL service, outsourcing, logistic service providers*

1. Introduction

The practice of outsourcing logistics operations has grown significantly over the past few years. Outsourcing is a strong trend and has been for decades existing in most industries. Companies try to simplify the structure of their organizations and focus on "core business", leaving behind the back everything that does not belong to that central part of their operations. By doing so, the number of companies participating in production and distribution set-ups increases and thus the number of external relationships between the companies grows. Outsourcing opens the door to resources not necessarily available in one's own organisation – world-class services, products, processes and technology – without the need to invest in infrastructure.

2. Concept of 3PL

The term 'third party logistics services' has been used in a number of ways, from describing one single service, e.g. the outsourcing of transport to describing the outsourcing of a set of complex processes. For those firms that provide third party logistic services, however, there are a number of established definitions [1, 2]. From the point of view of the buyer of these services, third party logistics can be seen as a combination of the following elements:

- an external agency provides all or a considerable number of the logistics services;
- the shipper uses a limited number of service providers;
- long-term and close business relations between service provider and customer in place of single business transactions;
- integrated logistics functions;
- both parties try to exploit the synergic benefits the partnership offers.

Originally, 3PL means outsourcing logistics activities including transportation and warehousing to outside firms, which are not a consignor or a consignee. However, it is not common 3PL practice to outsource a single activity of logistics independently, but to outsource multiple activities from the firm's strategic point of view.

3PL (or 3PL provider) has the following features at present:

1. integrated (or multi-modal) logistics service provider;
2. contract-based service provider;
3. consulting service provider.

Firstly, a 3PL provider is regarded as an integrated logistics service provider. IT-related activities for controlling goods flow such as order processing, and inventory management, among others are also included in the function of the 3PL provider. However, the 3PL provider need not provide all the services solely. The 3PL provider can outsource some activities to sub-contractors.

A 3PL provider can be classified into the asset-based and the non-asset-based. The asset-based 3PL provider owns some assets, particularly transport-related assets such as trucks, warehouses, etc., while the non-asset-based 3PL provider does not own such assets, and usually relies on sub-contractors' assets. Examples of non-asset 3PL providers include forwarders, brokers, marketing companies, and information system management companies.

Secondly, the service of 3PL is contract-based. Recently, a contract was written about the way to share responsibilities assuming various situations in detail. Such strict contract would make reliable relationship between the parties, and strengthen the alliance.

Thirdly, offering consulting-services to the firms is an important feature of the 3PL. The 3PL provider can make various advises to answer customers' requirements concerned with marketing strategy, information system configuration, cooperative transportation, etc.

Currently Logistics Service Providers offer a number of services in addition to transportation. These are cross-docking services in terminals, and storage or integrated logistics value-added services in warehouses and distribution centres. Table 1 shows common physical and administrative services provided by LSPs.

Table 1. The type of physical and administrative services provided by Logistics Service Providers

	Basic	**Intermediate**	**Advanced**
Physical services	storage good reception picking according to order and packing (pick & pack) re-packing and labelling return of goods delivery from storage	consolidation & deconsolidation preparation for freezing, thawing, sawing prepare for delivery and pack set building, sequencing, product resorting and labelling cross-docking	assembly of components operate vendor management inventories in stores or stock-keeping facilities recycling with waste handling and reconditioning unpacking and quality control
Adm. services	tendering and contracting other LSP tendering and contracting carriers insurance services stocktaking	payment services order administration and customer service claims handling export clearance and import clearance Track & Trace information forwarding services financial services provide one-stop logistics service purchase	forecasting and inventory management administration of minimum and protective inventories purchase and call-offs delivery planning and management and follow up exception management design of individual logistics setups implementation of logistics setups operation of customers' logistics setup responsible for the customers' logistics operations

3. Reasons Behind the Origin of 3PL

Continually pressured to improve the efficiency and reliability of their transportation and logistics operations without sending their overheads through the roof, shippers are realising the potential economic advantage of outsourcing their logistics activities.

In the early stages of logistics outsourcing, transport and warehousing activities came into focus. The effects of passing over the transport operation to a third party are obvious for those with moderate volumes of goods and widespread distribution areas, regions or countries. The outsourcing tendency has accelerated in recent years and more companies are now contracting their activities to external parties.

The principle reasons why companies use third party services are a need to focus on core activities, to cut costs, and at the same time provide their customers with better standards of service. Outsourcing gives companies the opportunity to concentrate their resources, spread their risks and focus on matters which are vitally important for their survival and future growth [3].

Lower logistics costs and improved services are the commonest reasons for using third party logistic services. When successful, outsourcing logistics activities and operations has meant savings of 10%–30% on costs. Furthermore, going by indicators that measure standards of service, outsourcing has been responsible for improvements in this area. Most savings on costs are normally achieved in those relating to capital tied up in stock and storage/warehousing costs [4].

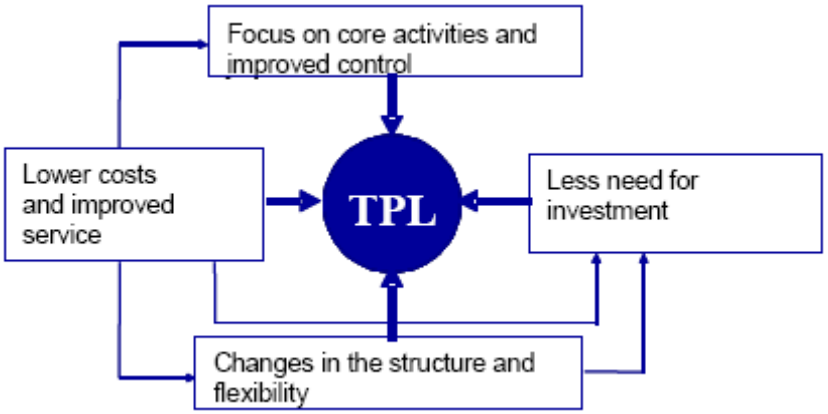

Figure 1. Third party logistics drivers

The basic assumption is that the provider of logistics services can exploit the economies of scale involved in providing the same service to more than one customer. One has grown accustomed to the notion that improved efficiency is a precondition of long-term financial benefit and better standards of service. Better efficiency can, for example, be achieved by improving the expertise of existing staff or by recruiting new skilled personnel.

4. Current State of European 3PL Market[1]

In total, 42% of the enterprises in Europe currently outsource their logistics operations to 3PLs.

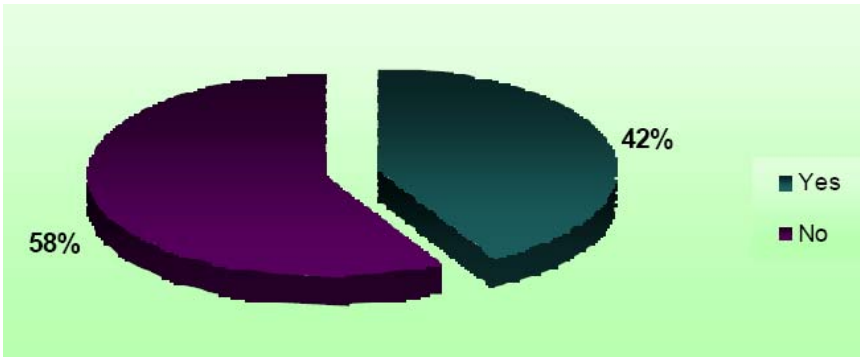

Figure 2. Share of outsourcing logistics operations

Taking into account that an increasing number of shippers are shifting to a non-asset based business model, one would expect that transport would top the list of logistics functions that are outsourced. Almost two thirds of the companies say they are outsourcing their transportation activities. Less than 10% of the respondents outsource their inventory management, while more than a third happily hands over their warehousing operations to 3PLs.

A quarter of the companies outsource their information systems. However, fleet management is only outsourced by 13% of the European enterprises.

Some interesting findings are in respect with the level of satisfaction expressed by the users of 3PL services.

Once the decision has been taken to outsource to a 3PL, satisfaction levels are generally good. A total of 79% of the companies selected ‘good’ (62%), ‘higher than expected’ (13%) or ‘outstanding’ (4%). In comparison, only 21% were somewhat less enthusiastic about the performance of their 3PLs.

[1] Based on the findings of the eyefortransport report „Outsourcing Logistics Europe 2006“

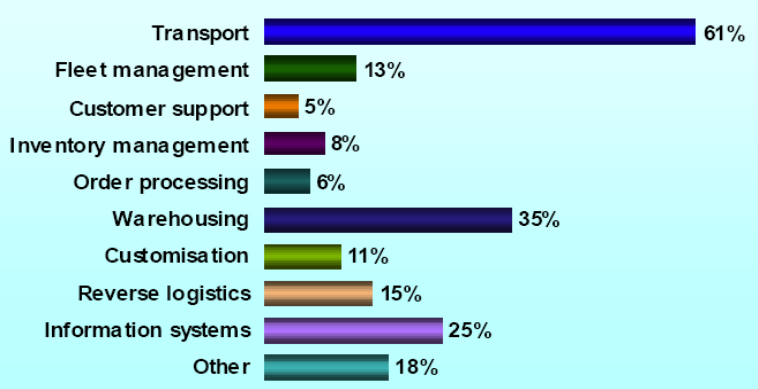

Figure 3. Outsourcing logistics operations

74% of the companies said that outsourcing inventory management and coordination of warehousing and manufacturing answers their logistics issues, which ties in with the 73% who face frequent and dramatic shifts in customer demand.

