PERIODICA POLYTECHNICA SER. TRANSP. ENG. VOL. 27, NO. 1–2, PP. 43–59 (1999)

MODELLING OF COMPUTER INTEGRATED TRANSPORTATION

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Received: June 30, 1999

Abstract

The modern control of physical processes of transportation requires the development and then the integration of computer aided functional subsystems. In this integrated system a database working as a network centre has to be created. The concept of computer integrated transportation is the integrated telematics computer use related to all parts of transport organisation and processes. The several computer aided functions begin with transport planning, continue with operative control of transport processes and are completed with account. Exact modelling is indispensable in analytic and design work. The presented metamodel involves the general and integrated inner structure and the general alphanumeric model of computer aided subsystems. The connection model of the computer aided subsystems helps analysis, evaluation and design of the complex information system of computer integrated transportation.

Keywords: computer integrated transportation, computer aided subsystems in transportation, modelling, alphanumeric models.

1. Antecedents and Bases of Computer Integrated Transportation

1.1. Disciplinary and Technical Antecedents of Coming into Being of the CIT

Long time development preceded the formation of the Computer Integrated Transportation (CIT). Results achieved in different branches of science and in technics rendered the creating of a high integrated system in transportation possible. The computer integrated transportation is a typical interdisciplinary specialization. Its essence is the system-view integration of means of the advanced transport technology, the telematics, namely the information technology, and the telecommunication technique.

The computer integrated transport system uses the principles and results of different disciplines to achieve its aims. It is in close relation with many branches of natural and technical sciences. The models are relying on that kind of disciplines that had been developed to establish the complex planning, organizing and control of complicated processes. From these mainly the cybernetics, the information theory, the informatics, the telematics, the system theory, the system technology and the system analysis play a significant role.

For practical realization of the computer integrated transport system is needed to use knowledge of many specialization. These special fields are parts of the transport science, like transport networks, vehicles, transport automatons, transport processes, transport technology, transport organization, transport economics, transport informatics, transport telematics.

Considering the technical means, the significant development in field of transport automatons, telecommunication technology, and computers has contributed to formation of integrated transport system. *Figure 1* gives a summary of disciplinar and technical antecedents of coming into being of the CIT.

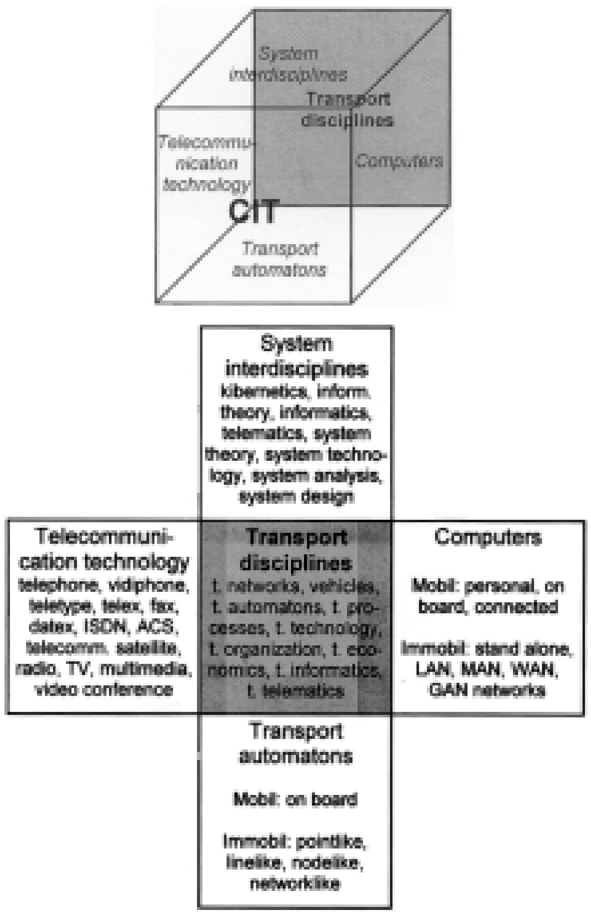

Fig. 1. Disciplinary and technical antecedents of coming into being of the CIT

1.2. The Computer Integrated Manufacturing (CIM), Like an Antecedent

For developing of computer integrated transportation it is needed to derive from the experience of Computer Integrated Manufacturing (CIM) [1].

Research work for years went before coming into being of computer integrated manufacturing. The bases of the CIM system were computer data-processing systems of the production engineering and production control system. The fundamental aim of researches was to integrate the information-processing tasks of economic and technological-construction fields into one system with common basic database.

