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ROUTING PROBLEMS BASED ON HILS SYSTEM PLATFORM

Andrzej Adamski

AGH Krakow University of Science and Technology, Krakow, **Poland**

ABSTRACT. Background: The logistic systems are very complex socio-technical systems. In this paper the proposal of application of the hierarchical multi-layers system platform HILS approach for the solution of the complex vehicle routing problems is presented. The interactive system functional structure was proposed which by intelligent dedicated inter-layers interactions enables the professional solutions of these practical problems. To illustrate these capabilities the complex example of the real-time VRP-SPD-TW routing problem was presented in which upper layers offers the context-related real-time updating network specifications that stimulates the adequate routing parameters and specifications updating for problem solution in optimization layer. At the bottom dispatching control layer the DISCON (Dispatching CONtrol) method from public transport was adopted to logistics applications in which the actual routing is treated as obligatory reference schedule to be stabilized. The intelligence aspects are related among others to HILS based decomposition, context-related trade-offs between routing modifications and corrective dispatching control capabilities e.g. priority or route guidance actions.

Methods: Decomposition of the vehicle routing problem for the HILS layers tasks creating the ILS system hierarchical structure. Dedicated solution method for the VRP-SPD-TW routing problem. The recognition of the control preferences structure by AHP-Entropy methods. DISCON and PIACON multi-criteria interacting control methods.

Results: Original formulation and solution of the vehicle routing problem by system-wide approach with essential practical advantages: consistency, lack of redundancy, essential reduction of dimension, dedicated formulation, multi-criteria approach, exploration of the integration and intelligence features supported by the intelligent PIACON-DISCON methods control activities

Conclusions: The presented proposal creates the professional approach to the solution of the crucial problems in logistics systems with the implementation of modern tools and enabling technologies.

Key words: ILS systems, systems intelligence, vehicle routing problems, multi-criteria dispatching control, system-wide approach, HILS system platform, decomposition of the optimisation problems.

INTRODUCTION

The provision by logistics systems of the high quality on-time and reliable service is a key operational problem which affects both customers (influences their service standards), logistic operators (best use of existing resources) and the city community (potential to mitigate of the negative congestion and environmental problems especially in the central parts of the cities).

There are many papers in scientific literature covering the development of various systems connected with above mentioned problems [Mingyong 2014, Shrestha 2014, Gorodestskii 2011].

The professional HILS (Hierarchical Integrated Intelligent Logistic Systems) platform for development of ILS systems was proposed from the perspective of modern system-wide capabilities supported by new available technologies and professional tools [Adamski 2003, 2011b]. The main functional

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features specifications of HILS includes: practically efficient individual ILS systems solutions, dedicated to high level of complexity, stimulating the system efficiency and productivity (e.g. system-wide activities coherency and understanding system processes/ mechanisms), exploration of system-wide communication and integrated functionalities, flexibility/intelligence, new ILS activity supporting technologies, vehicles/ digital maps platforms. This HILS platform is a crucial step enabling the development of practically efficient ILS systems proposals dedicated to very complex dynamic, stochastic and behavioral interactions existing in logistics processes [Adamski 2011b]. The real time system-wide identification, intelligent diagnosis, estimation and prediction of these interactions, conditioning the efficiency and productivity of the crucial HILS platform integrated functionalities (e.g. management, adaptation, routing/scheduling, surveillance and monitoring and direct control actions). These functionalities are realized in integrated way by the hierarchical multi-layer functional structure and are characterized by different tasks specifications (e.g. decisions time horizons, types of processes representations and optimization problems, reaction times to real time recognized and diagnosed events etc.). This HILS platform is embedded in a nowadays available advanced sensing, information, computer, communication enabling technologies supported by capabilities of vehicle platforms (e.g. vehicle navigation, location, v-v. v-i communication, vehicle-probe etc.). In addition it is supported by professional exploration of integration (co-operative complex systems approach with multi: networks/layers/users/services/ objectives specifications) and intelligence (recognizing, diagnosing and understanding complex interactions and behavioral patterns, decreasing uncertainty, unpredictability, recognizing the abnormal traffic events and opportunities for very efficient actions). [Adamski 2014].

Five Layers HILS in natural way integrate and vertically orders wide spectrum of decision making and optimal control functions that additionally are supported by integrated data, knowledge and tools basis equipped with dedicated DSS and CASD. At the upper layer the logistic strategy is created by multi-criteria approach integrating layers tasks. The management actions concerning the flows of materials, means, information in the areas of supply, production, distribution from the point of view of clients are realized. The typical integrated management activities consists of several stages: Activity Targets Establishing? Demand Estimation and Prognosis? Organization of Available Resources? Multi-criteria Decisions Optimization? General Level of Service Analysis. The general co-operative HILS multi-layers operation may be presented by the following cycle [Adamski 2011b].