Just over three quarters of the companies believe that outsourcing logistics activities is the answer when it comes to expanding distribution systems without major capital expenses in labour, assets and technology.

On average, three quarters of the companies said that outsourcing logistics to a 3PL solves the problems caused by suppliers and carriers who fail to coordinate shipments and deliveries, and late shipments that result in the loss of money and customers.

Since the majority of the companies currently using 3PLs are getting 'good' to 'outstanding' service (79%), it is not surprising that they would 'possibly' (52%) or 'very likely' (32%) increase their reliance on 3PLs.

5. Main Challenges to European 3PL Service Providers[2]

Maintaining profits under price pressures from customers is still seen as the biggest challenge to European 3PLs. A total of 79% of 3PL service providers said it was a 'big challenge' or a 'very big challenge'.

Relationship with customers is perceived as a big or very big challenge by 78% of 3PLs. This factor, in combination with the price pressures from customers, points to the considerable sensitivity of 3PLs to the markets they serve.

Globalisation of the 3PL market and delivering services in new geographic regions was rated a big or very big challenge by 68% of 3PL companies.

Consistently delivering the latest cutting edge technology to customers has been considered a big or very big challenge by 59%. Completing the 'top five' challenges as perceived in 2006 was competing with giant global 3PLs, considered a serious challenge by 52%.

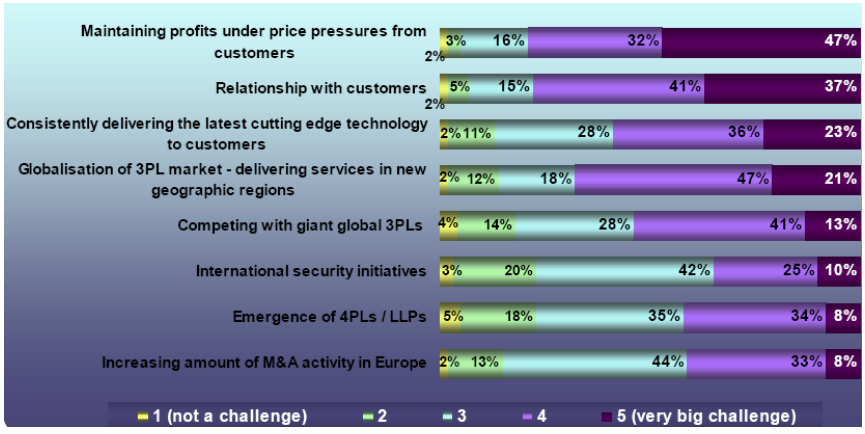

Figure 4. Main challenges for European 3PLs

[2] Based on the findings of the eyefortransport report „The European 3PL Market"

Conclusions

1. The practice of outsourcing logistics operations has grown significantly over the past few years. Continually pressured to improve the efficiency and reliability of their transportation and logistics operations without sending their overheads through the roof, shippers are realising the potential economic advantage of outsourcing their logistics activities.
2. European industry is currently experiencing a degree of transition, and increasing numbers of shippers are considering the merits of outsourcing one or more of their logistics operations. According to the results of survey intended to investigate European 3PL market, in total, 42% of the companies currently outsource their logistics operations to 3PLs.
3. The survey confirms that almost two-thirds of the enterprises outsource their transportation activities. Less than 10% of the companies outsource their inventory management, while more than a third happily hand over their warehousing operations to 3PLs. A quarter of the companies outsource their information systems. However, fleet management is only outsourced by 13% of the companies.
4. Competition among 3PLs has become intense. Therefore the main challenges for current 3PL services providers seem to be as follows: maintaining profits under price pressures from customers; relationship with customers (this factor, in combination with the price pressures from customers, points to the considerable sensitivity of 3PLs to the markets they serve); globalisation of the 3PL market and delivering services in new geographical regions; consistently delivering the latest cutting edge technology to customers; competing with giant global 3PLs; emergence of 4PLs/LLPs.
5. A total of 79% of the companies selected "good" (62%), "higher than expected" (13%) or "outstanding" (4%). In comparison, only 21% were somewhat less enthusiastic about the performance of their 3PLs.

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INTERNATIONAL STANDARDS FOR THE USE OF BIOMETRICS

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The systems of identification of an individual in the age of modern technologies are developing fast. However, not many of them received the global recognition. One of the world-wide accepted solutions is the use of such biometric features as the facial image and fingerprints of the person. Such globally interoperable biometric data shall be stored in the so-called "e-passport" and shall be readable in the countries other than the one, which has issued such passport.

This article raises the issues of the existing international technical and legal standards for production and use of e-passports containing the biometric data of individuals, necessary preconditions for the implementation of such standards at the national level, as well examines the regional approach of the European Union to this issue and the results, which were achieved to this day.

Keywords: *biometric features, security, e-passports, public key infrastructure, International Civil Aviation Organisation (ICAO) standards, European Union*

Part I

1. Introduction

The use of biometric features (referred further as biometrics) in the modern world has become increasingly extensive and multipurpose, both due to the rapid technical progress in this area and the growing security concerns.

It shall however always be remembered that actually took 40 years to develop the biometric technology into the one we know nowadays, as the work started as long time ago as back in 1968.

The use of biometrics as described in this article is presumed to increase the security of passports and other travel documents. But it has a spill-over effect on much broader range of subjects, such as:

- security of the states,
- control of legal migration,
- combating of illegal migration, people smuggling and trafficking in human beings,
- identity theft,

and many others.

The purpose of this article is to look on the current international standards, which are used in the area of biometrics, and, using as an example the European Union case, how and in which manner they are applied.

2. Regulations of European Union for the Usage of Biometrics

In order to properly examine the international standards in the area of biometrics, the close look on the practical value of biometrics is needed.

The experience of the European Union is an excellent example. Council Regulation 2252/2004/EC (entered into force on 18 January, 2005) has laid down standards for security features and biometrics in passports and travel documents issued by the Member States [1]. This Regulation applies to passports and travel documents issued by the Member States. It does not apply to identity cards issued by the Member States to their nationals or to temporary passports and travel documents having a validity of 12 months or less.

Additional technical specifications for passports and travel documents are established in accordance with the procedure referred to in Article 5(2) of this Council Regulation:

- additional security features and requirements including enhanced anti-forgery, counterfeiting and falsification standards;
- technical specifications for the storage medium of the biometric features and their security, including prevention of unauthorised access;
- requirements for quality and common standards for the facial image and the fingerprints.

As Council Regulation (EC) 2252/2004 has laid down standards for security features and biometrics in passports and travel documents, which are general and non-secret, the European Commission decided that they had to be completed with other technical specifications, which may remain secret. Following such a consideration and taking into account the procedure under Article 5(2) of the (EC) 2252/2004, on 28 February 2005 the Commission adopted Decision C(2005)409, establishing the technical specifications on the standards for security features and biometrics in passports and travel documents issued by the Member States [2] (an authentic English version of the whole of specifications has not been established as the United Kingdom and Ireland did not take part in the adoption of this Decision).

The technical specifications mainly deal with the implementation of the integration of biometric features (facial image and fingerprints) on a secured storage medium in the passport. This adoption also triggered the deadline for the implementation of the facial image in the passport, which was August 28, 2006 at the latest.

On 26 June 2006, the European Commission adopted Decision C(2006)2909 establishing the technical specifications on the standards for security features and biometrics in passports and travel documents issued by The Member States, which supplements previous Decision C(2005)409 with new subsections 5.4., 5.5. and its subsections, 6.1., 6.2. and 6.3. The new subsections regulate the Public Key Infrastructure for Passports and Inspection Systems, Certificates, Standard Compliance, as well as Functional and Common Criteria Evaluation.

Taking into account the statement by ICAO as "recommendation" requirements and the role of ISO in adopting the standards on the basis of ICAO documents, it is necessary to follow both organizations' requirements to ensure compliance of the standards.

The Annex to the detailed EU requirements for e-passports mentioned in Commission Decision C(2006)2909 shall be considered as a consolidated version of international standards (both ICAO and ISO). No additional standards of only EU requirements are established under the scope of (EC) 2252/2004.

On 18 October 2007, a Proposal from the Commission was introduced for a Regulation of the European Parliament and of the Council amending Council Regulation (EC) No 2252/2004 on standards for security features and biometrics in passports and travel documents issued by the Member States [3]. At the time of the Commission's proposal for Regulation (EC) 2252/2004 and the discussions on it in the European Parliament and the Council, no experiences with the use of biometric data for large-scale applications in travel documents were available. These new technologies of inserting chips with biometric data had not been applied or tried out before. During pilot projects of some Member States it appeared that the fingerprints of children under the age of six seemed not to be of a sufficient quality for one-to-one verification of identity. Furthermore, they are subject to important changes which make it difficult to check them during the entire period of validity of the passport.

Both for legal and security reasons it should not be left to the national legislation to define the exceptions from the obligation to provide fingerprints for passports and other travel documents issued by the Member States.

Consequently, the European Commission proposed an amendment to Regulation 2252/2004 in order to provide harmonised exceptions: children under the age of six years and persons, who are physically unable to give fingerprints, should be exempt from this requirement.

