

WEB OPERATIONS MANAGEMENT: A WEB-BASED DECISION SUPPORT SYSTEMS FOR CONCRET TRANSPORTATION IN INDUSTRIAL ARE OF THE SMART CITY

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ABSTRACT

On-line transport and communication activities make up for a significant part of total activities cost that are undertaken inside a Smart City. This is why, lately, a series of research activities have been developed with remarkable results, dedicated to methods and techniques for planning transport inside smart cities. These methods are based on multicriterial mathematical models and web collaborative systems that have the reduction of the costs stated above as primary objective. Decision Support System with WEB support (Web-based DSS) offer managers (from all levels: strategic, tactical, operational and real-time) access to these planning techniques and methods via the Internet through web browsers. This article presents an operational planning solution that offers a Web-based DSS as support to managers from the operational and real-time levels. These managers work with the DSS to plan transport of concrete and construction materials in an industrial construction area from a smart city. This type of DSS is used for both operational planning (days and work shifts) for cement transport and for accounting issues, tracking work results and supply of useful information in real-time to managers from all level. The software is open-source and can be utilized / adapted to transport planning inside industrial areas of smart cities.

Keywords: transport; collaborative systems; decision support systems; cement providers; web-based DSS.

1. INTRODUCTION

The planning of transport activities inside a smart city implies multicriterial decisions from all the four managing levels: strategic, tactical, operational and real-time. Decisions at the strategic level are related to transport infrastructure (road networks, terminals, parking lots) and to the selection of vehicles used in the transport process (trains, trucks, special equipment vehicles etc.). Tactical decisions comprise the update process for the transport infrastructure and the supply and adjustment of transport vehicles for the technical conditions required to fulfill the requirements and objectives of the overall process. Operational decisions focus on several other aspects like the volumes of construction materials that need to be transported from providers to clients, the types of transport vehicles used, route planning and transport vehicles scheduling and equipment types and delivery time. Real-time decisions focus on creating transport logs (routes and calendars) for each vehicle.

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Strategic and tactical decisions are made in the same time with decisions for supply and sale and are oftentimes related to large infrastructure projects (railways, roads, terminals, warehouses). Operational decisions focus on collaboration between companies for operational transport planning (decisions about the transport means and routes in real-time). When creating vehicle logs for each vehicle a minimization of costs is the main goal (building optimal routes and minimizing transport times). Multicriterial decisions on each level require the use of the facilities offered by Decision Support Systems that are capable of building a multitude of possible routes and select the route for each transport vehicle according with the main goals while considering the set of real restrictions that are enforced at any given time. When the goal is to achieve transport objectives while complying with technical and time restrictions the problem becomes a vehicle issue.

2. MODELING COMPLEX DECISION PROCESSES

Because economical process are very complex, a complex study of problems that require making decisions that rely on multiple criteria at the same time is needed. The thorough studies in this field and the complexity of computations that need to be made in real-time had great impact over what we nowadays call Decision Support Systems.

Decision Theory says that a decision process is characterized by the following elements:

- Decision criteria (the different points of view the problem is analyzed from);
- Objective (or objectives that are being pursued);
- Decision maker (the person or group of persons that look to make decision in order to accomplish the objective in the best possible conditions);
- The set of alternatives (is contains all of the possible actions that can be taken in order to achieve the objective);
- The set of possible states (each state represents the multitude of conditions that determines the apparition of a certain consequence for a certain alternative on a given objective);
- The set of consequences for alternatives (it comprises either exactly the same number of consequences as there are alternatives – one state means one certainty condition – or multiple possible consequences for each alternative – more possible states means conditions of risk or uncertainty);
- The utility that the decision maker looks for following the realization of a certain consequence

The multidimensionality, which signifies taking multiple criteria into consideration at once, represents the main obstacle that can be overcome by using the mathematical apparatus provided by the theory of mathematical programming using multiple optimum criteria.

For this kind of approach, we first need to outline the mathematical model for this complex decision process.