1. Coordination and Management layer offers ALIS (Advanced Logistics Information Service) concerning SupNet interactions, essential events (e.g. incidents, critical network elements), network state specifications, global preferences and constraints, and coordination premises.
2. Adaptation layer offers: dynamic network updating: structure (available elements), routes (patterns, nodes/links, specifica-tions), levels of congestion (incidents, available throughput)
3. Optimisation layer solves different types of VRP (Vehicle Routing and Scheduling) problems after robust estimation of the routing problem specifications (e.g. travel times)
4. Supervision and Monitoring layer offers the real-time monitoring of the logistic system environment as well as the monitoring of the crucial system parameters (e.g. operational efficiency of the system resources exploration , system reliability, shortages, costs, demands). The modern multi-media technologies are used for ALIS, visualization, warning and alarm generation purposes. The intelligent supervision diagnoses the abnormal system events recognized by monitoring actions. In consequence wide spectrum of professional anticipative and preventive actions practically on all layers of the proposed system can be realized.
5. Control Layer offers: very important new functional element of the bottom direct control layer concerns the full integration of the tasks of optimisation and intelligent supervision layers with the intelligent adaptive control actions realized by the multi-criteria DISCON and PIACON control methods [Adamski 2005, 2006, 2011a]. The practical proposals of traffic

multi-criteria control capabilities realized in ITS hierarchical multi-layer adaptive, optimisation and direct control structure were presented in [Adamski 2003].

In this context very important new adaptive layer tasks are concerned with existing ITS systems services e.g. vehicle route guidance in the network (e.g. to logistic centres) and automatic incidents detection and management. In this paper the HILS platform implementation for the very complex real-time vehicle routing problems will be presented with exploration of the original multi-criteria dispatching control actions dedicated to these routing problems.

VEHICLE ROUTING PROBLEMS

Vehicle routing problems are well serviced by the functionalities of the HILS platform. To illustrate of HILS application, the VRP-TW (Vehicle Routing Problem with Time Windows) is presented (see Fig.1). In this problem the HILS upper layers interactions offer the strategic context related updated demand and network specifications (i.e. adequate level of service specifications and routing parameters values for routing optimisation layer, supported by intelligent monitoring and supervision layer activity. At the bottom direct control layer the DISCON public transport dispatching control method was adopted to the real-time routing disturbances compensations with optimal routing treated as reference schedule to be stabilized by dispatching control actions. The formal VRP-TW typical routing problem specifications implemented in the optimisation layer are as follows: [Adamski, 2011b].

1. *Network specifications:* $G=(V,L)$ with customers located in the nodes $v\in V$ ($\#V=n$), selected dedicated for demand depots, and available L-links ($\#L=m$) or sub-areas.
2. *Nodes:* $\forall i\in V:\{d_i/p_i, TW_i=[ts_i, te_i], \tau_i, t^a_i\}$ represents respectively: customers demand forward/backward, time-windows, service/arrival times at customer i-th.
3. *Links:* $\forall(i, j)\in L: \{T_{ij} / D_{ij}, C_{ij}, U_{ij}\}$ represents respectively travel times/distances, costs, level of uncertainties
4. Routes specifications: originating/terminating at selected one/multi depots, homogeneous/ heterogeneous depots, available resources and functionalities.
5. Service specifications: (SP1: $\forall$i: must be assigned to exactly one/several routes/vehicles ; SP2: $\forall$i; is visited only ones/several times; SP3: demand all customers are serviced; SP4: type of obligatory LoS (Level of Service) specifications
6. Fleet of vehicles: homogeneous/heterogeneous; vehicle types related capacity
7. Customers: fixed/elastic demand; known delivery/pick-up demands
8. Adopted multi-criteria selected optimazation objectives: total distance /travel time, costs, LoS-measures, sum of lateness at customers, negative environmental impacts.

The typical VRP-TW problem in HILS platform can be formulated as follows: recognition of demand specifications and strategically compatible available dedicated service resources (localization of depots, admissible service areas and modes). Selection of demand related service standards specifications and optimisation specifications for VRP to be solved in optimisation layer. The selection of representative information sources and estimation, prediction and diagnose traffic situations in the selected areas. Generation by adaptive layer representative estimators of the parameters for routing optimisation problem. The formulation of dedicated optimisation problem with selection of types of ADV admissible *decision variables:* for example $x_{ijk}\in\{0,1\}$ binary variables used to assignment of the network arc (i, j) to the route of the k-th vehicle; $z_{ij}\in R_1^+$ demand delivered to customers routed after node "i", $y_{ij}\in R_1^+$ demand pick-up from customers routed up to node "i"

$$\text{(ADV):} \quad \{ x_{ijk} \in \{0,1\}; \quad y_{ij},\ z_{ij} \in R_1^+\}$$

Flow conservation principles for delivery demands and admissible routing flows:

(FCA): $$\sum_{i=1}^{N+1} z_{ij} - \sum_{i=1}^{N+1} z_{ji} = d_j \quad \forall j\neq 1;$$

$$\sum_{i=1}^{N+1} y_{ji} - \sum_{i=1}^{N+1} y_{ij} = p_j \quad ; \forall j\neq 1;$$

$$y_{ij} + z_{ij} \le cap \sum_{k=1}^{K} x_{ijk}$$

ILS upper layers LoS specifications: all customers must be visited only ones and assigned to exactly one route from finite set of routes/vehicles. Customers Visits Specifications are:

(CVS): $$\sum_{i=1}^{N+1}\sum_{k=1}^{K} x_{ijk} = 1 \quad \forall j\neq 1;$$

$$\sum_{i=1}^{N+1} x_{ijk} - \sum_{i=1}^{N+1} x_{jik} = 0 \qquad \sum_{i=1}^{N+1} x_{ojk} \le 1$$

Operational Specifications: travel times representation, service time windows functionalities, customers visiting times sequence, maximum admissible routes distances/ travel times are:

(OS): $$t_{ik}^{a} \in [t_{si}, t_{ei}];$$

$$t_{ik}^{a} + \tau_i + T_{ij} - M(1 - x_{ijk}) \le t_{jk}^{a};$$

$$\sum_{i=0}^{n}\sum_{j=0}^{n} c_{ij} x_{ijk} \le L$$

The identical fleet of vehicles k=1,..,K specifications $\forall k \in K$: {limited capacity cap_k =cap}. This type of VRP-TW optimization problem may be formulated as follows (see Fig.1):

$$\mathrm{PO}_{\min}\ X, Z \qquad Q = \sum_{k=1}^{K}\sum_{i=1}^{N+1}\sum_{j=1}^{N+1} c_{ij} \cdot x_{ijk}$$

$$||\,(\mathrm{ADV})(\mathrm{FCA})(\mathrm{CVS})(\mathrm{OS})$$

Testing example was selected from [Mingyong, Erbao, 2010] with HILS selected parameters values and problem specifications: types of problem real-time VRP-SPD-TW with CVS customers visits specifications and one recognized depot in v1.

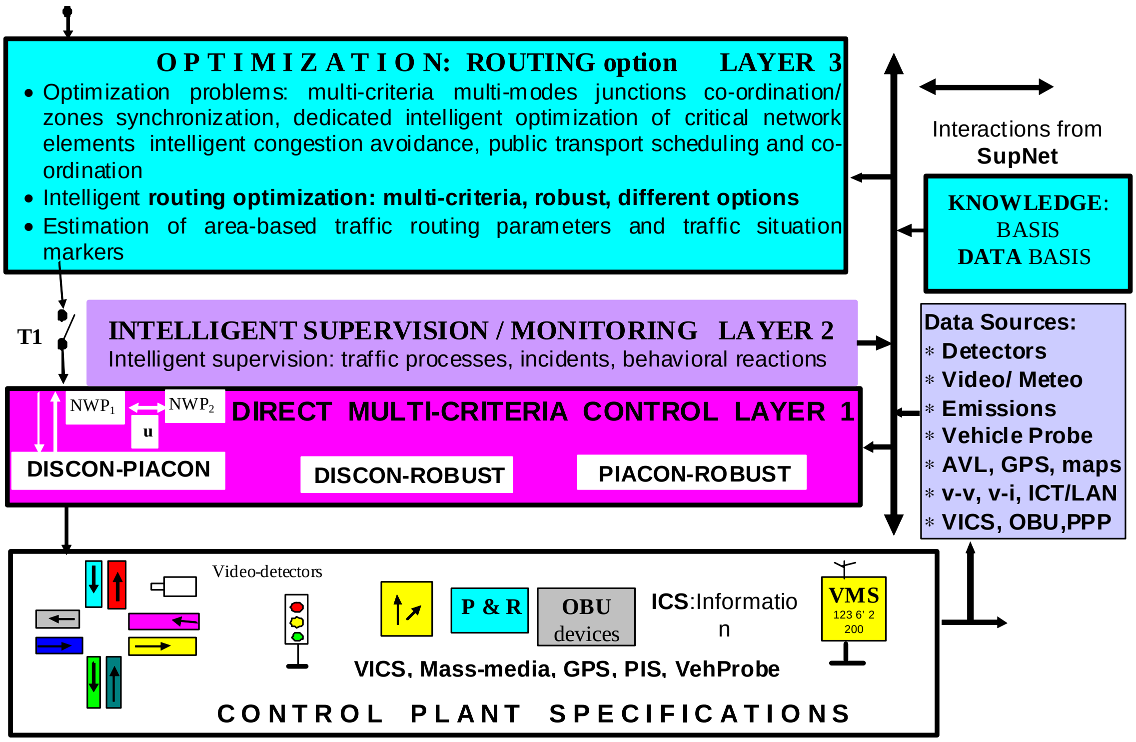

Fig. 1. Illustration of the vehicle routing dedicated HILS bottom layers functional co-operation
Rys. 1. Ilustracja funkcjonalnej kooperacji dolnych warstw HILS dedykowanej dla problemu wyboru tras

Table 1. The results of the numerical VRP-SPD-TW example
Tabela 1. Wyniki optymalizacji VRP-SPD-TW przykładu

<table>
<tr><th>vehicle</th><th>solution</th><th>distance/load</th><th>Optimal routes parameters</th></tr>
<tr><td>k=1</td><td>1-4-6-2-1</td><td>215/8</td><td><table><tr><td>i</td><td>1</td><td>4</td><td>6</td><td>2</td><td>1</td><td>L_1</td></tr><tr><td>k=1</td><td>8</td><td>5.5</td><td>7</td><td>8</td><td>8</td><td>215</td></tr></table></td></tr>
<tr><td>k=2</td><td>1-9-8-3-1</td><td>315/7</td><td><table><tr><td>i</td><td>1</td><td>9</td><td>8</td><td>3</td><td>1</td><td>L_2</td></tr><tr><td>k=2</td><td>7</td><td>7</td><td>6</td><td>5.5</td><td>5.5</td><td>315</td></tr></table></td></tr>
<tr><td>k=3</td><td>1-7-5-1</td><td>265/7</td><td><table><tr><td>i</td><td>1</td><td>7</td><td>5</td><td>1</td><td>L_3</td></tr><tr><td>k=3</td><td>7</td><td>7</td><td>6</td><td>6</td><td>265</td></tr></table></td></tr>
</table>

The suggested problem specifications by adaptive layer are as follows: N=8; $K \leq 5$; Cap=8; suggested fleet of homogeneous vehicles; Demand is fixed : d = [2 1.5 4.5 3 1.5 4 2.5 3] / p = [3 1 2 2 3 4 1.5 3]; estimated customers service times: τ=[1 0.5 1 1 1 1.5 1 0.8]; Time windows with starting/ending times: t_s =[6 5 1 4 3 2 4 1.5] / t_e= [7 7 3 7 5 5 6 4]; Costs: matrix $C=C^T$ the data over diagonal represented by vector; C=[40 60 75 90 200 100 160 80; 65 40 100 50 75 110 100;75 100 100 75 75 75;100 50 90 90 150; 100 75 75 100;70 90 75;70 100;100].