The conception of computer integrated manufacturing is complex. It means not only simply the integration of manufacturing equipment and computers but the union of technological, electronic and information systems as well. The concept of ‘integrated manufacturing’ was born in the beginning of 1970-s, according to today’s interpretation *on concept of computer integrated manufacturing* is meant the integrated use of computers in all fields being connected with the production, from the planning through the supplying to the comprehensive information system. Consequently, it means essentially the building of computer aided systems of different functions relating to production to a consistent information system [2]. Local network, uniform database and message services provide informatics connections for the application moduls in the CIM.

It shows the remarkable complexity of the CIM concept that it contains integration of three tendencies:

- the joint of the consecutive manufacturing phases so that the rate of production will be maximum,
- the integration of control levels being above each other,
- the integration of company functions working side by side.

The activity fields of CIM, although are first of all connected with the manufacturing, yet almost all of them demand the services of computer science in any way. Mostly two directional, complex data and information connections exist between the certain activity fields.

The basis activities realized in the CIM:

- the management of materials,
- the manufacturing of parts and the assembly,
- and the supervision of quality.

The main functions and activities, that are based on the basis activities and realized in the CIM, giving the usual abbreviations that is the initial letters of words in round brackets as well are the followings:

- Management Information System (MIS),
- Computer Aided Storage and Transportation (CAST),
- Production Planning Schedule (PPS),
- Computer Aided Process Planning (CAPP),
- Computer Aided Engineering (CAE),

– Computer Aided Quality Assurance (CAQA),
– Computer Aided Production Control (CAPC),
– Computer Aided Manufacturing, Maintenance (CAM).

The activity model of the CIM can be seen on the *Fig. 2* [1], which illustrates the activity hierarchy and the information connections of subsystems associated with certain main activities. The CIM means not exclusively the computerised connection and information flows of elements of the system, but prescribes the regulated and harmonious information exchange between the colleagues.

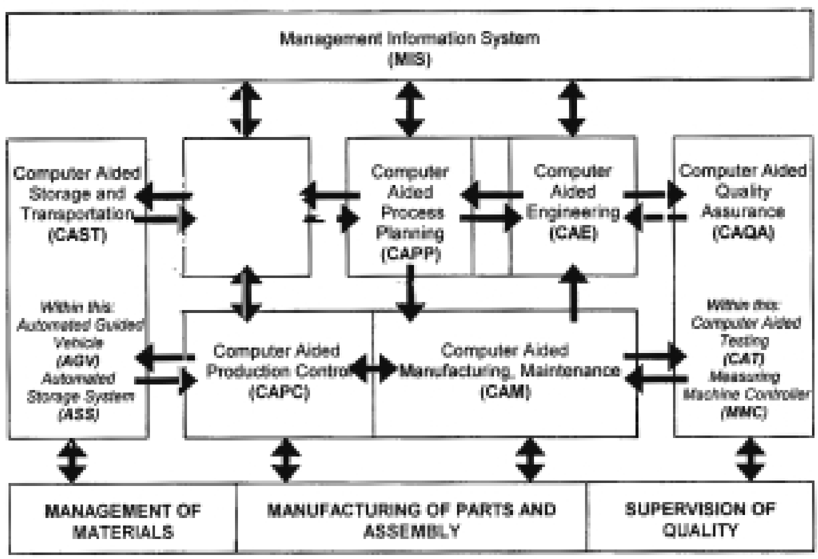

Fig. 2. Activity model of the CIM

The computer integrated, flexible manufacturing systems lay specific claims towards the transport system. There are several reasons for it.

– The decrease of the depths of manufacturing is a consequence of this kind of manufacturing systems, and being connected with it, the increase of the number of the providers (carriers).
– Transport system has to adjust itself to the ‘Just in time’ principle that is required in the manufacturing.
– The transport system has to be reliable and flexible.
– It is necessary to provide the appropriate accessibility to information regarding the loads.
– The manufacturing systems can require the use of special vehicles.

These requirements expect the realization of that kind of computer integrated flexible transport system (CIT), which is connected with the manufacturing system

(CIM) by means of supply-distribution systems (Computer Integrated Logistics = CIL). The flexible transport system creates the connections between the raw material and part sources and the consumers using appropriate technical, technological and informatics background. *Figure 3* shows the connection of the computer integrated transport and manufacturing system.