We consider a finite set of compatible and distinct criteria:

$$X = (X_1, X_2, X_3, \dots, X_n)$$

Where each criteria $X_j, j = (1, 2, \dots, n)$, has an importance coefficient associated: C_j , with

$$\sum_{j=1}^n C_j = 1$$

There is also a set of states defined as:

$$N = \{N_1, N_2, \dots, N_n\},$$

Where each state $N_k, k \in \{1, 2, \dots, s\}$ has associated a fulfilment probability p_k with

$$\sum_{k=1}^s p_k = 1;$$

We define the set

$$Y = X * N = \{Y_{jk}\},$$

Where the element Y_{jk} represents the criteria X_j in the state N_k . This element is in turn formed out of a set of levels (possible consequences): $Y_{jk} = \{x_{jk1}, x_{jk2}, \dots, x_{jkn}\}$.

There also is a set of decision makers defined as:

$$H = \{H_1, H_2, \dots, H_t\},$$

Each of these decision makers has associated a coefficient of competence a_h , so that

$$\sum_{h=1}^t a_h = 1.$$

The decision makers make use of a set of admissible alternatives:

$$A = \{A_1, A_2, \dots, A_m\}$$

Each alternative has multiple possible consequences associated according to the decision criteria considered and the existing state. We define the set of consequences in the following manner:

$$C = X * N * A = \{x_{jki}\}, i \in \{1, 2, \dots, m\},$$

With the observation that each consequence is a level $x_{ikj} \in Y_{jk}$.

The conventional utility U_{hjki} associated to the decision maker H_k and to the consequence x_{jki} will be a real number, determined by using the Neumann Morgenstern method.

The group utility associated to the set of decision maker H will be

$$U_{jki}^H = \sum_{h=1}^t a_j \bullet U_{hjki}$$

(we allow the hypothesis of adding utilities estimated by different people).

The complex utility will reflect the estimation of the H group, taking into account all the considered criteria:

$$U_{ki}^{HX} = \sum C_j \bullet U_{jki}^H$$

Depending of the probabilistic nature of the information regarding the realization of the consequences, we adopt the adequate decision rule as follows:

1. In a certainty scenario, the alternative that has the maximum complex utility is chosen;
2. In a risk scenario, the alternative that has a medium complex utility is chosen;
3. In a uncertain scenario, one of the following schemes is applied: Wald, Hurwicz, Savage or Laplace.

In order to solve this typical problem, we recommend using the French School point of view, that has build the basis of the well-known method of for classifying and choosing in respect to multiple points of view, also known as the ELECTRE method that is applied in solving numerous multidimensional decision problems. This method allows the comparison and classification of the elements of a set of objects M, while taking into account on n points of view, in order to find some homogenous subsets of elements and to build a hierarchy.

We consider a set $M = \{M_1, \dots, M_n\}$, whose elements we will call strategies or alternatives and m criteria or points of view $C = \{C_1, \dots, C_m\}$, which we use to analyze the n objects of M.

The elements of the M set are different in nature and can be:

- Chemical elements;
- The candidates of a contest or a selection for a job inside a company;
- The makers of a product (television, vehicle, computer etc.);
- New activities or products that are taken into consideration by a company;
- Possible technologies considered for creating a product.

The criteria that is used to analyze the objects of the M set ma have different importance levels and significance and are established for each problem:

- The presence or absence of a property;
- The recognition of a characteristic or appreciation regarding a quality factor;
- The issue of a grade or the evaluation of a quality factor.

The analysis of an element M_i using a criteria C_j yields a result a_{ij} that can be a numerical value, a grade assigned to the M_i element or a quality assessment (bad, good, very good etc.). Each a_{ij} element is assigned an appreciation grade a^*_{ij} that can be normalized to a certain scale. One of the most utilized scales is the one that uses 1 as the grade for the optimum version and 0 for the most disadvantageous one. The elements and criteria, together with the results, are represented in a table:

	C_1	C_2	...	C_m
M_1	a_{11}	a_{12}	...	a_{1m}
M_2	a_{21}	a_{22}	...	a_{2m}
.	.	.	...	.
M_n	a_{n1}	a_{n2}	...	a_{nm}

If the elements of the M set are possible ways for a decision maker to act and the elements of the C set are the decision criteria we are confronted with a typical multidimensional decision problem.

