INTEGRATING PROLOG INTO AN UNDERGRADUATE LOGISTICS COURSE

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ABSTRACT

Computer-based simulation games have been adopted in many classrooms with great success. One problem encountered with the adoption of such games is their full integration into the course of study. This paper presents three exercises which can be used to integrate PROLOG. a logistics game, into an undergraduate logistics course.

INTRODUCTION

PROLOG is a business logistics simulation game designed to be played on an IBM or IBM compatible personal computer. PROLOG was first presented and demonstrated at the 1985 ABSEL conference. [1) As with many simulation games designed for teaching PROLOG is most effective when thoroughly integrated into a course. The simulation provides the student with hands-on experience in designing and managing a logistics system. Throughout the course, analytical techniques can be applied to the simulated system of PROLOG to help the student make decisions about such things as inventory and routing. The purpose of this paper is to present several classroom assignments designed to integrate PROLOG into an undergraduate logistics course,

It is strongly advised that students be given PROLOG to expectant with early in the course. In this way they become very familiar with all of its variables. Then will attempt: to operate the logistics system on a trial and error basis is they go through the course and are presented with analytical techniques which help them to solve problems they have already been confronted with, their understanding of :he problem and its solution is greatly enhanced, These are not dry, lifeless exercises which interfere with their social activities but truly useful devices.

It should also he made clear that the techniques presented in this paper are basic, standard methodologies. They are also not a complete set of exercises but only a small sample. The intent of the paper is 1) to provide those using or planning to use PROLOG with a set of ready made exercises and 2) to stimulate those using PROLOG to devise sore exercises To even further integrate PROLOG into the undergraduate logistics course and to further enhance the learning experience of out students.

THE ECONOMIC ORDER QUANTITY

The concert of the economic order quantity is always presented in an undergraduate logistics course. Students can be asked to calculate the economic order quantities (EOQ) for raw materials and for finished goods to replenish warehouses in PROLOG. The EOQ formula is as follows:

$$EOQ = \frac{2\,(\text{Annual Demand})\,(\text{Ordering Cost})}{\text{Annual Inventory Carrying Cost per Unit}}$$

Ordering costs in PROLOG are $20. An estimate of annual demand can he calculated form Table I which presents a history of demands for 15 weeks. Multiplying average demand per week. 1859.5 units, by 52 produces an estimate of annual demand of 96,694. Annual inventory carrying costs per unit of finished product are $50.00 and $12.50 per unit for raw materials. The EOQ for kanutens and flugels can be calculated as follows:

$$EOQ/kanutens = \frac{2(96{,}694)(\$20)}{12.50}$$

$$= 556.26$$

$$EOQ/flugels = \frac{2(193{,}388)(\$20)}{12.50}$$

$$= 786$$

These EOQ’s can be modified in consideration of transportation costs. Rail rates are based on a 60,000 pound minimum weight and the capacity of each car is also 60.000 pounds. Since each unit weighs 100 pounds each rail car can hold exactly 600 units. Therefore, the EOQs should be modified to a multiple of 600 nearest the original EOQ. For example, instead of ordering 556 units kanutens, 600 units should be ordered, Ordering 600 units incurs the same transportation costs as ordering 556 units.

Warehouse replenishment EOQs depend on the markets served by the warehouse, If a warehouse is located at Able (see Figure 1) serving Roanoke and Charlotte with a combined average annual demand of 33,935, the EOQ is as follows:

$$EOQ = \frac{2(33.935)(\$20)}{50.00}$$

Trucking costs are based on a 100 units minimum and a capacity of 400 Using a tabular method the calculated EOQ can be compared to ordering 300 or 400 units in Table II.

In PROLOG transportation costs result in a major modification in the EOQ as demonstrated in Table II. The tabular method of comparing order quantities can also be used to compare raw materials orders as well. The tabular method is also a very Food way to demonstrate the relationships of the variables in the EOQ formula.

One other issue remains to be resolved. In PROLOG orders can only be placed once per week. Therefore a maximum of 52 orders per year is possible. Referring back to Table II placing 52 orders per year. or two truckloads per order results in an $8,353 penalty far not being able to order more frequently.

From those examples, it can be seen that PROLOG can be used effectively to demonstrate:

* the use or the LOP formula in a situation that the students are familiar with;
* the effect transportation costs can have in modifying EOQ’s: and

* how important transportation cost are in PROLOG relative to inventory carrying coats.

