Applied Mathematical Sciences, Vol. 1, 2007, no. 42, 2079 - 2090

A VRS Dimension Framework for Effective DSS Design

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Abstract

A specific Decision Support System (DSS) can actually serve the Vehicle Routing and Scheduling (VRS) activities of any firm that need to pickup or deliver commodities in a daily base. Such systems can be based on the combination of relational Databases and Geographical Information Systems (GIS). One can build the specific DSS using the tools offered by the programming environment. "Dromones II" is a specific DSS that was developed to assist the daily VRS activities of Greek transport firms. This system comes as subsequent of the initial DSS named "Dromones" that used hard time-windows in the route generation. The first step in the development of a specific DSS is the identification of the applying problem dimensions. Therefore, we surveyed the relevant literature to this problem area in order to identify the most significant dimensions. Actually, the cited dimensions are referring only to operational and tactical problems and have been derived from the analysis of various well-known VRS problems. In order to make easier the development procedure, we tried to classify the dimensions that have common characteristics in groups. According to our consideration, the dimension grouping can accelerate and make easier the development of any specific DSS.

Mathematics Subject Classification: 68U35

Keywords: Decision Support Systems, VRS activities, problem dimension grouping

1 Introduction

Trying to develop a specific Decision Support System (DSS) for Vehicle Routing and Scheduling activities of transport firms came up with the need to survey the various problem dimensions [12] and create a theoretical framework. This should assisted us in the successful setting up of the DSS "Dromones II" which covers a wide range of variations of the VRS problem encountered by transport firms. The main difference of the present system from DSS "Dromones" is the aspect of time-windows in route generation. The new system uses soft time-windows. Therefore, there is a greater degree of flexibility in the process of VRS decision-making. The system combines GIS features, database management system and several model management techniques to support routing, scheduling and decision-making processes needed by general transport firms.

Dantzing & Ramser [7] were the first to present the mathematical definition of the vehicle routing problem. In simple words, the problem focuses on the delivery of certain quantities of commodities to a number of customers who are scattered throughout a geographical area. A certain number of vehicles are available for these deliveries and each vehicle has a given capacity. Our purpose is to determine a set of routes that each one would start and finish in the depot so that the overall covered route can be minimized always under the conditions that all orders are being served and the issue of soft time-windows is taken into account. Datzing & Ramser define explicitly the following specifications:

- A set of n points , in which all orders are being delivered from a point P_0 (the depot).
- A quantity of orders q that has to be delivered in P_i $(i = 1, \dots, n)$.
- The capacity of the truck is C $(C > q_i$ for $i = 1, \dots, n)$
- A matrix of routs $D = [d_{ij}]$ that defines the route between each pair $(i, j = 0, \dots, n)$.

The objective is to find a set of routes that each would start and end at point P_0, in order to minimize the overall covered route from the trucks under the condition that all orders are delivered and the capacity of all trucks is respected.

There are a number of variations as far as the denomination of the present problem is concerned. Consequently, the present problem will be called as a classical vehicle routing problem (CVRP).

2 Grouping of VRS problem dimensions

Dimension Set / Dimension	Depots	Customers	Service orders	Vehicles	Transport network	Rules and goals
Activity form		x				
Arc features					x	
Clientel dynamics		x				
Depot volume	x					
Depot location	x					
Driver personal choices				x		
Driver profiles				x		
Geographical distance models					x	
Long-term elements						x
Order demands		x				
Order priority relations		x				
Order quantities		x				
Order segmentation			x			
Order service problem			x			
Order types		x				
Quantity measures				x		
Route special limitations						x
Time consumption at customers and			x			
Time-windows form			x			
Vehicle cabins				x		
Vehicle fleet positions				x		
Vehicle fleet size				x		
Vehicle speed				x		
Vehicle types				x		
VRS process objectives						x

Table 1: Grouping of VRS problem dimensions

For the successful develop-ment of the DSS "DromonesII" many significant dimensions of the VRS problem were considered.

Several came from the relevant bibliography [2], [1], [8] while others revealed from the field research conducted in various firms [11].

The grouping of the problem dimensions aimed to the formation of dimension groups with common characteristics.

Therefore, the formulation of the conceptual schema for the necessary database and the DSS rules definition were formulated without any severe problems.

3 Outcome measures

The outcome is characterized by the synthesis of the solution factors and the consumed resources for its achievement. The consumed time for the outcome achievement is the main point of the resource consumption.

The studied measures constitute an initial set of measures based on the general expectations as regards the VRS problem type and the DSS method. The absolute and relative significance of each measure depends on each decision-maker. Moreover, each decision-maker could set additional measures that would be relevant, according to his/her personal opinion, with the framework of the specific VRS problem (case of commodities transfer).