3. WEB-BASED DECISION SUPPORT SYSTEM

The increase of the number of construction sites inside a smart city and the increase in requirements for technical equipment for transport vehicles implies a tight collaboration between service providers and decision makers on different levels. This collaboration requires a flow of real time exchange of information.

A web-based decision support system offers access to decision makers, via Internet, to planning systems for product transport using a web browser. The decision makers specify to the DSS the transport requirements that are defined by: the type and attributes of the product, the volume, the weight and the schedule that the transport should follow (for example the time the transport needs to leave the provider and the time it needs to arrive at the client). Using data centralization facilities specific to these requests and delivery routes the DSS allows the decision makers to identify a number of routes and to communicate in real time with the service providers. The novelty of developing and using a DSS is that it offers alternatives for transport plans and logistic services to all decision makers on different levels (inside the same company or not). Also, such a system allows for transport planning management for different types of products with the possibility of using multi-trailers while obeying standards and confidentiality policies.

4. PRESENTING THE WEB-BASED DSS

While designing and developing the web-based DSS the Object Oriented Design methodology is used (OOM). This methodology uses objects to represent data structure models and software assembled into the final product following certain rules. Using this

model, each object has a number of attributes (for example “transport requests”), methods (for example “transport from / to”) and links to other objects in the system.

A web-based DSS stands out from a classical desktop DSS because it is accessible through the Internet, typically via a web browser. Another quality of a web-based DSS is that the system can be maintained by a provider and access to support can be offered via Internet or other type of wide area network on a subscription basis (per user, per session, monthly or yearly fee). The benefits for the users of the system are that there is no hardware cost for maintenance, instant access to software updates, small initial investment and reduced risk.

5. CASE STUDY

A web-based DSS has been implemented in the following case study that simulates the daily planning (using work shifts) of transport for different types of concrete within some construction sites from an industrial area. Also, the system is used to build periodic reports (daily, weekly and monthly) for these activities.

Problem formulation: A construction company subordinates m concrete factories ($F_1, F_2, \dots, F_m$) and n construction sites ($B_1, B_2, \dots, B_n$). Each of the suppliers ($F_i, i = 1, 2, \dots, m$) can produce p types of concrete ($M_1, M_2, \dots, M_p$). The construction sites request different quantities of one or more concrete types every day in accordance with the state of the works.

The set for the distances between providers and clients is known. Also, the daily production capacity for each factory is known and the daily requests for different types of concrete for each site. All of the concrete produced must be used in the construction plan.

We need to design and develop a web-based DSS that will be used to elaborate the daily delivery plan and the daily supply plan for each concrete type, taking into account the advancement of the construction for each site. Also, the system must offer the ability to track the advancement of the fulfilment of these plans in order to obtain a minimum cost of operation.

The following rules are applied:

1. Deviation by one square meter of concrete from the request of a construction site is penalized with 20 points;
2. Not using or overusing production capacities by one square meter of concrete is penalized with 20 points;
3. The cost of transport is 1 point for every square meter of concrete per kilometer;
4. The matrix of distances from suppliers to construction sites / clients and daily production capacities (in square meters of concrete) are specific to the industrial area of a smart city;
5. The daily requests of each construction site (work point) for each concrete type are filled into a standard form and are sent through the web-based DSS.

Notes:

1. Elaborate the mathematical model for the DSS and the web based software solution;
2. Design the system schema for this web-based DSS;
3. Design the blueprint for delivery for each supplier and concrete type;
4. Design the blueprint for the concrete supply plan for each construction site;
5. The web-based DSS, designed at 1, offers a daily operational plan. Design the periodical reports for tracking the daily plan fulfilment for supply and demand.

6. SOLUTION

The operational problem stated above has a daily frequency of events following the hypothesis that work is done in one daily shift, a frequency of 2 (or 3) times a day following the hypothesis that work is done in 2 (or 3) daily shifts. In order to solve the problem we use multidimensional operational research and web applications.