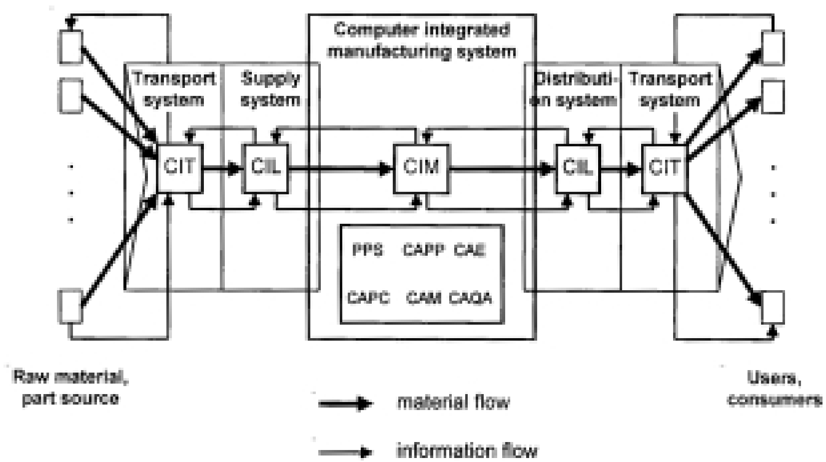

Fig. 3. Connection of the computer integrated transport and manufacturingsystem

1.3. The Definition of Computer Integrated Transportation

The *models* can be considered more or less true abstractions of objective reality. The *system model* is a simplified abstraction of the real system that stresses the substantial – from the point of view of research – attributes. It disregards all the attributes that are not specific with a view to set research.

At creating of *metamodel* of the computer integrated transport system the aim was not to overview the concrete solutions adopted already with success in some part of the world, but to present the general principles, models and methods that explore the purposes, functions, structure, connections with surroundings and most important features of CIT systems.

The *concept of computer integrated transportation* is meant to be the integrated use of telematics and computers, related to all parts of transportation. The several computer aided functions begin with transport planning, continue with operative control of transport and are completed with account. At integration these computer integrated systems have to be joined to a consistent information system [2].

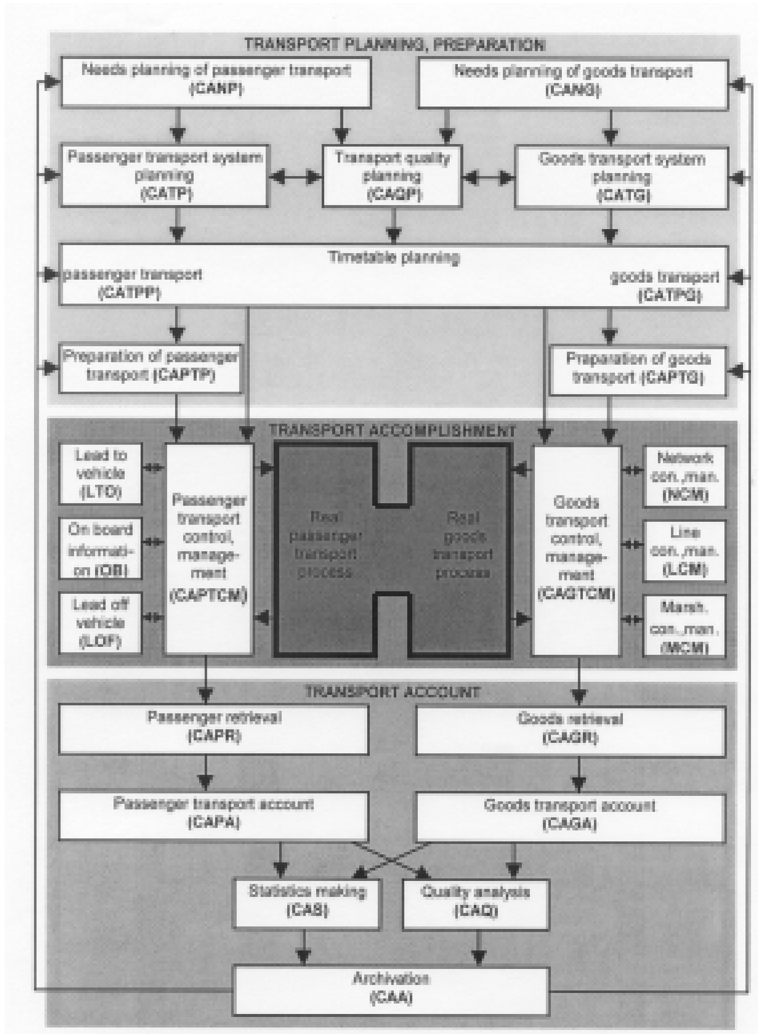

Fig. 4. Processlogical sequence of CA subsystems by CIT

2. The Components of Computer Integrated Transportation, the Computer Aided Subsystems

2.1. Main Groups of CA Subsystems

The Computer Aided (CA) subsystems can be classed around three groups by the process oriented approach. These groups are the followings:

– planning, preparation CA systems,
– accomplishment CA systems,
– account CA systems.

In these groups the systems can be distinguished separately connected to the passenger transport and to the goods transport. The initial letters of words of the systems' name are used to mark the systems.