Furthermore, as a supplementary security measure and in order to provide additional protection for children, the principle of "one person – one passport" has to be introduced. It is also recommended by the International Civil Aviation Organisation (ICAO) and it ensures that the passport and the biometric features are only linked to the person holding the passport. It is more secure if every person has his/her own passport. If, for example, a passport is issued that also includes the person's children, indicating only the names and without photographs, only the biometric data of the respective parent would be introduced on the chip. The biometric information of the children would not be stored. As a consequence, the identity of the children cannot be checked in a reliable way. This could promoter child trafficking. It was postulated that introduction of the principle "One person-One passport" would help to avoid this negative effect.

During pilot projects in some EU Member States it appeared that the fingerprints of children under the age of 6 seemed not to be of a sufficient quality for one-to-one verification of identity. Furthermore, they are subject to significant changes which make it difficult to check them during the entire period of validity of the passport or travel document.

On May 28, 2009 the abovementioned proposal was finally adopted as the Regulation 444/2009 of the European Parliament and of the Council amending Council Regulation 2252/2004 on standards for security features and biometrics in passports and travel documents issued by the Member States [4]. It was decided that children aged under 12 years are exempt from compulsory finger printing and not aged under

the 6 as it was mentioned in the Proposal. According to point 3 of Article 1 of the abovementioned Regulation additional technical specifications in accordance with international standards, including in particular the recommendations of the ICAO, for passports and travel documents relating to the following shall be established:

- additional security features and requirements, including enhanced anti-forgery, counterfeiting and falsification standards;
- technical specifications for the storage medium of the biometric features and their security, including prevention of unauthorised access;
- requirements for quality and common technical standards for the facial image and the fingerprints.

These provisions replaced the provisions under Article 2 of the Council Regulation (EC) 2252/2004.

The European Commission should also present the study until June, 2012 where reliability and technical feasibility, including through an evaluation of the accuracy of the systems in operation, of using the fingerprints of children under the age of 12 for identification and verification purposes should be examined.

As it is was previously mentioned EU requirements for biometrics in passports are based on the standards of ICAO, which were accepted by International Standards Organisation. Therefore there is a need to properly examine the interoperable global standards of biometrics, which were developed by the ICAO.

3. The International Civil Aviation Organisation and Its Impact on the Development of the International Standards

The first introduction of the interoperable global standard of biometrics in Machine Readable Travel Documents (MRTDs) was made public in 2003. Version 1.9 of Biometrics Deployment Technical Report discussed each of the issues in relation to the deployment of biometrics and was presented to the 14th ICAO Technical Advisory Group (TAG/MRTD) in mid-May 2003. TAG/MRTD endorsed the Technical Report, and ICAO subsequently adopted it as a key component of its global, harmonized blueprint for the integration of biometric identification information into passports and other MRTDs.

3.1. Doc. 9303

First published in 1980 as "A Passport with Machine Readable Capability", Doc 9303[5] is now published in three separate Parts [6].

Part 1 – Machine Readable Passport – Volume 1 Passports with Machine Readable Data Stored in Optical Character Recognition Format	Sixth Edition	2006
Part 1 – Machine Readable Passport – Volume 2 Specifications for Electronically Enabled Passports with Biometric Identification Capabilities	Sixth Edition	2006
Part 2 – Machine Readable Visas	Third Edition	2005
Part 3 – Size 1 and Size 2 Machine Readable Official Travel Documents	Second Edition	2002

The Sixth Edition of Doc 9303 Part 1, in two volumes, was published in September 2006. Volume 1 sets forth the specifications for a Machine Readable Passport (MRP), characterized by a visual inspection zone and a machine readable zone (MRZ) containing essential identification and document details in optical character recognition (OCR)-B typeface. Volume 2 sets forth the specifications for biometric enhancement of the MRP to become an "e-Passport".

The third Edition of Doc 9303 Part 2 – Machine Readable Visas – was published in 2005. Specifications provide for a visa format in two sizes – Format A, sized to fill a passport page, and the smaller format B. Like the MRP, the machine readable visa is a standard format consisting of a visual inspection zone and a machine readable zone. However, the Third Edition requires that a space be provided for a portrait of the holder, and fewer layout options than the previous edition allowed.

The Second Edition of Doc 9303 of Part 3 – Size-1 and Size-2 Machine Readable Official Travel Documents, was published in 2003. Specifications provide for machine readable cards in two sizes: TD-1, an ID-1 size plastic card, and TD-2 having the dimensions defined for the ID-2 type card (ISO/IEC 7810). In addition to the visual inspection zone and the machine readable zone, the specifications provide for the addition of "optional capacity expansion technologies" to increase data storage on the documents.

3.2. Doc. 9303 Part 1

The current edition updates and replaces the specifications for MRPs as published in the fifth edition (2003) and represents a substantial modernization of the material contained in previous editions. In particular, this sixth edition incorporates the new globally interoperable standards for biometric identification of the holder and for the storage of the associated data on a contactless integrated circuit. In consequence, some other biometric identification methods and data storage media, described in the fifth edition, are no longer to be regarded as options within the globally interoperable standard.

The first volume, known as Doc 9303 Part 1 Volume 1, is an updated version of the fifth edition containing all the specifications required for a State to issue a MRP book where the State does not wish to incorporate the global facilitation for its citizens that will be available with machine assisted biometric identification.

It also defines the MRP specifications which allow compatibility and global interchange using both visual (eye readable) and machine readable means. The specifications lay down standards for passports which can, where issued by a State or organisation and accepted by a receiving State, be used for travel purposes.

The second volume, known as Doc 9303 Part 1 Volume 2, contains additional specifications for the globally interoperable system of biometric identification and its associated data storage utilizing a contactless integrated circuit. The specifications contained herein were drawn up following a detailed study over several years carried out by the ICAO Technical Advisory Group's New Technologies Working Group (NTWG) beginning in 1998. The study examined different biometric identification systems, concentrating on their relevance to the facilitation for a traveller in applying for and obtaining a biometrically enabled passport and in using that passport for travel between States.

The specifications for the new globally interoperable system contained in this Volume Two are only for use by States wishing to issue a passport designed to facilitate cross-border travel with enhanced security by incorporating the globally interoperable machine assisted biometric identification/data storage system. These States will therefore need to observe the specifications in both Volumes to conform to the standards laid down in ICAO Doc 9303 Part 1.

4. International Standards Organisation (ISO)

The technical specifications sections of Doc 9303, Parts 1, 2 and 3 have received the endorsement of the ISO. Due to cooperation between manufacturers of travel documents and equipment with TAG/MRTD on technical issues with the participation of ISO, the ICAO specifications have achieved, and are expected to continue to receive, the status of worldwide standards by means of a simplified procedure within ISO.

Taking into account the above-mentioned, Doc 9303 formally can be considered as international recommendations and not as standards.

5. E-Machine Readable Passports

According to ICAO, in implementing biometrics standards for MRPs, the key considerations are:

- Global Interoperability – the crucial need for specifying how the biometrics deployed are to be used in a universally interoperable manner;
- Uniformity – the need to minimize via specific standard setting, to the extent practical, the different solution variations that may potentially be deployed by member States;
- Technical Reliability – the need for provision of guidelines and parameters to ensure that Member States deploy technologies that have been proven to provide a high level of confidence from an identity confirmation viewpoint; and that States reading the data encoded by other States can be sure that the data supplied to them is of sufficient quality and integrity to enable accurate verification at their end;

- Practicality – the need to ensure that recommended standards can be operationalized and implemented by States without having to introduce a plethora of disparate systems and equipment to ensure they meet all possible variations and interpretations of the standards;
- Durability – the systems introduced will last the maximum ten-year life of a travel document, and future updates remain backwards compatible.
- Biometrics can be used to improve the quality of the background checking performed as part of the passport, visa or other travel document application process, and they can be used to increase the strength of the binding between the travel document and the person who holds it.

The major components of a biometric system are:

- Capture – acquisition of a raw biometric sample;
- Extract – conversion of the raw biometric sample data to an intermediate form;
- Create Template – conversion of the intermediate data into a template for storage;
- Compare – comparison with the information in a stored reference template.

These processes involve:

- the enrolment process which is the capture of a raw biometric sample. It is used for each new person (potential MRP holder), taking biometric samples to establish a new template. This capture process is the automatic acquisition of biometric features via a capture device such as a fingerprint scanner, photograph scanner, live-capture digital image camera, or live-capture iris zooming camera. Each capture device will need certain criteria and procedures defined for the capture process – for example, standard pose facing the camera straight-on for a facial recognition capture; whether fingerprints are captured flat or rolled; eyes fully open for iris capture.
- the template creation process preserves the distinct and repeatable biometric features from the captured biometric sample and is generally via a proprietary software algorithm to extract a template from the captured image which defines that image in a way it can subsequently be compared with another captured image and a comparative score determined. Inherent in this algorithm is quality control, wherein through some mechanism, the sample is rated for quality. Quality standards need to be as high as possible since all future checks are dependent on the quality of the originally captured image. If the quality is not acceptable, the capture process should be repeated.
- the identification process takes new samples and compares them to the saved templates of enrolled end users to determine whether the end user has enrolled in the system before, and if so, whether in the same identity.
- the verification process takes new samples of an e-Passport holder and compares them to the previously saved templates of that holder in order to determine whether the holder is presenting in the same identity.

In biometrics terminology:

- "verify" means to perform a one-to-one match between proffered biometric data obtained from the MRTD holder now, and a biometric template created when the holder enrolled in the system;
- "identify" means to perform a one-to-many search between proffered biometric data and a collection of templates representing all of the subjects who have enrolled in the system.