The optimal routing proposals from optimization layer are presented in Table1.

Optimal dispatching control for VRP-SPD-TW problem solutions is realized at the bottom direct control layer (see Fig. 1) and is dedicated to compensate off-reference trajectory (determined in optimization layer by routes selection) deviations and essential increasing the robustness of the actual obligatory trajectory. Dispatching control actions dynamically evolving in 2-D (time and space) are integrated in DISCON (DISpatching CONtrol) method [Adamski 1998, 2011a] in an optimal dynamic control strategy resulting from the minimization of some selected measures of service standards e.g. off-reference routing trajectory deviations. Wide spectrum of DISCON control tasks (punctuality, regularity, synchronizing priority control) call for a multi-criteria integrated approach. In the papers [Adamski 1998,2003] the 1-D and 2-D (primal and dual) dynamic control plant representations have been developed and illustrated by a family of single criteria optimal control DISCON solutions of dead-beat, LQ, LQG type. The efficient dispatching multi-criteria priority control mode at traffic signalized intersections was proposed as an option in the PIACON (Polyoptimal Intelligent Adaptive CONtrol) method [Adamski 2006]. The originally different options of the DISCON method were developed and implemented in the public transport [Adamski 2005, 2011a].

In this paper some adaptations of the DISCON method to logistics routing problems are proposed. The operation of logistics vehicles in urban areas is influenced both by traffic conditions (e.g. traffic congestion, traffic events, interactions of drivers with actual traffic situations) as well as by customers demand (e.g. 2-D spatio-temporal demand randomness and behavioral uncertainty). In DISCON real-time dispatching control method these aspects are represented in the control model by disturbances and parameters variation and guaranty of robust features of generated control actions. Nowadays advanced computer, sensors, communication and control technologies create the family of new enabling technologies for advanced control actions. The new capabilities of hierarchical multi-layer ITS-ILS systems concern the system functionalities realized in integrated network-related way on different system layers. More available traffic data sources (e.g. video detectors, lasers, vehicle probes [Leihs, Adamski 2011], VICS vehicle platforms, GPS offer more network-related information enabling to formulate and solve more advanced system layers tasks. In particular, the advanced sensor systems offering high quality 2-D traffic data concerning the individual vehicles (e.g. vehicle type recognition and tracking) that through effective communication media can be gathered remotely and integrated across hierarchical ITS-ILS systems platforms. The monitoring and intelligent surveillance layer tasks are a typical in this area and require dedicated data fusion for intelligent traffic situations diagnosis tools. The advanced multi-criteria traffic control layer fully integrated with monitoring and surveillance layer uses these diagnosis results for generation of adequate structures of preferences in multi-criteria intelligent control (e.g. the traffic situations markers mechanism used in the PIACON method [Adamski 2003]. This allows among others to realize real-time congestion-related multi-criteria control actions and explore the beneficial network-related synergic effects by multi-layer integrated operation. In the logistics systems it may be especially explored in the real-time priority control area by integration of PIACON-DISCON methods. Priority control option in DISCON method is an essential component of the control actions aimed in reduction off-reference trajectory and off-scheduled time window deviations. In DISCON these control options are called respectively; the punctuality and synchronizing dispatching control options dedicated to real-time recognized traffic preference situations. The multi-criteria adaptive priority control providing in real-time offers important advantages: flexibility, efficiency, robust features. Therefore, the robust real-time priority control features of PIACON-DISCON methods will be also explored in the context of logistics vehicles “reference trajectory” robust prediction, estimation and control solutions embedded in multi-layer HILS platform. DISCON control problem: reference trajectory deviations i.e. dynamic propagation off-schedule arrival t^a_{ij} /travel times T_{ij} deviations $x_{ij} = t^a_{ij} - t^{as}_{ij}$ / $z_{ij} = T_{ij} - T^s_{ij} + w_{ij}$ will be represented by punctuality control model and admissible deviations and control actions:

(DCS): $x_{j+1} = x_j + u_j + z_j$;

$$x_j \in [xLB_j , xUB_j] \; ; \quad u_j \in [uLB_j , uUB_j]$$

At this point all DISCON public transport dynamic dispatching control options (deterministic, stochastic, single/multi-criteria, robust, anticipative, priority control) [Adamski 1998, 2003] are available for HILS application. For example LQ/LOG logistic bottom direct HILS control layer dispatching control problems may be formulated as follows:

PO $_{\min}$ u_j

$$J_{T-j} = \|x_T\|^2_{Q_T} + \sum\nolimits_{k=j}^{T-1} \|x_k\|^2_{Q_k} + \|u_k\|^2_{R_k}$$

| (DSC)

where Q_k , R_k are symmetric nonnegative definite weighting matrices, the first and the second term may be regarded as the off-reference trajectory deviations penalties at terminal (T) and all customers points. The last term penalize the weighted sum of squares of control actions.