The following table includes a number of preliminary measures regarding economical aspects; levels of customer service and driver working conditions related to the solution factors [11].

Factor	Measure
Economical aspects	• Total traveled distance • Total time consumption • Number of used cars • Total fuel cost • Total cost of vehicle use • Cost of additional car leasing
Customer service level	• Percentage of serviced customers • Percentage of serviced customers within the time-windows • Total number of time-windows violations • Declination percentage between serviced and ordered quantities of orders
Driver working conditions	• Percentage of serviced customers in eligible service areas • Declination percentage between actual and desirable working hours schedule • Declination percentage between actual and desirable duration of the driver pauses • Total waiting time before the time-windows start of various customers

Table 2: Preliminary measures of outcome evaluation

The overall evaluation is generally a synthesis of specific measures and estimations of their relevance with the problem according to the perception of each decision-maker [12]. Using his intuition and based on his subjective valuations, the decision-maker selects one of the following route patterns:

- Pick up
- Delivery
- Delivery and pick up when the vehicle returns (backhaul)
- Pick up and delivery when the vehicle returns (reverse-backhaul)
- Combination of pick up and delivery

The decision-maker options aim to satisfy the goals set by his/her transport firm as regards as the route generation, namely,

- To serve as many as possible customers within the firm working hours (06.00–18.00)
- To serve the regular customers with priority
- To retain the service consistency regarding the new customer orders (soft time-windows)
- To keep route costs down, especially the elastic expenses like fuel consumption etc.

In this aspect, the use of "Dromones II" allows the decision-maker and the firm respectively

1. To create pick-up and delivery combinations based on the firm aims (priorities)
2. To select the best route option, based on the available data, for each case
3. To intervene for the adjustment of the resulted solutions (routes) in dynamic situations like demonstrations, accidents, driver demands etc

4 The DSS "Dromones II" objectives

The main goal of the specific DSS "Dromones II" is to facilitate the decision-maker in the processing of the next day orders and generating feasible routes depending on the chosen service pattern. The last is specified on the basis of the firm's current goals.

The decision-maker knows, from the previous day, the number of customers that demand service for the next day, their order quantities, their time limitations (time-windows) as well the service kind, namely, delivery or pick up. In our case, the customers can demand either delivery or pick up. They can't ask both on the same time. The decision-maker is also aware of the number of vehicles that he can use in a route as well as their transport capacity. In our case, all vehicles are of the same type; therefore they have the same capacity. There is a specific working hour schedule for the vehicle crews. In this schedule, there is an obligatory pause of 30 minutes at noun. The pause period can be just before or after the service of a customer and it's considered as a mandatory waiting time.

In workload periods, the decision-maker sets the service of as many as possible customers as a main objective. He seeks the maximum performance of the used firm resources i.e. vehicles, drivers etc. His intention is to get the maximal utilization of the vehicle capacity and to expend into the maximum the working hour schedule of the vehicles and the drivers. The decision-maker's intentions are diversified when the total quantity of the existed orders is less than the total transport capacity of the available vehicles. Then, he sets as a main goal the reduction of the varied route cost through the minimization of the total route time. In that case an additional goal comes up which is the exploitation of the free firm resources after the route termination. This goal doesn't concern only the specific route but the routing and scheduling process as a whole. In praxis, the decision-maker can satisfy the above demand by

a) generating a new route that will take into account the rest time period for the working hours completion

b) rescheduling the first route in order to service all delivery and pick up orders that exist

Figure 2: Proposed route data (serviced and non-serviced customers)

The derived routes can be evaluated by using alternative utility functions [11], which can indicatively include measure like:

- Total route time
- Total cost of vehicle utilization

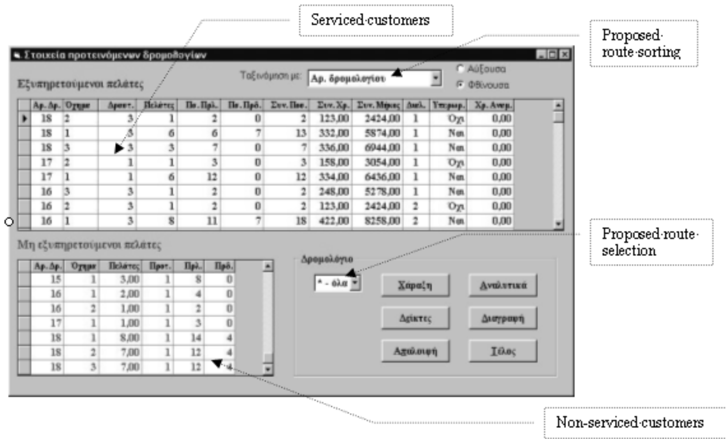

Figure 1: Proposed route data (serviced and non-serviced customers)