After a five-year investigation into the operational needs for a biometric identifier, which combines suitability for use in the MRP issuance procedure and in the various processes in cross-border travels, consistent with the privacy laws of various States, ICAO has decided that facial recognition shall become the globally interoperable biometric technology. A State may also optionally elect to use fingerprint and/or iris recognition in support of facial recognition.

As the result of such a study, ICAO Doc 9303 only considers three types of biometric identification (automated means of recognizing a living person through the measurement of distinguishing physiological or behavioural traits). These are the physiological ones of:

- facial recognition (mandatory);
- fingerprint (optional);
- iris recognition (optional).

An international Standard, ISO/IEC 19794, composed of several Parts, provides specifications for these types of biometric identification. Issuing States shall conform to these specifications.

"E-Passports" is the term used by ICAO to simplify the understanding of globally-interoperable MRPs containing biometrics. The e-Passport has to be capable of being used by any suitably equipped receiving State to read from the document a greatly increased amount of data relating to the MRP itself

and to its holder. This includes mandatory globally interoperable biometric data that can be used as an input to facial recognition systems, and, optionally, to fingerprint or iris recognition systems. The specifications require the globally interoperable biometric data to be stored in the form of high resolution images on a high capacity contactless integrated circuit (IC), the IC also being encoded with a duplicate of the MRZ data. The specifications also permit the storage of a range of optional data at the discretion of the issuing State.

Any MRP that does not comply with the specifications given in ICAO Doc 9303 Part 1 Volume 2 may not be called an e-passport and may not display the e-passport logo.

The data storage capacity of the IC is specified to be a minimum of 32 kB, which is large enough to store the mandatory facial image and, also mandatory, a duplication of the Machine Readable Zone data. However, the optional storage of more than one facial image and/or fingerprint/iris images requires considerably larger data capacity. Some States are planning to use ICs with data capacities ranging from 64 kB to 1 MB.

The ICAO vision for the application of biometrics technology encompasses:

- specification of a primary interoperable form of biometrics technology for use at border control (verification, watch lists) as well as by carriers and document issuers and specification of agreed supplementary biometric technologies;
- specification of the biometrics technologies for use by document issuers (identification, verification and watch lists);
- capability of data retrieval for a maximum ten-year validity, as specified in Doc 9303;
- having a no proprietary element to ensure that any States investing in biometrics are protected against changing infrastructure or suppliers [7].

For this moment, specifications for MRTDs have been formulated and today almost 90 percent of the ICAO member states are issuing a MRP. Not only enabling the standardisation of document formats, MRTDs facilitate the accurate and efficient input of personal information to computerised systems serving border security and facilitation functions. The ICAO objective of having all the Member States issuing MRPs by April 1, 2010, is now very much attainable and not simply a target as it has been twenty years ago [8].

6. European Union Standards for Use of the Biometrics in E-Machine Readable Passports

As it was mentioned above, the Annex of Decision C (2006)2909 could be used as a guide for introducing the international standards of technical specifications for introducing e-MRPs.

The Annex is based on international standards, especially ISO standards and ICAO recommendations on Machine Readable Travel Documents, and accommodates:

- specifications for biometric identifiers: face and fingerprints;
- storage medium (chip);
- logical data structure on the chip;
- specifications for the security of the digitally stored data on the chip;
- RF compatibility with other electronic travel documents.

6.1. Face

The face as the primary biometric should have a standard compliance with the facial image and must be stored as Frontal image [9], according to:

- ICAO NTWG, Biometrics Deployment of Machine Readable Travel Documents, Technical Report, Version 2.0, 05 May 2004;
- ISO/IEC 19794-5:2005, Biometric Data Interchange Formats – Part 5: Face Image Data.

The face is to be stored as a compressed image file, not as vendor specific template. Although both JPEG and JPEG2000 compression is standard compliant [10], JPEG2000 is recommended for EU-Passports because it results in smaller file sizes compared to JPEG compressed images. Storage requirements for JPEG compression are approx. 12–20 Kbyte per photo, but for JPEG2000 compression approx. 6–10 Kbyte per photo.

Photograph Taking Guidelines taking into account the requirements of facial recognition technology have to be adopted according to ICAO standards [11].

6.2. Fingerprints

The EU legal framework requires fingerprints as the secondary biometric to be introduced in e-passports. Its standard should be compliant with:

- ICAO NTWG, Biometrics Deployment of Machine Readable Travel Documents, Technical Report, Version 2.0, 05 May 2004;
- ISO/IEC 19794-4:2005, Biometric Data Interchange Formats – Part 4: Finger Image Data;
- ANSI/NIST-ITL 1-2000 Standard "Data Format for the Interchange of Fingerprint, Facial, Scarmark & Tattoo (SMT) Information"; FBI: Wavelet Scalar Quantization (WSQ).

The primary fingerprints to be incorporated into the EU e-passports shall be plain impressions of the left and right index finger.

In the case of insufficient quality of the fingerprints and/or injuries of the index fingers, good quality, plain impressions of middle fingers, ring fingers or thumbs shall be recorded (the storage format CBEFF – Common Biometric Exchange Format Framework) will record the type of fingers used (left index, right middle, etc.) in order to ensure verification with the correct finger.

The fingerprints must be stored as images according to ISO/IEC 19794-4:2005, the quality of the fingerprint images shall be according to the ISO standard mentioned and ANSI/NIST-ITL 1-2000 Standard "Data Format for the Interchange of Fingerprint, Facial, Scarmark & Tattoo (SMT) Information". According to the latter a compression of the images using the WSQ-algorithm must be used in order to decrease the file size.

The use of fingerprint images requires approximately 12–15 Kbyte per finger.

6.3. Chip

Storage medium (RF-Chip architecture) should have a standard compliance with:

- ICAO NTWG, Biometrics Deployment of Machine Readable Travel Document, Technical Report, Version 2.0, 05 May 2004;
- ISO/IEC 14443, Identification cards – Contactless integrated circuit(s) cards – Proximity cards;
- ICAO NTWG, Use of Contactless Integrated Circuits In Machine Readable Travel Documents, Technical Report, Version 3.1, 16 April 2003.

According to the above-mentioned documents, both type A and type B RF-interfaces are considered to be ICAO Standard compliant.

ICAO compliant passports will be equipped with either A or B type RF interfaces, requiring border inspection systems to accommodate both standards for passports.

According to the ICAO Logical Data Structure [12], alphanumeric data of the MRZ of the document and digital document security data (PKI) must be stored on the chip together with the biometric identifiers.

On the EU level, the states are required to use appropriately sized RF chips to hold the personal data and biometric features according to the Council Regulation (EC) No 2252/2004 on standards for security features and biometrics in passports and travel documents issued by the Member States.

The alphanumeric data, printed in the MRZ of the passport, according to ICAO Doc 9303, Part 1 Machine Readable Passports, Sixth Edition, 2006 (remained draft in the text of the Annex), have to correlate to the data digitally stored in the chip according to ICAO NTWG, Development of a Logical Data Structure – LDS for optional capacity expansion technologies, Technical Report, Revision 1.7, of 18 May 2004. Chip Logical Data Structure should be developed according to the latter.

6.4. Data security and integrity issues

The integrity, the authenticity and confidentiality of the data, digitally stored in the passport's chip, have to be equally secured. This requires the following mandatory/optional international standards on:

- Passive Authentication – required for all data (ICAO mandatory security feature);
- Active Authentication – optional;
- Chip Authentication – additional protection on the EU level required for all data at the time when fingerprint data are introduced or at the latest 36 months after the adoption of the technical specifications. Such a protection must not be enforced by the chip, but EU-Inspection systems must use this mechanism, if supported by the chip;
- Basic Access Control – required for all data;
- Terminal Authentication – additional protection required for fingerprint data.

For more information on this subject, the following documents should be consulted:

- ICAO NTWG, PKI for Machine Readable Travel Documents Offering ICC Read-Only Access, Technical Report, Version 1.1, October 01, 2004;
- ISO/IEC 7816-4:2005, Identifications cards – Integrated circuit cards – Part 4: Organization, security and commands for interchange;
- Advanced Security Mechanisms for Machine Readable Travel Documents, Version 1.0, 2005.

6.5. Requirements of the European Union for Public Key Infrastructure for Passports and Inspection Systems

In order to ensure integrity and authenticity of the digital data stored on the chip, a PKI is introduced:

Each EU Member State must set up only a single Country Signing CA acting as the national trust point for all receiving states and at least one Document Signer issuing passports. Details on this PKI infrastructure (including signature algorithms, key lengths, and validity periods) can be found in ICAO NTWG, PKI for Machine Readable Travel Documents Offering ICC Read-Only Access, Technical Report, Version 1.1, October 01, 2004.

To prevent unauthorized inspection systems to access fingerprint data, another PKI is introduced:

Each EU Member State must set up only a single Country Verifying CA acting as the national trust point for the passports issued by this Member State and at least one Document Verifier managing a group of authorized inspection systems. Details on this PKI infrastructure can be found in Advanced Security Mechanisms for Machine Readable Travel Documents, Version 1.0, 2005.

Conclusions

In the area of use of the biometrics the significant progress was reached during the last 5 years and it is widening in the daily life. The electronic passports with the biometrics are already in use in about 90 percent of ICAO Member States.

Although this article touched mainly the current technical solutions for the use of biometrics in passports; it shall not be forgotten, that in order to effectively implement these solutions and benefit from the results of such a use any state must comply with such criteria as:

- to have high level of personal data protection ensured,
- to have a modern civil register system,
- to have a proper equipment in place in order to capture, process and store the biometrics of the persons for the purpose of the issuance of passports,
- to have complex system to be used for the identification of the persons already having e-passports with biometrics (e.g. at the border crossing points),
- to ensure the complex approach to all the above mentioned components in order to treat them as one sophisticated public data management system.