In addition the vehicle load balance equation and fuel consumption minimizing vehicle routing option can be added to DISCON multi-criteria dispatching control [Adamski 2011b].

For a given time window TW=[a_j,b_j] the reference point of vehicle arrival to j-th customer can be selected for example as aj + TW/3. The logistics' services consist in different routes assigned to different vehicles therefore in the illustrative example of the DISCON LQG control solution we have three routes for three vehicles (see Fig. 2). In Fig. 2-4 the LQG DISCON solutions for the optimal routes selected in the optimisation layer and high quality of the Kalman filter estimations of the system states for selected routes are presented.

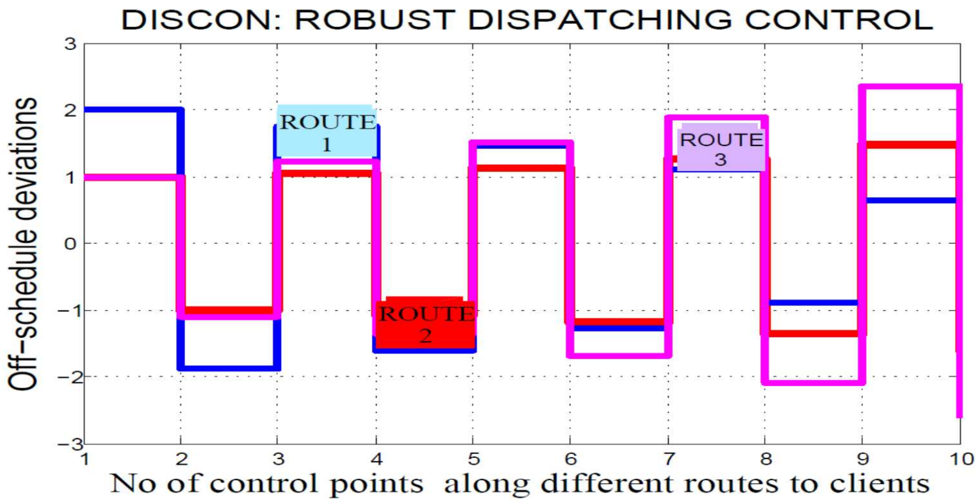

Fig. 2. DISCON off-reference trajectory compensating control actions along the three routes
Rys. 2. DISCON sterowanie kompensujące odchyłki wzdłuż trzech tras od referencyjnej trajektorii

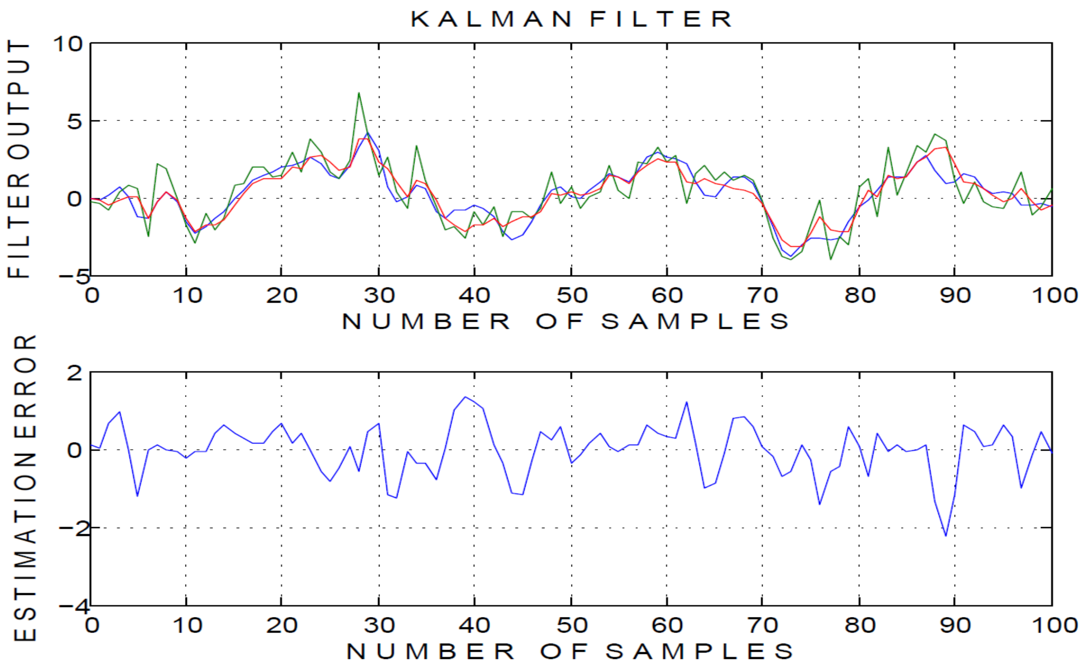

Fig. 3. DISCON: " reference trajectory" LQG dispatching control mode based on Kalman Filter route 1
Rys. 3. DISCON: mod sterowania dyspozytorskiego LQG bazujący na filtrze Kalmana - trasa 1