CA systems of transport planning, preparation:

– needs planning of passenger transport: CANP,
– needs planning of goods transport: CANG,
– passenger transport system planning: CATP,
– goods transport system planning: CATG,
– transport quality planning: CAQP,
– timetable planning of passenger transport: CATPP,
– timetable planning of goods transport: CATPG,
– preparation of passenger transport: CAPTP,
– preparation of goods transport: CAPTG.

CA systems of transport accomplishment:

– passenger transport control, management: CAPTCM,
– passenger lead to vehicle: LTO,
– passenger information on board: OB,
– passenger lead of vehicle: LOF,
– goods transport control, management: CAGTCM,
– goods transport control, management on network: NCM,
– goods transport control, management on line: LCM,
– goods transport control, management at marshalling: MCM.

CA systems of transport account:

– passenger retrieval: CAPR,
– goods retrieval: CAGR,
– passenger transport account: CAPA,
– goods transport account: CAGA,
– prepare of statistics: CAS,
– quality analysis: CAQ,
– prepare of archives: CAA.

In addition to systems classed among three main groups the Computer Aided Management Information System (CAMIS) works aiding the decision making tasks of transport control people. This system is on the highest level of hierarchy of systems.

2.2. The Processlogical Order of CA Subsystems by CIT

The systematization of stated CA subsystems following the schedule of whole transport process can be seen in *Fig. 4.* The logical connections between the subsystems and the direction of connections also can be seen in the figure.

The real passenger and goods transport processes are in the middle of entire process. There are close connections between these two processes, seeing that forwarding of passengers and goods occurs with making use mostly of the same infrastructure. For this reason the operation of timetable-making for passenger and goods transport cannot be separated.

In the figure it can be seen that one part of archival data are used by the computer aided subsystems of transport planning and preparation phase. This feedback makes taking into consideration the processed, systematic data regarding the transport tasks of previous period possible at planning and preparation of later transport plans.

3. Inner Structure of Subsystems

3.1. General Inner Structure of CA Subsystems

It is needed to simplify to the possible degree the computer aided subsystems of transport system before the integration of them, even if that kind of efficient instruments available like that are provided by the most modern informatics infrastructure. This step is a substantial prerequisite for joining the certain subsystems into a consistent system.

Each subsystem has information connection with several other subsystems. It means that the subsystem makes use of the output information of other subsystems for functioning, and the output information of the subsystems is used for the input information of other subsystems. The general inner structure of subsystems can be seen in *Fig. 5,* where the subsystems are designated only with CA. In the figures and in the following at taking the alphanumerical models down the general notation below can be used:

A – algorithm of the subsystem,
${}_iI$ – input information of subsystem algorithm,
${}_TI$ – stored information used by subsystem algorithm,
${}_oI$ – output information of subsystem algorithm.

Next to symbols in right lower index using capital letters is the abbreviation of the subsystem name, and/or the numerical index indicating the further differentiation.

Within a subsystem the algorithms determine the processes. The algorithm is a kind of procedure sequence to solve a set task whose essence is to decompose the task in succession of unambiguously defined elementary steps (operations). In what follows the algorithm is regarded as a *procedure to solve a task using computer.* The number of algorithms (n) depends on the number of tasks executed within the subsystem. Among the different algorithms can be overlaps, namely the certain

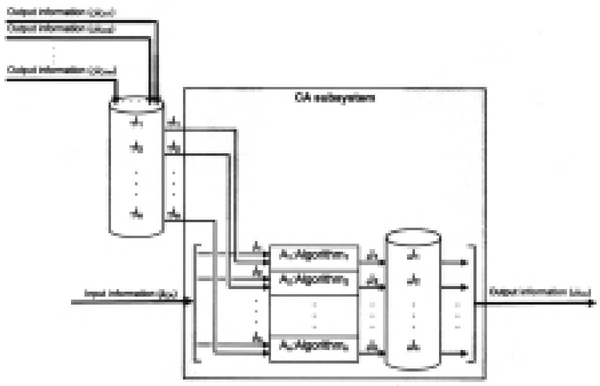

Fig. 5. The general inner structure of subsystems

operations (operation sequences) of the subsystem can constitute the part of several algorithms, too. One algorithm makes use of that part of input information of the subsystem that is necessary as input data for the own operations. Consequently, each group of input information can be used by several algorithms.

Beside the input information, stored data are also needed for functioning of algorithms. Similarly to the input information, each group of the stored data can be used by several algorithms, too, that is among the stored information used by certain algorithms can be overlaps. The output information of connected subsystems (m) gets to the common database of the stored information.

The output information originating in outcome of executed algorithms is stored in the database of the subsystems till the additional use. Although among the output data of algorithms are common ones, still the output information of the certain algorithms have to be handled separately.

3.2. Inner Structure of Computer Aided Preparation of Passenger Transport Subsystem (CAPTP)

The stated general inner structure of the subsystems can be illuminated by an example regarding a concrete subsystem. The chosen subsystem is the computer aided preparation of the passenger transport subsystem (CAPTP).