- Violation number of the customer time-windows (soft)
- Declination percentage between actual and desirable working hours (or vehicle traveling) schedule

The significance (influence) rate of each measure can be determined with regard to each decision-maker's perception about the above measures or other similar. For the DSS "Dromones II" have been selected several measures (transport firm goals) of the above table, which are classified in two sets:

a) Total order quantity > vehicle capacity

- $\mathbf{a}_{1.}$ Maximization of serviced customers' number (with priority)
- $\mathbf{a}_{2.}$ Maximization of the vehicle plentitude (serviced quantities/capacity)
- $\mathbf{a}_{3.}$ Minimization of the vehicle utilization cost
- $\mathbf{a}_{4.}$ Keeping of working hours (or vehicle traveling) schedule

b) Total order quantity $\leq$ vehicle capacity

- $\mathbf{b}_{1.}$ Minimization of route time
- $\mathbf{b}_{2.}$ Minimization of the vehicle utilization cost
- $\mathbf{b}_{3.}$ Minimization of the customer time-windows violations
- $\mathbf{b}_{4.}$ Keeping of working hours (or vehicle traveling) schedule

The selection and classification of the above goal sets is based on the manual route generation process of some transport firms in Thessalonica. These goals represent the way that the involved firms and respectively their people (decision-makers) perceive the whole VRS process in praxis. It might be pointed out that in our case, in the vehicle utilization cost is included the fuel cost together with the vehicles' damping cost (purchase, rental or leasing), the maintenance cost and the spare parts cost. Actually, the kilometric travel cost of a vehicle inside or outside a city is calculated by the use of existing formulas.