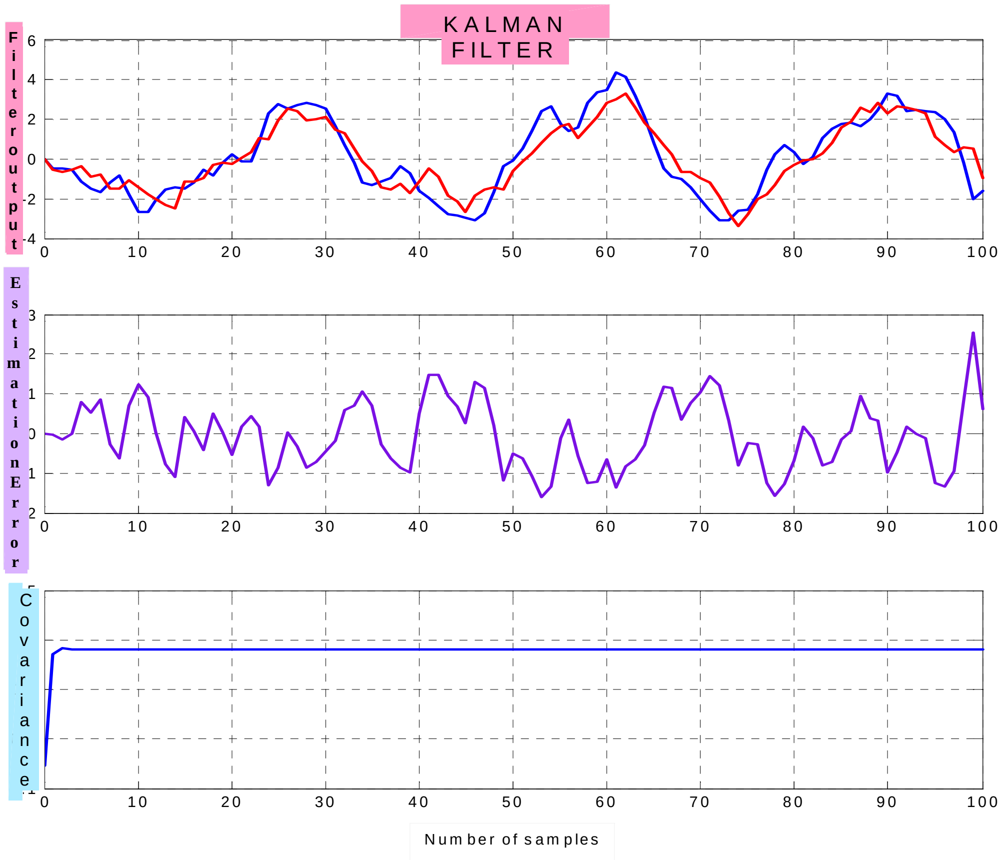

Fig. 4. DISCON: " reference trajectory" LQG dispatching control mode based on Kalman Filter - route 2
Rys. 4. DISCON: mod referencyjnego sterowania dyspozytorskiego LQG bazujący na filtrze Kalmana - trasa 2

ROBUST DISPATCHING CONTROL IN LOGISTICS

Wide spectrum of DISCON control options (punctuality, synchronizing and priority control) call for a multi-criteria integrated approach. Special emphasis is placed on the practical usability of the optimal solutions which are to a high degree determined by their robust features. Practically, distributed control hardware architecture with on-board computers, vehicle location and identification (AVLI) systems and decentralized adaptive control scheme seems to be most promising solution. The efficient dispatching multi-criteria priority control mode at traffic signalized intersections was proposed as an aggregated option of the PIACON-DISCON methods [Adamski 2006a, 2011b]. After the detection of the vehicle arrival to the junction and evaluation of its measure of deviations, the dynamic trade-offs with conflicting individual traffic and public transport demands are established by PIACON and appropriate priority robust control options for DISCON are proposed in terms of "robust reference trajectory" [Adamski 2005].

The special emphasis has been devoted to multi-criteria robustness features of the dispatching control actions. Reference trajectory priority control is similar to offered by DISCON-PIACON [Adamski 2005] interaction for public transport. After the detection of the vehicle arrival to the junction and evaluation of its measure of deviations the dynamic trade-offs with conflicting traffic and robust criteria (expressed in terms of norms of the Hardy spaces H_2 and H_∞.) demands are established by PIACON and appropriate robust local reference priority options called the "local reference trajectory" for DISCON are proposed. In the logistics applications (i.e. single vehicle at single intersection) some simplified approach can be proposed. The supervision and monitoring layer recognize the control preferences structure for PIACON control method but the DISCON dispatching control method can influence the importance of some priority control measure in preference structure dedicated to real-time dispatching control of the logistics vehicle. To reduce along logistics vehicle routes the influence of the dispatching control actions subjectivity and recognize the adequate preference structure of the control criteria in a given traffic situation, the AHP-Entropy method was used and the ranking is realized (at supervision and monitoring layer) according to calculated distance d2 and close–degree to the ideal point. There are eight control performance criteria (C1-C8) to be evaluated: number of stops, delays, capacity, queues, discomfort measures, priorities, dedicated modes, degree of flexibility. These criteria to be evaluated by six traffic situations markers (TSM1-TSM6) [Adamski 2003] representing traffic conditions and operational events such as traffic blockings, operational priorities, network synchronization requirements: free flow, near capacity, over-saturated, priorities, "synchro". The proposed approach consists of 5 steps (see Table 2-3):

A. Standardize the TSM (Traffic Situations Markers) and determine target matrix;

B. Determine the entropy indicator weight λ_e for TSM;

C. Calculate the weights by AHP and combine with λ_e to get comprehensive weight WW;

D. Construct the normalized matrix to determine the ideal point;

E. Calculate the distance d2 and close degree to ideal point to sort control criteria in preference structure.

Table 2. TSM- Traffic Situations Markers based traffic conditions
Tabela 2. Markery Sytuacji Ruchowych dla opisu warunków ruchu