Finally it is also very likely that based on the current experiences of the ICAO Member States, and, in particular those, which are also EU Member States, the new technical solutions will be elaborated by the international organizations in the long-term perspective.

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PERFORMANCE IMPROVEMENT STUDIES OF AN AIRPORT TERMINAL USING DISCRETE-EVENT SIMULATION

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Air travel sector is experiencing phenomenal growth and capacity of airport terminals and associated infrastructure is being seriously challenged. Terminal managements have to take decisions on a variety of issues related to long-term, medium-term and short-term planning. Simulation modelling has been widely used for the design and performance improvement of logistic terminal systems. In this paper we discuss a framework for developing categories of simulation models related to strategic, tactical and operational problems of an airport terminal. We also discuss the use of such models to help solve problems of strategic nature related to fixed facility, tactical problems related to variable facilities, and operational problems related to transient entities and their schedules.

Keywords: *Simulation modelling, Performance improvement, Airport Terminal Systems*

1. Introduction

The transport sector is increasingly being regarded as one of the best engines for economic growth and social development. Air, sea, road and rail are the transport modes used to carry people, bulk cargo and other items. A terminal is a node in a transport network between the supplier and customer. Transient items (such as rakes, ships, air planes and passengers) come to terminals, wait for some service in the space provided by terminals and get service using terminal facilities and equipment. After getting service, transient items may wait again in the terminal space so as to depart at scheduled departure time. Terminals systems are complex systems having many interconnected components. A terminal must be planned to ensure an acceptable level of service to its customers in terms of waiting times and turnaround times. Terminal managements have to take decisions on a variety of issues related to long-term, medium-term and short-term planning. Many problems of terminals systems are originated from external factors like the differences of varying demand and supply in many elements of supply chains linked to the terminals.

The modelling of airport terminal operations has advanced significantly over the last 15 years. Use of simulation models as decision support aids or design tools in terminal development projects has been steadily increasing. Some existing models are “strategic” in nature sacrificing level of detail in exchange for speed and flexibility, while others are primarily “tactical” incorporating high levels of detail in data and system definition. Mumayiz [1] and Tosic [2] have presented exhaustive overviews on the development of terminal simulation technology and on their applications to airport terminals. Passenger terminal facility design issues are discussed in Odoni and de Neufville [3] and IATA [4]. Recent reviews on airport modelling literature can be found in Pendergraft et al. [5] and Lindh et al. [6].

2. The Problem and Objectives

In this paper we discuss a framework to create categories of models related to the operations of Cochin International Airport Limited (CIAL). CIAL was founded as a green field project about fourteen years back. Initially there were only a few domestic flights operating from this airport and therefore the available facilities were abundant. However, soon the airport became quite busy with the commencement of many new international flights and cargo movements. This has led to a scenario where there was urgent need to synchronize the system and get maximum performance out of it in the short run. In the long run facilities needed to be augmented. Decision support systems that could help in solving the above problems were required. Simulation has been used for the above as is evident from literature. It was proposed to develop a simulation model of the passenger terminals of the above airport with the following objectives.

1) To develop an integrated simulation model that models passenger flow and aircraft schedules.
2) To develop models with capability to determine resource utilization at a high level of detail.
3) To allow planners to see operational constraints and bottlenecks, as opposed to inferring operational limitations through reviewing the statistical reports, graphs and charts.
4) In the wake of increasing passenger loads, the models were required to be versatile to study many different terminal problems like the requirement of number of flight parking bays, the number of X-ray baggage checking machines, and study the impact of these changes in operational issues like rearranging schedules/passenger arrival patterns and to investigate possibility of additional schedules.

Simulation models can be developed in different ways depending on the types of problems. As Booch et al. (7) notes:

1) The choice of models has a profound influence on how a problem is attacked and how a solution is shaped.
2) Every model may be expressed at different levels of precision.
3) The best models are connected to reality.
4) No single model is sufficient.

We find that little is discussed in literature on development of models for performance improvement studies related to airport terminals, when many different problems need to addressed. In this section we discuss an approach used by us for identifying problem categories and model types related to three different types of terminal system problems. Such categorization is useful in two ways:

a) Model reuse: The model elements are decided during the conceptual modelling stage and final models would be built upon these elements. It would be very difficult even for the developer to change the nature of simulation blocks later, when a slightly different problem needs to be studied. If simulation elements are decided with model flexibility in mind (to solve a category of problems), such models could easily be modified in future to solve similar problems.
b) Ease of use: It would be easier for the end user of simulation model to select right type of model(s) to solve the problem in mind.

We have developed three categories of models to help solve these many problems. The model classification is based on the characteristics of facilities, which are briefly mentioned in the next section.

3. Characteristics of Facilities Providing Service

Terminals systems have many facilities providing service to their customers. Generally these facilities can be classified as fixed facilities and variable facilities. Fixed facilities are fixed to a position and could not be easily moved from one place to another place. In contrast, variable facilities are the facilities that could be deployed as per need. Fixed and variable facilities are utilised to give service to transient entities that pass through the system. Few examples of facilities and transient entities of airport terminal systems are given in Table 1. The efficiency of terminal systems is largely dependent on various characteristics of fixed and variable facilities (depicted on Figure 1). James and Bhasi [8] lists many characteristics of terminal system facilities that affect performance of terminal systems like number, position in flow sequence/process, cycle time, variability and repair/maintenance. An approach, which would explicitly identify facilities and transient items at the time of conceptual modelling would help in focusing on a variety of problems related to terminal systems.

Table 1. Examples of fixed and variable facilities and transient entities in Transport Terminals

Items	**Airport Terminal**
Fixed facilities	Runway Parking Bays Terminal Space
Variable facilities	X-ray machines Check-in counters Immigration counters
Transient entities(Flow items)	Passenger Flights Baggage

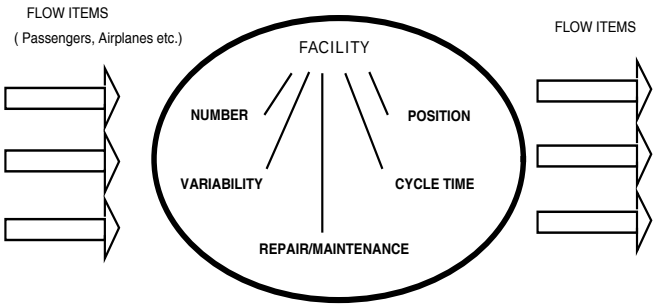

Figure 1. Facilities and characteristics

4. Model Logic

A basic model of the airport terminal was developed first, based on the flow of passengers in the terminal as well the movement and parking of planes within the terminal. The modelling was done in the simulation package Extend(of Imagine That Inc.). The generation of entities depended upon the type of problems studied (various types of models and entity generation is discussed in detail in section 5). The flights were given attributes related to its type, whether international or domestic and ground time required. The passenger arrival and departure processes are shown in Figures 2 (processes of international and domestic terminals are slightly different). The departing passengers were assigned various attributes of flights, check-in counters, terminal type, gate, etc. Both streams (passengers and airplanes) were batched together when departing passengers had completed all processes depicted in the flow diagram. When all departing passengers arrived for their corresponding flight, the airplane was taxied to runway. Take-off permission was given only if there was no other plane in the runway (only one plane – take-off or landing – was permitted at a time in the runway).

The Airport authorities provided data on the originating passenger percentage. Once total originating passengers per flight were calculated, an arrival time distribution was applied to represent the fact that passengers arrive at various times before their flight. Passengers arrive to the terminal at various times, generally within 1 to 3 hour prior to their flight. From the data provided by the terminal authorities at the terminal's security check point, we observed that passenger arrival rates at this point follows a normal distribution with a mean of 65 min prior to departure and a standard deviation of 15 min. The number of persons arriving at the check-in area could be easily estimated considering the index of the last passenger minus the index of the first passenger arrived at the check-in during the interval under consideration (usually the check-in peak hour). Check-in opening depended on the flight destination and common use of check-in desks between carriers was allowed. For each facility, the graphs of performance measures such as facility throughput (for example the cumulative number of served passengers), number of transients in queue, expected queue time etc are provided. To simplify modelling, we have not separated passengers into passenger classes like business class, economy class, etc. Other assumptions are as follows:

1) Resources like pilots, crew etc were assumed to be available as and when required.
2) It was assumed that all flights coming to the terminal leave as soon as passenger disembarking, ground handling and passenger boarding was over.
3) Passengers proceed directly from facility to facility.
4) Transit passengers processes were not considered for modelling.

Model verification and validation. The models were verified and validated. In the simulation models, the key entities are passengers and airplanes that move through a set of processes and activities that consume resources. We have attached several plotters and information blocks at various flow points in the model. These blocks were used to verify the model. The traffic is low in early hours of the day and hence the period from 00-2:15 AM was used to warm up and load the simulation system. Results were collected during the peaking period of 2.15 AM to 12 AM in 10 minute intervals. Each simulation runs were replicated 100 times to achieve required statistical confidence. Plots of actual system history and the model results showed similar behaviour for flights and passenger profiles over a long period of time.