I. Mathematical model elaboration

By analyzing the problem data that refers to daily production capacity (in square meters) for each supplier F_i ($i = 1, 2, \dots, m$) and daily requirements for every type of concrete by each consumer (in square meters) the following situations for production capacities and requests for different concrete types () over the course of a day (or shift) ensue:

$$\begin{aligned} \text{a) } \sum_{i=1}^m a_i &= \sum_{j=1}^n \sum_{k=1}^p b_j^k \\ \text{b) } \sum_{i=1}^m a_i &> \sum_{j=1}^n \sum_{k=1}^p b_j^k \\ \text{c) } \sum_{i=1}^m a_i &< \sum_{j=1}^n \sum_{k=1}^p b_j^k \end{aligned}$$

The mathematical model needs to follow the general situation presented above. Apparently, the problem data lead towards the solution with p distribution models (one for each concrete type). These models are linked by the available capacities a_i^k of supplier F_i for the type M_k .

In order to go past this situation (when the quantities a_i^k are not known, only $\sum_{k=1}^p a_i^k = a_i$ is known) a distribution model is constructed in the form of a standard table.

Within this table a fictional supplier F_{m+1} and a fictional consumer B_{n+1} are introduced, the unknown data being written as x_{ij}^k , where $i = 1, 2, \dots, m+1$ represents the code of the supplier, $j = 1, 2, \dots, n+1$ represents the code of the consumer, $k = 1, 2, \dots, p$ represents the code of the concrete type and the coefficients d_{in+1} and d_{m+1j} are some arbitrarily large values.

With this in mind, we can rewrite the restrictions of the mathematical model as follows:

a) Supply restrictions

$$\sum_{j=1}^{n+1} \sum_{k=1}^p x_{ij}^k = a_i, \text{ for } i=1,2,\dots,m$$

b) Restrictions for total satisfaction of consumer requests for each concrete type:

$$\sum_{i=1}^m x_{ij}^k = b_j^k, \text{ for } j=1,2,\dots,n \text{ și } k=1,2,\dots,p$$

c) Compensation restrictions:

$$\Delta = \sum_{i=1}^m a_i - \sum_{j=1}^n \sum_{k=1}^p b_j^k$$

If $\Delta > 0$, then we add the following restrictions to a) and b):

$$\sum_{j=1}^n \sum_{k=1}^p x_j^k = \Delta, \text{ for } j=n+1$$

$$\sum_{i=1}^n x_{in+1} = 0$$

If $\Delta < 0$ then the compensation restrictions will be:

$$\sum_{i=1}^m \sum_{k=1}^p d_{ij}^k x_{ij}^k = 0, \text{ for } j=n+1$$

$$\sum_{i=1}^n x_{in+1} = \Delta$$

If $\Delta = 0$ then in order to apply the same structure, the restrictions become:

$$\sum_{j=1}^n \sum_{k=1}^p x_j^k = 0, \text{ for } j=n+1$$

$$\sum_{i=1}^n x_{in+1} = 0$$

d) Restrictions of negativity for variables:

$$x_{ij}^k \geq 0 \text{ for } i=1,2,\dots,m+1, j=1,2,\dots,n+1 \text{ și } k=1,2,\dots,p$$

The objective function is:

$$Z = \min \sum_{i=1}^{m+1} \sum_{j=1}^{n+1} \sum_{k=1}^p d_{ij}^k x_{ij}^k$$

II. Solving the mathematical model using a software component

The data for the mathematical model outline above can be grouped in two different classes. On one side there is the data that follows the pattern d_{ij}^k , d_{ij}^{*k} , d , a_i . This data is constant and we are going to call it fixed data. On the other side the quantities b_j^k vary and can only be known at certain times (the day prior to the day a solution to the model is needed).

Because the mathematical model refers to a repetitive situation with a daily frequency, the solver will be a component in a software system that will include a package of programs available to solve transport and distribution problems.

What needs to be noted is that the user of this software system only needs to enter the data for the variables on a daily basis. The fixed data is stored in memory. The user will receive, in table form, information regarding the production and delivery plans for quantities of concrete type M_k that needs to be produced by supplier F_i , and the plan to supply the B_j consumer with the required quantities of the M_k concrete type.