This subsystem makes use of output information of three computer aided subsystems ($m = 3$) for functioning, the passenger transport system planning (CATP), the timetable planning of passenger transport (CATPP), and the prepare of archives (CAA). These pieces of information are stored in common database.

Within the subsystem four functions can be distinguished ($n = 4$). These are:

A_1 – asking for timetable information,
A_2 – itinerary preparation,
A_3 – seat reservation,
A_4 – ticket purchase.

The algorithms executing these tasks include common operations, too. For example one operation sequence (subalgorithm) is the part of all of first three algorithms. It accomplishes the searching of services between two points, and the searching of transport means running on these services and given by appropriate identify mark and time data. Consequently, the input data are needed for this algorithm-part (origin point, destination point, time data, comfort class, etc.) and correspond in case of all three of algorithms, too.

Similarly, all three of algorithms make use, for example, of data of the services planned by the CATP subsystem or timetable data planned by CATPP subsystem. These data – with archival data – can be retrieved from the common database containing the output information of CATP, CATPP and CAA subsystems.

The output data of algorithms of the computer aided preparation of passenger transport subsystem (CAPTP) remain in output database of the subsystem for longer or shorter time. For example, the data of itineraries are used immediately. For later use, the making use of data of seat reservation at passenger retrieval is an example. In the computer integrated transport system the output information of the computer aided preparation of passenger transport subsystem (CAPTP) is used by the computer aided passenger transport control, management (CAPTCM), and the computer aided passenger retrieval (CAPR) subsystems.

4. Alphanumeric Model of Subsystems

4.1. General Alphanumeric Model of CA Subsystems

Let mark A_{CAs} the s-th algorithm of the subsystem,
$_iI_{CAs}$ the input information of s-th algorithm of the subsystem,
$_TI_{CAs}$ the stored information used by s-th algorithm of the subsystem,
$_oI_{CAs}$ the output information of s-th algorithm of the subsystem, where $s = 1, 2, \ldots n$.

It happens that domain extends not uniformly from 1 to n.

At this notation the result of s-th algorithm of the subsystem using input $_iI_{CAs}$ and $_TI_{CAs}$ information can be represented by model function:

$$_oI_{CAs} = A_{CAs}\left({}_iI_{CAs}, {}_TI_{CAs}\right). \tag{1}$$

The output information of the subsystem can be expressed as the sum of output information of the algorithms

$$ {}_oI_{CA} = \sum_{s=1}^{n} {}_oI_{CAs}. \tag{2} $$

Because of the mentioned overlap possibilities the algorithm, the input information, and the stored information needed for functioning of the subsystem can be formed as the union of the certain components. Namely:

$$ A_{CA} = \{A_{CA1}, A_{CA2}, \dots, A_{CAn}\} = \bigcup_{s=1}^{n} A_{CAs}, \tag{3} $$

$$ {}_iI_{CA} = \{{}_iI_{CA1}, {}_iI_{CA2}, \dots, {}_iI_{CAn}\} = \bigcup_{s=1}^{n} {}_iI_{CAs}, \tag{4} $$

$$ {}_TI_{CA} = \{{}_TI_{CA1}, {}_TI_{CA2}, \dots, {}_TI_{CAn}\} = \bigcup_{s=1}^{n} {}_TI_{CAs}. \tag{5} $$

The sequence of representation of relations reflects an output oriented approach.

The stored information needed for functioning of the subsystem can be represented as the sum of output information of that subsystems, that provides data for functioning of the algorithms. Namely:

$$ {}_TI_{CA} = \sum_{r=1}^{m} {}_oI_{CAr}, \tag{6} $$

where ${}_oI_{CAr}$ $(r = 1, 2, \dots, m)$ marks the output information of the certain subsystems being taken into consideration.

4.2. Alphanumeric Model of Computer Aided Preparation of Passenger Transport Subsystem (CAPTP)

The stated general alphanumeric model of the subsystems can be illuminated by an example regarding a concrete subsystem. The chosen subsystem is the computer aided preparation of passenger transport subsystem (CAPTP).