AAHP						**WW**
1.0000	2.0000	5.0000	7.0000	2.0000	1.0000	0.3330
0.5000	1.0000	3.0000	5.0000	2.0000	1.0000	0.2158
0.2000	0.3333	1.0000	5.0000	1.0000	2.0000	0.1473
0.1429	0.2000	0.2000	1.0000	3.0000	2.0000	0.0969
0.5000	0.5000	1.0000	0.3333	1.0000	1.0000	0.0889
1.0000	1.0000	0.5000	0.5000	1.0000	1.0000	0.1181
λmax = 6.4339		CI = 0.02868		CR = 0.02313		
λe =	0.3915	0.1490	0.1985	0.1252	0.0696	0.0663

Table 3. Preference structure
Tabela 3. Struktura preferencji

C -criteria	d2	Ranking	Close-degree	Ranking
C1	0.2814	2	0.3397	1
C2	0.2611	1	0.4376	2
C3	0.2952	3	0.5646	3
C4	0.4048	6	0.6041	6
C5	0.4045	8	0.6530	8
C6	0.3212	7	0.7098	5
C7	0.4013	5	0.7562	4
C8	0.3230	4	0.7909	7

In Fig. 5 the corresponding example of such above preference related delay -capacity mode for PIACON control method generated from supervision and monitoring layer is presented .

Different points from Compromise Set offers different signal plans/ green signals for traffic signal groups therefore DISCON methods preserving compatibility of the general control preference structure can in intelligent way influence the dedicated green signal from the point of view priority control of the logistics vehicle. The robust control measures considered in multi-criteria PIACON control method will verified the DISCON influences.

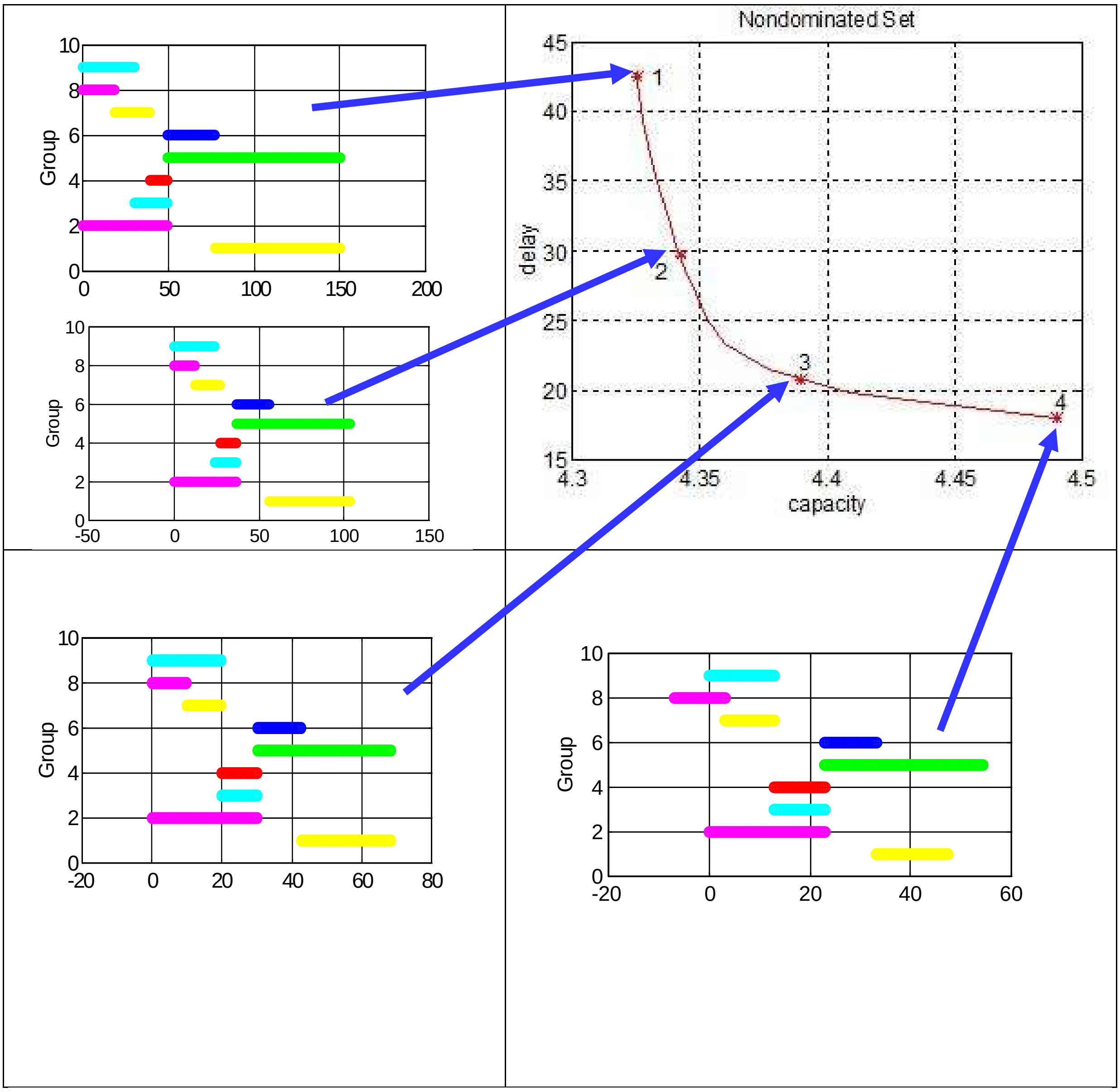

Fig. 5. PIACON capacity-delay trade-offs mode selection based on recognized preference structure
Rys. 5. PIACON wybór zbioru kompromisów przepustowość- straty czasu bazując na rozpoznanej strukturze preferencji