The software product that will solve this operational problem needs to provide:

- a procedure for collecting and validating requests b_j^k ;
- a procedure for automatic generation of the mathematical model described previously;
- a procedure to solve this mathematical model;
- procedures to decode the optimal operational solutions
- a procedure to list reports for production and delivery (Report 1) and reports for supply (Report 2).

The following is an operational plan for a single day.

Report 1

DAILY DELIVERY PLAN

DAILY DELIVERY PLAN			DATE: 15.05.14		
Supplier and Capacities	Consumers	QUANTITIES BY CONCRETE TYPES			
		A	B	C	D
F1= 300	B1	30	40	10	25
	B2	60	25	20	10
	B3	0	60	0	20

Total by type		90	125	30	55
Total by supplier		F1= 300			
DAILY DELIVERY PLAN			DATE: 15.05.14		
Supplier and Capacities	Consumers	QUANTITIES BY CONCRETE TYPES			
		A	B	C	D
F2= 200	B2	20	60	30	25
	B4	20	0	35	10
Total by type		40	60	65	35
Total by supplier		F2= 200			
DAILY DELIVERY PLAN			DATE: 15.05.14		
Supplier and Capacities	Consumers	QUANTITIES BY CONCRETE TYPES			
		A	B	C	D
F3= 100	B4	70	10	5	10
	B5	70	15	5	10
Total by type		140	35	10	20
Total by supplier		F3= 100			

Report 2

DAILY SUPPLY PLAN

DAILY SUPPLY PLAN					DATE: 15.05.14				
Consumers and Supply needed					Suppliers	CANTITĂȚI BY TYPE DE BETON			
						A	B	C	D
B1= 30	40	10	25	F1	30	40	10	25	
					Total by type	30	40	10	25
					Total by consumer	B1= 105			
DAILY SUPPLY PLAN					DATA: 15.07.03				
Consumers and Supply needed					Suppliers	CANTITĂȚI BY TYPE DE BETON			
						A	B	C	D
B1= 30	40	10	25	F1	30	40	10	25	
					Total by type	30	40	10	25
					Total by consumer	B1= 105			
DAILY SUPPLY PLAN					DATE: 15.05.14				

Consumers and Supply needed	Suppliers	CANTITĂȚI BY TYPE DE BETON			
		A	B	C	D
B2= 20 60 30 25	F2	20	60	30	25
	Total by type	30	60	30	25
	Total by consumer	B1= 135			

DAILY SUPPLY PLAN DATE: 15.05.14

Consumers and Supply needed	Suppliers	CANTITĂȚI BY TYPE DE BETON			
		A	B	C	D
B2= 20 60 30 25	F1	20	60	30	25
	Total by type	20	60	30	25
	Total by consumer	B2= 135			

DAILY SUPPLY PLAN DATE: 15.05.14

Consumers and Supply needed	Suppliers	CANTITĂȚI BY TYPE DE BETON			
		A	B	C	D
B3= 60 25 20 10	F1	60	25	20	10
	Total by type	60	25	20	10
	Total by consumer	B3= 115			

DAILY SUPPLY PLAN DATE: 15.05.14

Consumers and Supply needed	Suppliers	CANTITĂȚI BY TYPE DE BETON			
		A	B	C	D
B4= 20 65 35 30	F1		60		20
	F2	20		35	10
	F3		5		
	Total by type	20	65	35	30
	Total by consumer	B4= 150			

DAILY SUPPLY PLAN DATE: 15.05.14

Consumers and Supply needed	Suppliers	CANTITĂȚI BY TYPE DE BETON			
		A	B	C	D
B5= 70 10 5 10	F3	70	10	5	10
	Total by type	70	10	5	10
	Total by consumer	B1= 95			