The model *Eqs* (1)–(6) stated at the general model, for instance, in case of this subsystem can be represented as follows:

$$ {}_oI_{CAPTPs} = A_{CAPTPs}\left({}_iI_{CAPTPs}, {}_TI_{CAPTPs}\right), \tag{7} $$

$$ {}_oI_{CAPTP} = {}_oI_{CAPTP1} + {}_oI_{CAPTP2} + {}_oI_{CAPTP3} + {}_oI_{CAPTP4}, \tag{8} $$

$$ \begin{aligned} A_{CAPTP} &= \{A_{CAPTP1}, A_{CAPTP2}, A_{CAPTP3}, A_{CAPTP4}\} \\ &= A_{CAPTP1} \cup A_{CAPTP2} \cup A_{CAPTP3} \cup A_{CAPTP4}, \end{aligned} \tag{9} $$

$$
\begin{aligned}
{}_iI_{CAPTP} &= \{{}_iI_{CAPTP1}, {}_iI_{CAPTP2}, {}_iI_{CAPTP3}, {}_iI_{CAPTP4}\}\\
&= {}_iI_{CAPTP1} \cup {}_iI_{CAPTP2} \cup {}_iI_{CAPTP3} \cup {}_iI_{CAPTP4}, \qquad (10)\\
{}_TI_{CAPTP} &= \{{}_TI_{CAPTP1}, {}_TI_{CAPTP2}, {}_TI_{CAPTP3}, {}_TI_{CAPTP4}\}\\
&= {}_TI_{CAPTP1} \cup {}_TI_{CAPTP2} \cup {}_TI_{CAPTP3} \cup {}_TI_{CAPTP4}, \qquad (11)\\
{}_TI_{CAPTP} &= {}_oI_{CATPP} + {}_oI_{CATP} + {}_oI_{CAA}. \qquad (12)
\end{aligned}
$$

Content of notation used at the above relations:

$_oI_{CAPTP1}$ – data of timetable extracts,
$_oI_{CAPTP2}$ – data of itineraries,
$_oI_{CAPTP3}$ – data and data assemblies regarding the reserved seats,
$_oI_{CAPTP4}$ – data and data assemblies regarding the purchased tickets,

A_{CAPTP1} – algorithm of asking for timetable information,
A_{CAPTP2} – algorithm of itinerary planning,
A_{CAPTP3} – algorithm of seat reservation,
A_{CAPTP4} – algorithm of ticket purchase,

$_iI_{CAPTP1}$ – fed data by passenger at asking for timetable extract,
$_iI_{CAPTP2}$ – fed data by passenger at asking for itinerary,
$_iI_{CAPTP3}$ – given data by passenger at seat reservation,
$_iI_{CAPTP4}$ – given data by passenger at ticket purchase,

$_TI_{CAPTP1}$ – stored data needed for timetable extract making,
$_TI_{CAPTP2}$ – stored data needed for itinerary planning,
$_TI_{CAPTP3}$ – stored data needed at seat reservation,
$_TI_{CAPTP4}$ – stored data needed at ticket purchase.

In the same manner we can prepare alphanumeric model equations for every subsystem related to transport planning and preparation, and transport account. The next chapter describes the CA subsystem of transport accomplishment phase in details.

5. The CA Subsystem of Transport Accomplishment Phase, and its Alphanumeric Model

5.1. Main Components for Inner Structure of CA Subsystem of Transport Accomplishment

The structure and function of the computer aided passenger transport control, management and computer aided goods transport control, management subsystems (CAPTCM, CAGTCM) partly differ from that of the other CA subsystems. These subsystems are based on the real passenger and goods transport processes.

Part systems aiding the lead of passenger to vehicle (LTO), the information service on board of vehicle (OB), and the lead of passenger off vehicle (LOF) are closely connected with the passenger transport control and management subsystem (CAPTCM). The algorithm of the mentioned three subsystems constitutes the part of algorithm of the passenger transport control and management subsystem (CAPTCM). And these algorithms make use of stored information of CAPTCM subsystem, too.

Similarly, part systems aiding the control of goods transport on the network (NCM), on the line (LCM), and at the marshalling (MCM) are in close relations with the goods transport control, management subsystem (CAGTCM). The algorithm of the listed three subsystems constitutes the part of algorithm of the goods transport control, management subsystem (CAGTCM). And the mentioned algorithms make use of stored information of CAGTCM subsystem too.

The structure of the CA subsystem of the transport accomplishment phase can be seen in *Fig. 6.* In the figure and at taking the alphanumerical model down we have disregarded inner, according to tasks decomposition of subsystems. This decomposition can be done in a way stated at general inner structure of CA subsystems, and on the basis of (2)–(5) equations of alphanumeric model.