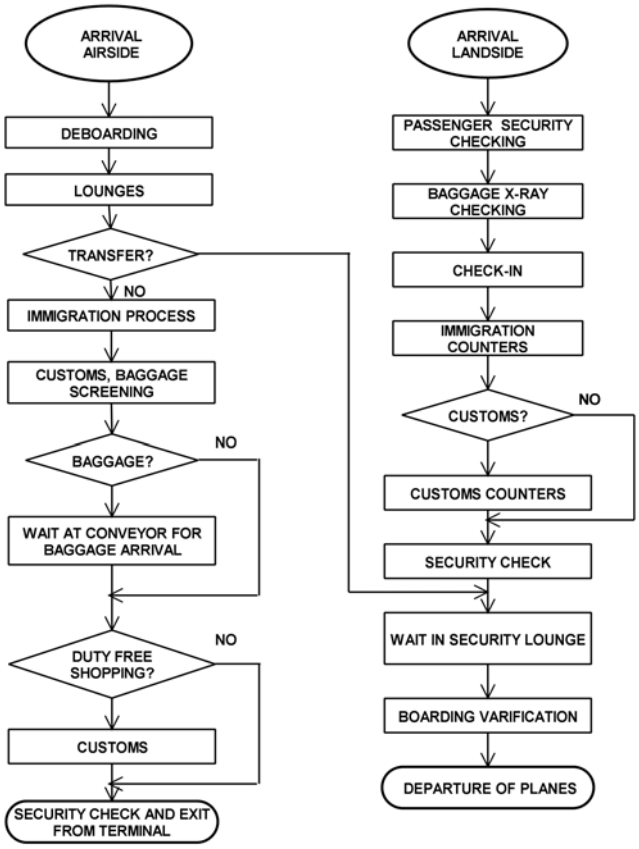

Figure 2. Passenger arrival and departure processes in an airport

5. Identifying Problem and Model Categories

After considering different ways of categorising terminal problems, we have found out, that grouping problems on the basis of whether they are operational, tactical or strategic would be a good method. Table 2 lists some examples of decision problems related to an airport terminal in each of above category.

Table 2. Examples of facility related decision problems of airports

	Decision Problem
Strategic level	Impact of long-term forecasts(flights) on Runway capacity Study of requirement of number of parking bays based on forecast loads Study of requirement of terminal space to meet future capacity needs
Tactical level	Study of requirement of number of X-ray machines Estimation of Maximum Occupancy of an area to determine Heating/Ventilation System requirements.
Operational level	Rearranging schedules/Passenger reporting times to level peak load Investigating the possibility of including more flight schedules Deployment of facilities

For model categorisation, our approach was to identify the fixed facilities, variable facilities and transient entities that pass through the service system, and develop models focused on each of these categories. This approach helped us in designing and developing various simulation elements at the time of conceptual modelling. We have developed three types of models designated as: FIXED FACILITY FOCUS (FFF) models, VARIABLE FACILITY FOCUS (VFF) models and TRANSIENT ENTITY FOCUS (TEF) models and used them to help solve problems of strategic nature related to fixed facility, tactical problems related to variable facilities, and operational problems related to transient entities and their schedules. Slightly different models of each type were developed for the analysis of the particular problem considered. More details on each of above types of models are given below.

FFF Models were used to study problems of strategic nature; and when using such models for experimentation, all the entities i.e. fixed, variable and transient, were allowed to be changed in number. Such models totally discarded time schedules for arrival or departure of transient entities. Transient entities (like passengers and planes) were generated according to specified statistical interarrival time distributions. In **VFF Models**, some restrictions were imposed for changing number and position of fixed facilities and only variable and transient entities were allowed to be changed in its number for experimentation. This resulted in models that were useful for the study of tactical decisions, such as that of changing the number of variable facility and flow routes. Such models were not totally free of time schedules for transient entities. **TEF** models most accurately represented the actual system configuration and such models were used for study of operational problems such as impact of breakdown and repair times, schedule changes and waiting and service times of transient entities. In **TEF** Models**,** provision was given only for changing number and time schedules for transient entities and the configurations of fixed and variable facilities remained the same as that of the system under study. Due to the nature of operating under pre-schedules, these models offered only very little flexibility for studying tactical and strategic decision problems.

6. Some Results

FFF, VFF and VEF simulation models of Cochin International Airport (CIAL) Terminal were used to help solve a few decision problems of terminal management (see Table 3). Table 3 shows a summary of few important results obtained in each category of problems by experimenting with the corresponding types of models. The Discrete Event (DE) plotters attached to various resources and queue blocks indicated the behaviour of transient entities.

Table 3. Decision problems and some important results/findings related to Airport

Decision problems	Description	Model Category	Some important results/findings
Strategic level			
Number of parking bays required	At present the airport uses ten parking bays. Out of these 10 parking bays, two were reserved for big planes like A-330, B-777(we call it type1 bays and other bays type 2 bays). When these slots were free, more international planes were accommodated in these bays due to the availability of aero bridges. How many parking bays are required to meet the anticipated demand?	FFF	In order to meet the given forecast demand, there was a need to augment type 1 bays from present number of two to three
Tactical level			
Number of X-ray machines required	The X-ray machines at CIAL, could handle about 250 bags per hour. This was a critical resource and undesired large queues in the area were found, due to insufficient number of X-ray machines	VFF	Three X-ray machines simultaneously deployed could reduce average passenger wait times at the given loads near to zero
Operational level			
Planning new flight schedules	Finding slack times of utilization of terminal equipment for planning new flight schedules	TEF	When slack times of flight were used for scheduling new flights, major equipment utilisation was verified using the model

Number of parking bays required. The number of parking bays required for parking the arriving planes till its departure depends on the arrival rate of planes, the parking time and the preference of international/domestic flights on type of bays. An FFF model was run under various scenarios of flight arrival and number of bays. We have used Taguchi L12 orthogonal arrays (for a discussion on use of Taguchi methods in simulation see Dooley and Mahmoodi, [9]) for the following experiments (See Table 4 for details of factors and responses). Plots for signal to noise(S/N) ratio for average wait time at bay 1 (Figure 3) indicated that wait time for parking bays was significantly influenced by the number of type 1 bays and in order to meet forecast demand, there was a need to augment type 1 bays from present number of two to three.

Table 4. Factors and responses in Taguchi L12 experiment

Factors	Number of Type 1 Bays (type 1)	Number of other Bays (type 2)	Flight Peak Arrival Rate per hour (arr)	Usage proportion of Type 1 Bays	
				intpr (Intenational flights)	dompr (Domestic flights)
Levels	2, 3	8, 10	3,4.5	0.75, 0.90	0.25,0.40
Response	Average wait time for bays				

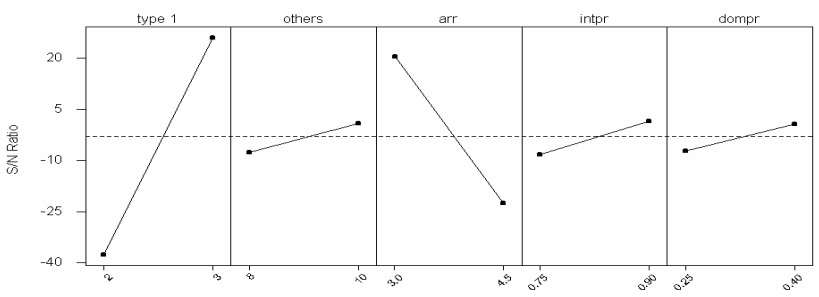

Figure 3. Plot of S/N Ratio's Of Average Wait time For Bays

Number of X-ray baggage screening machines required. If sufficient numbers of X-ray machines are not available, undesired large queues (indicated by peaks in DE plots of queue length) are formed in the area. Figure 4 shows a plot of queue length for the cases of two and three X-ray machines. We observed a considerable reduction in queue length when three machines were simultaneous deployed instead of two machines thus improving the level of service (LOS).

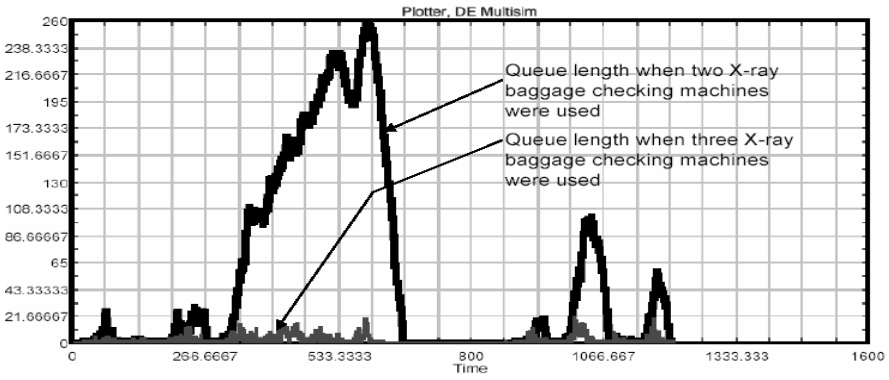

Figure 4. Plot of queue length for the cases of two and three X-ray baggage checking machines

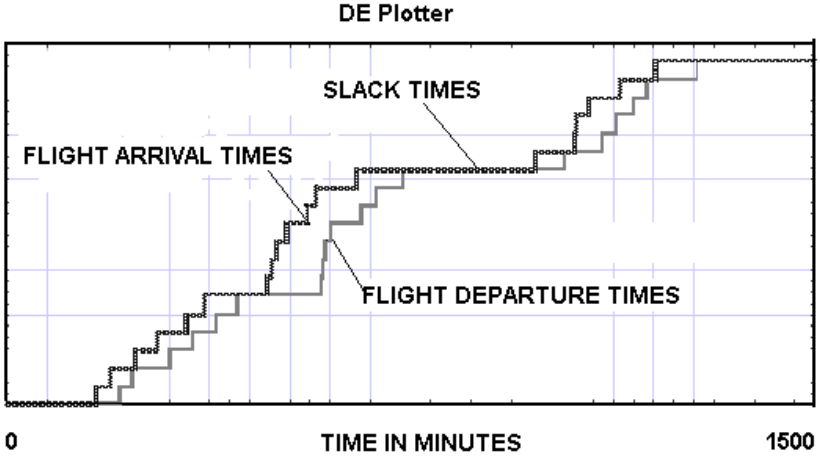

Figure 5. DE plot of flight arrival and departure times

Planning new flight schedules. A TEF simulation model was used to study the effective utilization of available resources on a day to day basis. Discrete-Event (DE) plotters have shown traffic of transients like airplanes and passengers passing through the terminal system. Figure 5 shows a DE plot of flight arrivals and departures on a particular day. Such plots help in easy identification of slack times for testing the timing of new schedules. When slack times of flight were used for scheduling new flights, major equipment utilization was checked using the model.