5 Indicative programming code

Public Sub ShapeRoutes()

```
Dim SeiraDb As Connection, NoCrit As String, SendCrit As String
If IsNull(Me![StartPoint]) Or IsNull(Me![FinalPoint]) Then MsgBox "Wrong start- or endpoint": Exit Sub
SQLApplied "UPDATE RouteBaseData SET RouteBaseData.VisitOrder = 0 WHERE (((RouteBaseData.VisitOrder)>1));" ' set zero to visit order
SQLApplied "UPDATE RouteBaseData SET RouteBaseData.RouteServed=null;"
If MsgBox("Delete old Data?", 4 + 48 + 256, "Option selection") = 6 Then
SQLApplied "DELETE * FROM RouteProposed"
SQLApplied "DELETE * FROM CustomersUnserved"
End If
Oxima = 1: VehicleAvailable = Me![VehicleCardinal]
ProposedRouteCode = DMaxim("RouteProposedCode", "RouteProposed", "")
NextVehicle:
SQLApplied "DELETE * From RouteOutTimed"
TimeAvailable = Val(Me![Orario]): NextPause = 1: NoMoreLoad = False
SumPause = Me![PauseNo] * CLng(Me![PauseDuration] * 20)
CurrentCollectLoad = 0: CurrentDeliveryLoad = 0
CurrentTime = Format(Me![OrarioStart], "hh:nn")
Stype = Me!DromID: RouteDistance = 0
If Stype = 1 Then ' *** pickup
NoCrit = "[CustCollecting]= True"
CurrentVehicleLoad = 0
ElseIf Stype = 2 Then '*** delivery
NoCrit = "[CustDelivering]= True"
CurrentVehicleLoad = QuantityToDeliver '*** initial delivery quantity
Else
NoCrit = "[CustCollecting]= True" & " OR [CustDelivering]= True"
CurrentVehicleLoad = QuantityToDeliver '*** initial delivery quantity
End If
DeliveryQuant = CurrentVehicleLoad '*** quantity to delivery
SendCrit = NoCrit ' criteria to transfer
NoCrit = NoCrit '& " OR [VisitOrder]=1" '*** store inclusion
RouteInfoStart '***update of initial evaluation criteria
Set NSeira = New Recordset
NSeira.Open "Select NID, RouteServed From RouteBaseData WHERE " & NoCrit & ";", DB, adOpenStatic, adLockOptimistic 'SeiraDb
If NSeira.RecordCount = 0 Then MsgBox "No customers have been selected for visit", 0 + vbCritical, "Error message": Exit Sub
```

```
ReDim NodeSeira(NSeira.RecordCount + 1) ' array population
i = 1
NodeSeira(1) = Me![StartPoint]
NSeira.MoveFirst
While Not NSeira.EOF
i = i + 1
NodeSeira(i) = NSeira!NID
SQLApplied "UPDATE RouteBaseData SET RouteBaseData.RouteServed = 1 WHERE (((RouteBaseData.NID)=" & NSeira!NID & "));"
NSeira.MoveNext
Wend
CandNode = NodeSeira(1) '*** startpoint of current route
For h = 2 To i
If NoMoreLoad = True Then
MsgBox "Overload !!" & " Position = " & h & " Node = " & CandNode
Else
Epomeno = NextStop(CandNode, SendCrit) ' update of visit order
SQLApplied "UPDATE RouteBaseData SET RouteBaseData.VisitOrder = " & h & " WHERE (((RouteBaseData.NID)=" & Epomeno & "));"
CandNode = Epomeno
If NextPause > 0 Then '*** Driver pause checking
If TimePassed > CLng(PauseArray(Me![PauseType].ListIndex + 1, 1) * 20) * NextPause Then TakeBreak '**** creation of a pause break
End If
End If
Next h
RouteRefinement '**** keeping of firm time schedules
FinishRoute '**** route creation to route endpoint
RouteInfoEnd '*** update of final evaluation data
'**** next vehicle
If DCounted("RouteServed", "RouteBaseData", "[RouteServed]>0") > 0 And VehicleAvailable > 1 Then
If MsgBox("Do you want to create a route for the next vehicle;", 4 + 48 + 256, "Option selection") = 6 Then
SQLApplied "DELETE RouteBaseData.RouteServed FROM RouteBaseData WHERE (((RouteBaseData.RouteServed)=0));"
Oxima = Oxima + 1: VehicleAvailable = VehicleAvailable - 1
GoTo NextVehicle
End If
End If
RouteCreationFinal '*** Route creation on the map
End sub 'Public Sub ShapeRoutes
Public Function TimeSchedule(ByVal CandCode As Integer, EpiTime As Variant, DriTime As Variant) As Variant
    '**** check if it has to move to the next customer or to wait
Dim NextCust As Variant, FirstTime As Variant
Set Anamoni = New Recordset
NextCust = Null
Anamoni.Open "RouteOutTimed", DB, adOpenStatic, adLockOptimistic
With Anamoni
Anamoni.MoveFirst
```

```
FirstTime = DateDiff("n", !ArrivalTime, !OpenTime) + !DriveTime
Do While Not Anamoni.EOF
If FirstTime < DriTime And FirstTime > 0 Then ' wait option
OutWindowed = 0 : NextCust = !PToNode
DelayTime = DateDiff("n", !ArrivalTime, !OpenTime)
SQLApplied "DELETE * FROM RouteOutTimed WHERE PFromNode =" & Cand-
Code
Exit Do
End If
Anamoni.MoveNext
Loop
End With
Anamoni.Close
If IsNull(NextCust) Then TimeSchedule = Null Else TimeSchedule = NextCust
End function      'Public Function TimeSchedule
Public Sub TimeFramesControl() '*** final update of time schedule keeping
Dim InTimed As Variant
SQLApplied "UPDATE RouteProposed INNER JOIN RouteBaseData ON RoutePro-
posed.PToNode = RouteBaseData.NID SET RouteProposed.ValidWorkTime = True WHERE
(((RouteProposed.RouteProposedCode)=" & ProposedRouteCode & ") AND ((RoutePro-
posed.VehicleNo)=" & Oxima & ") AND ((RouteProposed.ArrivalTime) Between [Route-
baseData].[OpenTime] And [RoutebaseData].[CloseTime])); "
InTimed = DCounted("[ValidWorkTime]", "RouteProposed", "[RouteProposedCode]="
& ProposedRouteCode & " AND [VehicleNo]=" & Oxima & "AND [ValidWorkTime]=
True")
If IsNull(InTimed) Then InTimed = 0
SQLApplied "UPDATE RouteEvaluation SET RouteEvaluation.RealTimeFrames = " &
InTimed & " WHERE (((RouteEvaluation.RouteProposedCode)=" & ProposedRouteCode
& ") AND ((RouteEvaluation.VehicleNo)=" & Oxima & "));"
End sub      'Public Sub TimeFramesControl
```

6 Conclusions

Specific Decision Support Systems can be developed combining databases and Geographical Information Systems [12]. The Vehicle Routing and Scheduling (VRS) activities, that include delivery and/or pick-up, might adequately be served by means of a specific DSS. Usually, the available GIS environments have their own databases. One can build the DSS geographical substructure using the tools offered by the available environment. As regards the decision mechanism, one can develop program modules in order to satisfy the special needs of the DSS designed.

The present identification and grouping of the various VRS problem dimensions can actually be helpful to anyone trying to develop a specific DSS for transport activities that include delivery and pick-up. In this paper, we present the most significant dimensions that have been derived from the analysis of various well-known VRS problems. Any dimension of strategic nature has purposively been excluded from our survey and only dimensions of operational and tactical problems have been included [11]. This dimension type should be a future research objective in order to develop an integrated DSS for VRS activities. This work can contribute in the DSS development for VRS activities by comprising a theoretical framework for anyone trying to identify the standing specifications and constraints in the specific area.

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Received: January 29, 2007