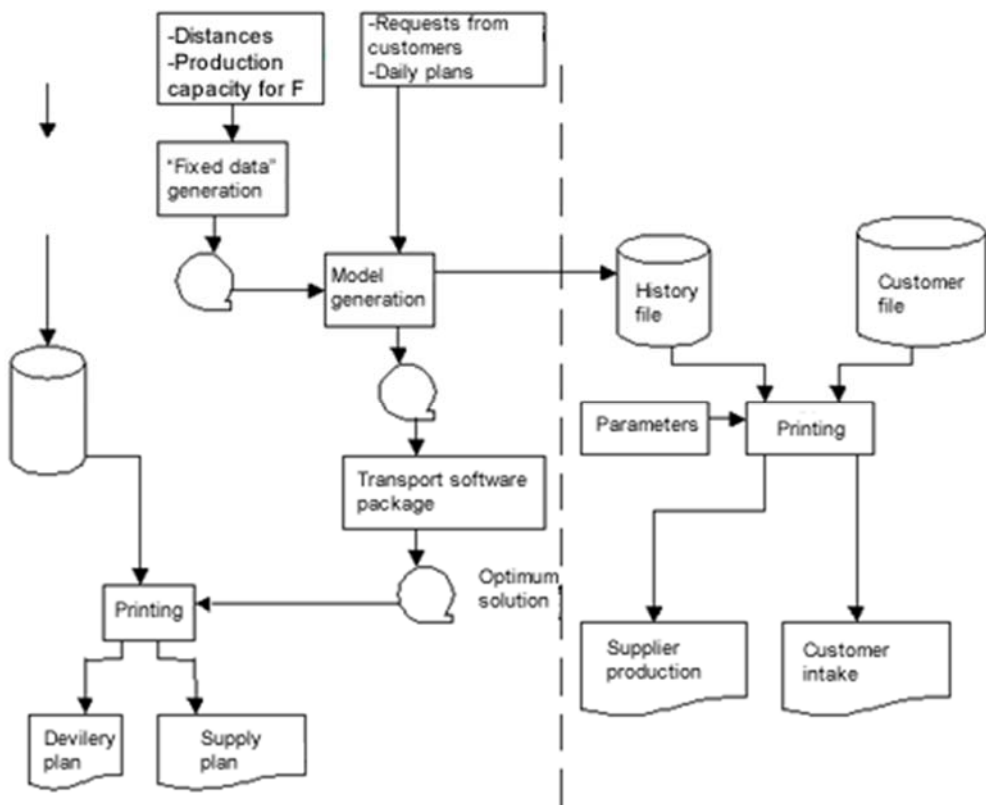


Figure. 1 Application system diagram

The software that is described in Figure 1 offers daily operational planning capabilities. The several incidents that can develop over the course of one day (weather conditions, technical problems, organizational problems etc.) lead to deviations from the planned data. Because of this, the software needs to be updated with capabilities of tracking plan fulfilments by sending the achievements of the day prior to the current day using a history file format. Monthly, yearly or on demand this file can be used in order to obtain the state of achievements for suppliers F_i , consumers B_j and concrete types M_k .

The system diagram in Figure 1 contains both the Daily Planning component and the Achievements Tracking component.

III. Implementing the application

- Data is gathered using standard forms and the fixed data file is generated;
- Daily each consumer collects requests for the next day for each concrete type M_k and the achievements for the previous day; this data is collected by using standard forms and is sent using the web-based DSS to a central storage facility;

- The core of the application runs and the reports are generated and sent directly to the suppliers (the plans for manufacturing and transport) and the consumers (the supply plan).

The accounting department and the company management will receive periodically (or on demand) reports of achievements for a certain period of time.

7. CONCLUSIONS

The operational planning of transport in an industrial area of a smart city uses multicriterial decision making for subjects like: construction site requests, supplier production capacities, concrete types, transport times (concrete cannot be stored), the types of transport vehicles required, the distances matrix etc.

The presented web-based DSS is a collaborative system between a DSS and a web application based on mathematical methods for multicriterial decision making and access to the database via a web application. It has the following main components:

1. The database (with fixed data: the distance matrix, the production capacities for suppliers, transport vehicles; variable data: construction site daily concrete requests for each concrete type, delivery times);
2. System components (web user interface used to collect variable data and to edit daily plans of supply and transport), adequate mathematical models;
3. Web components for support that are connected to road conditions and weather forecasts; modules for planning the daily transport activities for requested concrete types;

The users of this system are the decision makers (organized on decision levels), end operators and administrators. Each of these users has different access rights.

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