Conclusions

In this era of globalisation, organisations are continuously making changes in its structure and operations. Modelling studies are useful in predicting the impact of these changes. It is not always easy for organisations like airports to develop models each time a problem needs to be solved. They prefer versatile simulation models which could help them solve many decision problems. We have developed three types of models simulation models designated as Fixed Facility Focus models, Variable Facility Focus models and Transient Entity Focus models and used them to help solve problems of strategic nature related to the fixed facilities, tactical problems related to the variable facilities, and operational problems related to the transient entities and their schedules. The framework presented here is also suitable for hierarchical decision-making in the sense that any change in the configuration of fixed facilities (strategic problems) may necessitate further investigation on the changes required for variable facilities (tactical problems) and then to the schedules of transients (operational problems) and vice versa. It is possible to extend our modelling approach to more transport systems (like rail and container terminals) for performance reliability studies Another area of future work would be to search and find more ways of categorising problem types and making model types that match with these categories.

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- recent publications have appeared in Organizational Science and in Interacting with Computers

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CUMULATIVE INDEX

COMPUTER MODELLING and NEW TECHNOLOGIES, volume 13, No. 3, 2009

(Abstracts)

Metaphors are commonly used in our every day language. They structure our perceptions and understanding and are known to be very useful for educating new concepts. Metaphoric-based interfaces are considered in the HCI field as usable and easy to learn, because metaphors relate user actions in computerized systems to already familiar concepts.

The general idea of metaphors is to transfer knowledge from the familiar and usually more concrete world to the unfamiliar and more abstract world. A suitable metaphor enables the user to function effectively in the new system, even without perfect understanding. Visual metaphors not only make a new system easier and simpler to learn, but also have a considerable effect on user experience. Although the intent of the metaphor at the beginning is to aid understanding and usability, metaphors are used also as a motivator, at first to get the user to use the system, then to make him productive and keep his interest. Information organization is a very important aspect in today computerized environments. Metaphorically speaking, searching information is often described as looking for a needle in a haystack. Designing interfaces for young children is a very challenging activity.

The aim of this research is to design and then evaluate two hierarchical metaphoric-based systems suitable for children's educational programs for searching for information about animals and continents: the cabinet (object-container, nested) metaphor and the tree (parent-child) metaphor. We first seek to find which metaphor is more suitable for the design of children's interfaces. We also are interested in examining whether children transfer hierarchical organization of one kind to the other. In a laboratory experiment, participants interacted with two metaphoric-based systems for educating children. Our children participants used the systems to find answers for questions regarding animals and continents. We measured performance in the tasks, and subjective aspects such as experience and user satisfaction. We tested the hypotheses that children cognitively transfer hierarchical organizations.

Keywords: *hierarchical recursive metaphors, information organization*

The literature displays change point detection problems in the context of one of key issues that belong to testing statistical hypotheses. The main focus in this article is to review shortly nonparametric retrospective change point policies, proposing new relevant tests based on Mann-Whitney type statistics. Asymptotic approximations for the significance level of the suggested tests are obtained analytically. Monte Carlo experiments show that the rate of convergence of our asymptotic is fast, and provide accurate results for a level of significance of the suggested tests for sample sizes commonly observed in practice.

Keywords: *change point; nonparametric tests; Mann-Whitney statistics; threshold limit value*

Checking comparative efficiency of public services becomes nowadays an ever growing demand. In developed countries, relative assessment of such services is carried out on a timely basis, to facilitate the process of continuous improvement. In many cases, information regarding comparative efficiency of structural units within a public service causes employees to compete for better achievements, thus enabling mutual improvement of all units involved.

Setting up efficiency targets for public service units necessarily causes employees to maintain awareness of their duties both to the employer, namely the government, as well as to improve and upgrade the quality of service provided to the citizen.

In this course, we witness comparative efficiency assessment of public schools, hospitals, police stations, academic institutions, etc.; the common grounds for all these organizations is their dedication to serve the general public for non-profit purposes, as well as the great number of measurable inputs and outputs to be assessed. In this paper, we will demonstrate efficiency assessment of structural units within the public defense authority in Israel, by means of the Data Envelopment Analysis (DEA) and subject to two ranking methods: Super Efficiency and Cross Efficiency. The efficiency assessment has been carried out among 5 counties (80 units in total) between 2001–2004 on a quarterly basis.

In the given research 3 different inputs and 2 outputs have been investigated. Efficiency ranking and assessment of public defense authority units, to our best knowledge, was never investigated before in scientific literature, which contributes to the novelty of our research.

Keywords: *Data Envelopment Analysis (DEA); Ranking; Super Efficiency; Cross Efficiency; Public defense*

A. Baublys. Modelling of Freight Flows in the Regional Trade Network, *Computer Modelling and New Technologies*, vol. 13, No 3, 2009, pp. 35–43.

The synthesis of regional road transport freight system's topological structure enables the assessment of impact exercised by various structural characteristics on the functioning of system. For this reason increases the quality of project solutions in the stage of system structural synthesis.

Models of optimisation and simulation (included into the simulation procedure of optimisation of topological structure) have other possibilities as well. For instance, simulation model enables the solution of such various objectives of functional analysis of systems as, for example, the efficiency comparison analysis of stability of structure undergoing the changes of meanings of system's parameters, the analysis of managing impacts of various types, loading technologies, etc.

Keywords: *road transport freight, the simulation procedure of optimising*

A. Vasilis Vasiliauskas, J. Barysienė. Review of Current State of European 3PL Market and It's Main Challenges, *Computer Modelling and New Technologies*, vol. 13, No 3, 2009, pp. 44–48.

This article examines basic reasons behind the use of 3PL, i.e. the main drivers of outsourcing (Part 2) as well as explains the essence of 3PL service (Part 3). Part 4 is dedicated to the analysis of current state of 3PL market in Europe. Finally, Part 5 gives an overview of main challenges that European 3PL service providers currently are facing.

Keywords: *3PL service, outsourcing, logistic service providers*

G. Gromov. International Standards for the Use of Biometrics, *Computer Modelling and New Technologies*, vol. 13, No 3, 2009, pp. 49–57.

The systems of identification of an individual in the age of modern technologies are developing fast. However, not many of them received the global recognition. One of the world-wide accepted solutions is the use of such biometric features as the facial image and fingerprints of the person. Such globally interoperable biometric data shall be stored in the so-called "e-passport" and shall be readable in the countries other than the one, which has issued such passport.

This article raises the issues of the existing international technical and legal standards for production and use of e-passports containing the biometric data of individuals, necessary preconditions for the implementation of such standards at the national level, as well examines the regional approach of the European Union to this issue and the results, which were achieved to this day.

Keywords: *biometric features, security, e-passports, public key infrastructure, International Civil Aviation Organisation (ICAO) standards, European Union*

K .C. James. Performance Improvement Studies of an Airport Terminal Using Discrete-Event Simulation, *Computer Modelling and New Technologies*, vol. 13, No 3, 2009, pp. 58–64.

Air travel sector is experiencing phenomenal growth and capacity of airport terminals and associated infrastructure is being seriously challenged. Terminal managements have to take decisions on a variety of issues related to long-term, medium-term and short-term planning. Simulation modelling has been widely used for the design and performance improvement of logistic terminal systems. In this paper we discuss a framework for developing categories of simulation models related to strategic, tactical and operational problems of an airport terminal. We also discuss the use of such models to help solve problems of strategic nature related to fixed facility, tactical problems related to variable facilities, and operational problems related to transient entities and their schedules.

Keywords: *Simulation modelling, Performance improvement, Airport Terminal Systems*

COMPUTER MODELLING and NEW TECHNOLOGIES, 13.sējums, Nr. 3, 2009

(Anotācijas)

A. Kacs, D. Vasermans. Divu hierarhiski rekursīvu metaforu tematiska izpēte informācijas organizēšanas nolūkā: kabineta metafora *versus* koka metaforai, *Computer Modelling and New Technologies,* 13.sēj., Nr.3, 2009, 7.–17. lpp.

Metaforas parasti tiek lietotas mūsu ikdienas valodā.. To struktūra ir mūsu uztvere un saprašana, un tā ir ļoti lietderīga jaunu konceptu apguvē. Uz metaforu bāzēts interfeiss tiek izskatīts *HCI* laukā kā lietošanas vērts un viegli iemācāms tāpēc, ka metaforas atstāsta lietotāja darbības datoru sistēmās jau iepriekš pazīstamus konceptus.