CONCLUSIONS

The ILS systems are good examples of socio-technical very complex systems. In this paper the proposal of the exploration of the system-wide intelligent dedicated interactions of the hierarchical multi-layers HILS platform for the solution of the complex real-time VRP vehicle routing problems was presented. An illustrative example of the real-time VRP-SPD-TW routing problem was solved. In this example the HILS upper layers offer the context-related LoS and network specifications that determine the adequate routing parameters and problem optimization specifications for optimization layer. The HILS platform related new proposal of the multi-layer decomposition of this problem offering very important problem advantages (consistency, lack of redundancy, essential reduction of dimension, dedicated formulation, inter-layer coordination). At the bottom dispatching control layer the DISCON method from public transport was adopted to logistics applications with actual routing treated as obligatory reference schedule to be stabilized by real-time dispatching control actions realized along these routes. The intelligence aspects are related among others to context-related trade-offs between routing modifications and corrective dispatching multi-criteria control capabilities e.g. priority or route guidance actions.

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PROBLEMY WYBORU TRAS BAZUJĄCE NA HILS PLATFORMIE SYSTEMOWEJ

STRESZCZENIE. **Wstęp:** Zastosowano hierarchiczną wielowarstwową platformę systemową HILS do rozwiązywania złożonych problemów wyboru tras dla pojazdów logistycznych.

Metody: Dekompozycja problemu wyboru tras na zadania warstw systemowych tworzących hierarchiczną strukturę ILS systemu. Dedykowana metoda rozwiązania problemu wyboru tras dla problemu VRP-SPD-TW . Metody rozpoznawania struktury preferencji sterowania wielokryterialnego AHP - Entropia. DISCON i PIACON metody optymalnego sterowania dyspozytorskiego i ruchu indywidualnego jedno/wielokryterialne.

Wyniki: Sformułowano i rozwiązano oryginalny problem wyboru tras przy pomocy podejścia systemowego oferującego istotne zalety praktyczne, redukcja wymiarowości i redundancji, systemowe wielo-kryterialne podejście, eksploracja cech integracji i inteligencji wspomaganej inteligentnymi działaniami sterującymi.

Wnioski: Proponowane podejście stanowi profesjonalne rozwiązanie kluczowych problemów spotykanych w systemach logistycznych z wykorzystaniem nowoczesnych narzędzi i technologii umożliwiających.

Słowa kluczowe: ILS systemy, inteligencja systemowa, problemy wyboru tras, sterowanie dyspozytorskie, podejście systemowe, systemowe struktury hierarchiczne, HILS platforma systemowa, dekompozycja problemów optymalizacji

PROBLEME DER ROUTENAUSWAHL GESTÜTZT AUF DIE HILS-SYSTEMPLATTFORM

ZUSAMMENFASSUNG. Einleitung: Für die Lösung von komplizierten Problemen bei der Routenauswahl für Logistik-Transportfahrzeuge hat man eine hierarchische Hils-Mehrsichten-Systemplattform in Anspruch genommen.
Methoden: Es wurde eine Dekomposition des Problems der Routenauswahl bis auf die Aufgaben der einzelnen Systemschichten, die eine hierarchische Struktur des Hils-Systems bilden, vorgenommen. Die weiteren angewendeten Methoden: dedizierte Methode für die Lösung des Problems der Routenauswahl für das VRP-SPD-TW-Problem, die Methoden für die Erkennung der Präferenzstruktur der AHP-Entropie-Mehrkriterien-Steuerung, ferner die Mehtoden von DISCON und PIACON für eine optimale Dispositionssteuerung und für die Ein/Mehrkriterien-Steuerung des Individualverkehrs.
Ergebnisse: Es wurde ein Konzept ausgearbeitet und ein kompliziertes Problem der Routenauswahl durch ein systemhaftes, praktische Vorteile bietendes Herangehen gelöst. Die anderen Vorteile des Konzeptes sind: Reduktion der Dimensionalität und der Redundanz, das systemhafte Mehrkriterien-Herangehen an die Problemlösung, Exploration von Merkamlen der Integration und der durch intelligente Steuerungsaktivitäten unterstützten Intelligenz.
Fazit: Das vorgeschlagene Herangehen stellt eine professionelle Lösung der schlüsselhaften, in Logistiksystemen auftretenden Probleme unter Anwendung von modernen Tools und brauchbaren Technologien dar.

Codewörter: ILS-Systeme, System-Intelligenz, Probleme der Routenauswahl, dispositorische Steuerung, systemhaftes Herangehen, hierarchische Systemstrukturen, HILS-Systemplattform, Dekomposition von Optimierungsproblemen

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Andrzej Adamski
Institute of Automatics and Bio-cybernetics
AGH Krakow University of Science and Technology
Al. Mickiewicza 30, 30-059 Kraków, **Poland**
e-mail: aad@agh.edu.pl