5.2. *Alphanumeric Model of CA Subsystem of Transport Accomplishment Phase*

Accordingly, the model equations regarding to the passenger transport part of the transport accomplishment phase are:

$$A_{LTO}, A_{OB}, A_{LOF} \subset A_{CAPTCM}, \tag{13}$$

$${}_oI_{CAPTCM} = A_{CAPTCM}\left({}_iI_{LTO}, {}_iI_{OB}, {}_iI_{LOF}, {}_TI_{CAPTCM}\right), \tag{14}$$

$${}_TI_{CAPTCM} = {}_oI_{CAPTP} + {}_oI_{CATPP}, \tag{15}$$

$${}_oI_{LTO} = A_{LTO}\left({}_iI_{LTO}, {}_TI_{CAPTCM}\right), \tag{16}$$

$${}_oI_{OB} = A_{OB}\left({}_iI_{OB}, {}_TI_{CAPTCM}\right), \tag{17}$$

$${}_oI_{LOF} = A_{LOF}\left({}_iI_{LOF}, {}_TI_{CAPTCM}\right). \tag{18}$$

In the same way like model equations regarding to passenger transport part of the transport accomplishment phase, the relations modelling the functioning of goods transport part can also be represented on the basis of *Fig. 6.*

6. Connecting of CIT Subsystems into a Consistent System

The essence of the computer integrated transportation is to integrate the computer aided or computer controlled functional subsystems into a consistent system. In accordance with it, every model that abstracts the functional structure of the CIT has to place the subsystems able to work independently in the complete system. *Figure 7*

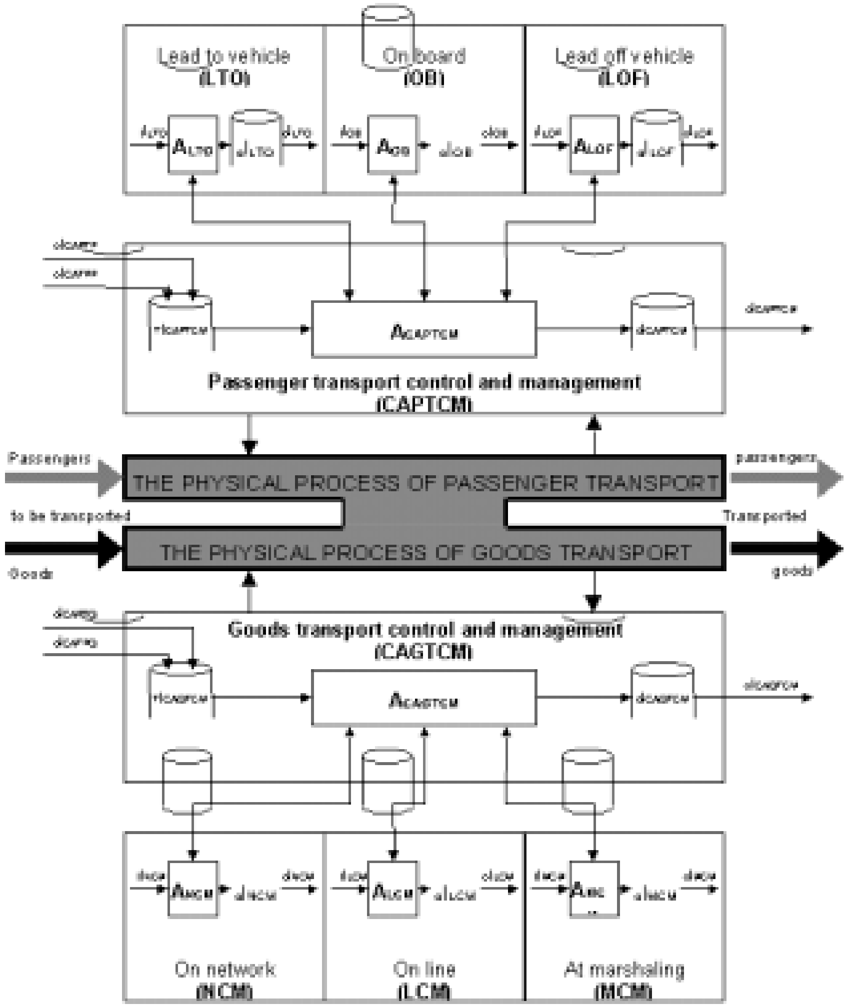

Fig. 6. Structure of CA subsystem of the transport accomplishment phase

shows the connection model of the CIT subsystems. In the figure can be found the main functional subsystems and the most important information connections of subsystems between each other.

The CIT establishes not only the transport process but makes closer, regular and frequent relations between the different functional units by means of use of one fundamental resource of processes, the *information*. On the one hand the information systems connected with certain functions have to execute the own specific tasks, on the other hand have to use information produced by other units