Metaforu vispārējā ideja ir nodot zināšanas no pazīstamas un parasti lielākoties konkrētas pasaules nepazīstamajai un lielākoties abstraktai pasaulei.

Šī pētījuma mērķis ir modelēt un pēc tam izvērtēt divas hierarhiskas uz metaforu bāzētas sistēmas, kuras ir piemērotas bērnu izglītošanas programmai par dzīvnieku valsts un kontinentu informācijas iegūšanu un izpēti: kabineta (objekta-rezervuāra, ligzdveida) metafora un koka (vecāki-bērns) metafora. Vispirms mēs izpētām, kura metafora ir visvairāk piemērota, lai konstruētu bērnu interfeisus. Bez tam mēs arī esam ieinteresēti izpētē, vai bērni nodod hierarhisko organizāciju no viena veida otrā. Laboratorijas eksperimentā dalībnieki sadarbojās ar divām uz metaforu bāzētām sistēmām bērnu izglītošanā. Mūsu bērni-dalībnieki lietoja sistēmas, lai rastu atbildes uz jautājumiem, kuri attiecās uz dzīvniekiem un kontinentiem. Mēs vērtējām izpildi pēc uzdevumiem, un subjektīvie aspekti ir tādi kā pieredze un lietotāja gandarījums. Mēs testējām hipotēzes, ka bērni kognitīvi nodod hierarhisko organizāciju.

Atslēgvārdi: *hierarhiskas rekursīvas metaforas, informācijas organizācija*

G. Gurevičs. Asimptotiskais sadalījums Mann-Whitney tipa statistikai neparametrisko izmaiņu punkta problēmām, *Computer Modelling and New Technologies,* 13.sēj., Nr.3, 2009, 18.–26. lpp.

Literatūra atspoguļo izmaiņu punkta atklāšanas problēmas viena galvenā izdevuma kontekstā, kas pieder pie testējamām statistiskām hipotēzēm. Šī raksta galvenais mērķis ir īsumā pārskatīt neparametriskas retrospektīvas izmaiņu punkta politikas, piedāvājot jaunus atbilstošus testus, pamatotus uz *Mann-Whitney* tipa statistiku. Asimptotiskās aproksimācijas piedāvāto testu nozīmīguma līmenim tiek iegūtas analītiski. *Monte Carlo* eksperimenti parāda, ka mūsu asimptotiķa proporcijas konverģence ir ātra, un nodrošina precīzus rezultātus piedāvāto testu nozīmīguma līmenim.

Atslēgvārdi: *izmaņu punkts, neparametriskie testi, Mann-Whitney statistika, sākumpunkta limita vērtība*

V. Hadads, A. Ben-Jears, L. Frīdmans. Efektivitātes salīdzinošā analīze un sabiedriskās aizstāvības autoritātes ranžēšana Izraēlā, *Computer Modelling and New Technologies,* 13.sēj., Nr.3, 2009, 27.–34. lpp.

Sabiedrisko pakalpojumu kontrolei mūsdienās ir ļoti liels pieprasījums. Attīstītajās valstīs šādu pakalpojumu relatīvs novērtējums tiek veikts periodiski, lai sekmētu nepārtrauktu procesa uzlabošanos. Daudzos gadījumos informācija, kura prasa strukturālo vienību salīdzinošu efektivitāti sabiedriskajos pakalpojumos izraisa nodarbināto sacensību par labākiem rezultātiem, tādējādi iedarbinot visu iesaistīto vienību savstarpējo uzlabošanos.

Izvirzot sabiedrisko pakalpojumu efektivitātes uzlabošanās mērķus, nodarbinātajiem rada uzturēt īpašu vērību attiecībā uz veicamo darbu izpildi, piesaistot kā darba devēju, tā arī valdību sabiedrisko pakalpojumu kvalitātē, sniedzot tos pilsoņiem.

Šajā sakarā tiek novērots salīdzinošās efektivitātes novērtējums sabiedriskajās skolās, slimnīcās, policijas iestādēs, kā arī austākajās mācību iestādēs. Strukturālo vienību efektivitātes novērtējums Izraēlā tika veikts no 2001–2004 gadam 5 reģionos, pielietojot datu analīzi – *Data Envelopment Analysis (DEA)* un divas ranžēšanas metodes – *Super Efficiency* un *Cross Efficiency*.

Atslēgvārdi: *datu analīze – Data Envelopment Analysis (DEA); ranžēšana; pilnīga efektivitāte – Super Efficiency; Cross Efficiency; publiskā aizstāvība*

A. Baublys. Kravu plūsmu modelēšana reģionālajā tirdzniecības tīklā, *Computer Modelling and New Technologies,* 13.sēj., Nr.3, 2009, 35.–43. lpp.

Reģionālo ceļu kravu transporta sistēmas topoloģiskā struktūras sintēze veicina ietekmes novērtēšanu, kas ir izvērtēts no dažādu strukturālu sistēmu funkcionēšanas raksturojumu viedokļa. Šim nolūkam projekta risinājumu kvalitāte uzlabojas sistēmas strukturālās sintēzes stadijā.

Optimizācijas un imitācijas modeļiem ir arī citas iespējas. Piemēram, imitācijas modelis sekmē tādu dažādu sistēmas funkcionālās analīzes mērķu risinājumu kā, piemēram, stabilitātes salīdzinošās analīzes efektivitāte, kas pakļauta sistēmas parametru nozīmju izmaiņām; dažādu tipu regulēšanas analīze; iekraušanas tehnoloģijas u.c.

Atslēgvārdi: *ceļu kravas transports, optimizēšanas procedūras imitācija*

A. Vasilis Vasiliauskas, J. Barisiene. Eiropas 3PL tirgus pašreizējā stāvokļa pārskats un tā galvenie uzdevumi, *Computer Modelling and New Technologies,* 13.sēj., Nr.3, 2009, 44.–48. lpp.

Rakstā tiek izskatīti pamata gadījumi, kas ļauj izmantot 3PL, t.i., galvenais līgumdarbu piesaistīšanas virzītājspēks (2. daļa), kā arī izskaidro 3PL servisa būtību (3. daļa). Šī darba 4. daļa ir veltīta Eiropas 3PL tirgus pašreizējā stāvokļa analīzei. Savukārt 5. daļā ir dots pārskats par galvenajiem izaicinājumiem, ar ko Eiropas 3PL tirgus servisa nodrošinātāji pašreiz saskaras.

Atslēgvārdi: *3PL serviss, līgumdarbu piesaistīšana, loģistikas pakalpojumu nodrošinātāji*

G. Gromovs. Biometrikas lietošanas starptautiskie standarti, *Computer Modelling and New Technologies,* 13.sēj., Nr.3, 2009, 49.–57. lpp.

Individualitātes identifikācijas sistēmas moderno tehnoloģiju laikmetā attīstās ļoti ātri. Tomēr ne visas no tām ir guvušas globālo atzinību. Viens no pasaules pieņemtajiem risinājumiem ir tādu biometrijas īpašību lietošana kā personas sejas izteiksme un pirkstu nospiedumi. Šādi savstarpēji operējami biometrijas dati tiks glabāti tā saucamajā e-pasē un būs nolasāmi arī citās valstīs, ne tikai tajā, kura ir izsniegusi šādu pasi. Šis raksts paceļ strīdus jautājumu jau par eksistējošiem starptautiskajiem tehniskajiem un likumdošanas standartiem par e-pases, kura satur indivīda biometrijas datus, uzrādīšanu un lietošanu. Bez tam raksts izpēta arī ES reģionālo pieeju šim strīdus jautājumam, kā arī sniedz tos rezultātus, kas ir sasniegti šodien.

Atslēgvārdi: *biometrijas īpašības, drošība, e-pases, Starptautiskā Civilās aviācijas organizācijas – International Civil Aviation Organisation (ICAO) – standarti, sabiedriskā koda infrastruktūra, Eiropas Savienība*

K. C. Džeimss. Lidostas termināļa pētījuma izpildes uzlabošanās diskrēta notikuma imitācijas ietvaros, *Computer Modelling and New Technologies,* 13.sēj., Nr.3, 2009, 58.–64. lpp.

Gaisa ceļošanas sektors izbauda fenomenālu izaugsmi un lidostu termināļu jaudu, līdz ar to tam piekļaujošamies infrastruktūra tiek nopietni izaicināta. Termināļa pārvaldei ir jāpieņem lēmumi daudzos strīdus jautājumos, kas attiecas uz ilglaicīgu, vidēju un īsu periodu plānošanu. Imitācijas modelēšana tiek plaši lietota loģistikas termināļa sistēmas projektēšanai un darbības uzlabošanai. Šajā rakstā autors iztirzā simulācijas modeļa, kas attiecas uz lidostas termināļa stratēģijas, taktikas un darbības problēmām, attīstības kategoriju struktūru. Bez tam tiek arī iztirzāti tādi modeļi, kas palīdz risināt stratēģiskas dabas problēmas, attiecināmas uz nemainīgām iekārtām, taktiskas problēmas attiecināmas uz mainīgām iekārtām un darbības problēmas attiecināmas uz pagaidu objektiem un to grafikiem.

Atslēgvārdi: *imitācijas modelēšana, darbības uzlabošana, lidostas termināļa sistēmas*

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