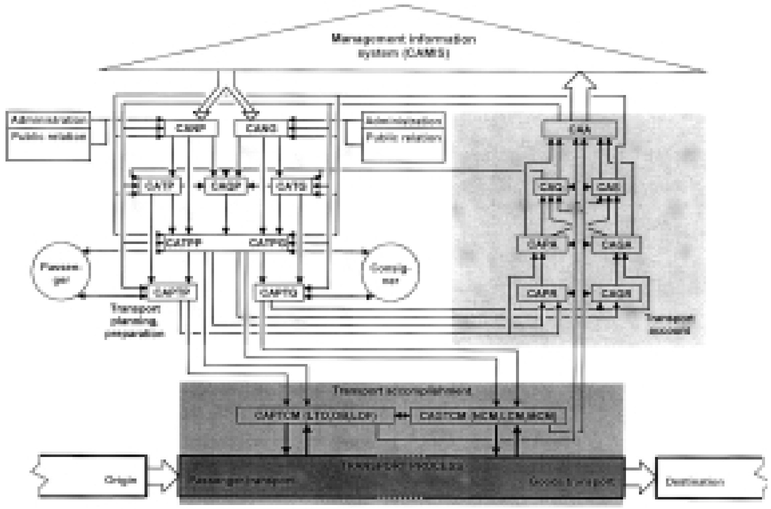

Fig. 7. The subsystems of CIT connected to an integrated system

and have to forward information for the other components of the information system being related with them.

An integrated information system means at the same time the more intensive use of data processing tools and the forming of a consistent, open computer structure, that contains computers, databases, knowledge bases, user applications, communication systems which are needed for local and long-distance networks, as standard elements.

In a computer integrated transport system a huge information mass has to be handled quickly, safely and continuously. Therefore, the use of modern *information technology* is indispensable. Its most important advantage is that computers are able to provide a fixed performance in constantly decreasing prices, increasing reliability and more user-friendly features. The unified information flows increase the flexibility, on the other hand the technique offers alternatives for the organization.

The computer aiding of the integration of transport accomplishment functions (CIT) is much more than the use of the up-to-date technique. The CIT is not a ready-to-use, standard product but a fit solution that is developed by none-series conception, with cooperation of all individual departments of the transport company. This kind of 'ambition for full-scale' is unimaginable without an overall methodology, then again there are numerous specialities at realization in practice.

At forming of the individual subsystems providing the certain functions the aim was to develop the optimum operation of the given subsystem. At integration of subsystems, instead of optimum operation of subsystems, the ambition for optimum operation of a complete system has to be succeeded. The *optimatization* means in the most common sense of the word that we do that kind of measures in a system that we can achieve *maximal effect* with.

At creating of the computer integrated transport system a *database functioning as the centre of the network* is needed. For producing the appropriate informatics, telematics tools and the tools of computer technique have to be used. In this database all the data flows logically assemble together [3]. The data handled in the common database by database system can be stored decentralized, distributed, too. The sector model illustrating the functions of the computer integration transport system relied on common database can be seen in *Fig. 8.*

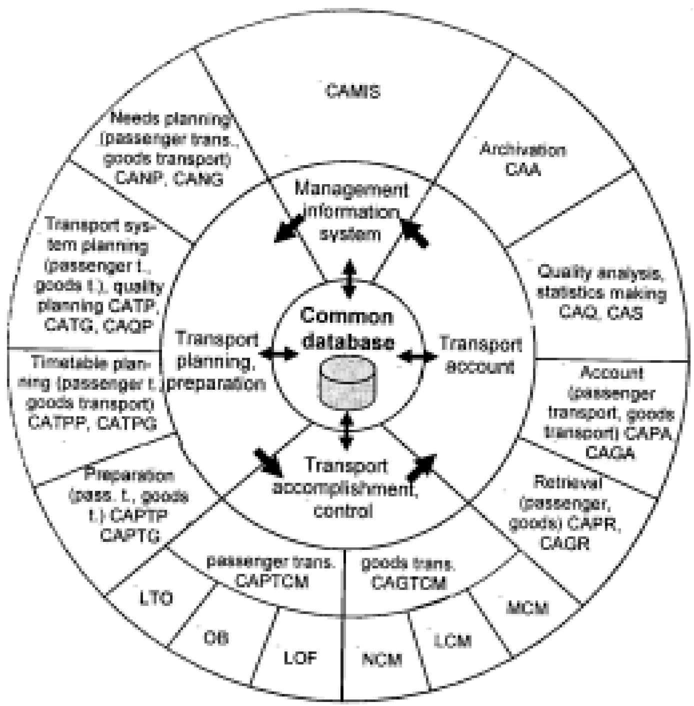

Fig. 8. Sector model of the computer integrated transport

The consistent database-handling in the CIT system makes regular comparing of the planned and real data regarding the quality of transport possible. It makes the detection of unfavourable occurrences, tendencies resulting during the accomplishment of transport task, then its regulation back possible. It is important for that reason, because the quality insurance, the control and recording of quality indexes are important tasks in the field of transportation, too. This requirement can be granted by use of *control structures.*

7. Conclusions

The increasing demands in the transportation are aimed at quickness, elasticity, reliability in sum increase of level of transportation. In accordance with it, the modern control of physical process of transport requires the developing of the communication, information and informatics systems on high level, and then the integrated building together with these components. The creation of the stated computer integrated transport system is great leap forward the realization of this aim.

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