For the EOQ assignment students should be asked to:

1) Calculate the EOQ's for each raw material.
2) Calculate the EOQ for the finished product at a warehouse located in Able and serving Roanoke and Charlotte.
3) Determine if consideration of transportation charges would cause you to modify your EOQ calculated in 2 above.
4) For 1, 2 and 3 above assume you can place as many orders as possible. Now calculate what the maximum limit of 52 orders per year (one each period) will do to your EOQ.
5) Are there other uses for the EOQ in PROLOG? In other logistics systems?

LOCATION DECISIONS

There are a number of location techniques which can be taught in a logistics class. The grid technique is one which is relatively easy and is often presented to undergraduate students.[2] PROLOG can be used as a basis for grid location analysis. For example, students can be asked to determine the market center for a warehouse to serve the nine PROLOG markets or perhaps the least coat location for a new plant to replace the one in Cincinnati.

Figure I presents the PROLOG market area with a gird of one inch squares superimposed over it. The moat basic analysis assumes that the markets all have equal demand and that the only costs of any consequence are transportation costs from the warehouse location to each of the markets. Table 3 presents the grid locations and the average demands for all of the markets, The simple center of the market is calculated as follows:

$$\text{East Coordinate} = \frac{5.9 + 2.4 + 1.3 + 0.0 + 3.0 + 2.0 + 4.7 + 2.9 + 1.4}{9}$$

$$= 2.62$$

$$\text{North Coordinate} = \frac{5.9 + 4.8 + 5.9 + 6.1 + 6.9 + 0.0 + 3.2 + 1.8 + 2.7}{9}$$

$$= 4.14$$

Thus, the simple center of the PROLOG markets is located at coordinates 2.62 East and 4,14 North. Students can be asked prior to this exercise where they think the center is and usually they are pretty close. This has obviously been a very simple analysis which assumes several very important factors to be unimportant. One of them is demand. Adding demand to the analysis will improve the answer. Table III contains the average weekly demand for each marker. Incorporating demand into the analysis results in the following coordinates:

$$E = \frac{142(5.9)+190(2.4)+186(1.3)+134(0.0)+264(3.0)\quad 310(2.0)+98(4.7)+43(2.9)+192(1.4)}{142+190+186+134+264+310+343+192}$$

$$= \frac{4672}{1859}$$

$$= 2.5$$

$$N = \frac{142(5.9) + 190(4.8) + 186(6.1) + 264(6.9) + 310(0.0) + 98(3.2) + 343(1.8) + 192(2.7)}{1859}$$

$$= \frac{6935.6}{1859}$$

$$= 3.73$$

The ton mile center is therefore located at 2.5 East and 3,73 North. It's important to point out to students that this technique assumes equal access to all points and that in reality the highway and rail system will not provide equal access. Thus, this technique can only be an approximation. In addition, the exact location will depend upon a number of factors including the availability of land, utilities, labor, taxes, highway and rail access, etc.

Another, more complicated analysis is to add the raw materials to the exercise to determine a better plant location. Their location is not given in the PROLOG manual. It only states that one is 5D0 miles and the other is 1,000 miles away from Cincinnati. We will assume that they are located due east of Cincinnati and that one inch on the map equals 100 miles. Therefore, kanutens originate from 10 east and 3.6 north. Weekly orders of flugels average 3,600 units and weekly orders of kanutena average 1,800 units. Assume that no field warehouse will be used for finished products and that deliveries from the new plant to each marker will be by truck and the raw materials will arrive by rail. Transportation cost are therefore $0,03/cwt./mile for raw materials and $0.06/cwt./mile for finished product. The coordinates for the new plant are calculated as follows:

$$E = \frac{(.03)(10)(1800)+(.03)(5)(3600)+(.06)(142)(5.9)+(.06)(190)(2.4)\ (.06)(186)(1.3)+(.06)(134)(0.0)+(.06)(264)(3.0)+\ (.06)(310)(2.0)+(.06)(98)(4.7)+(.06)(343)(2.9)+(.06)(192)(1.4)}{(.03)1800+(.03)3600+(.06)142+(.06)190+(.06)186+(.06)134+\ (.06)264+(.06)310+(.06)98+(.06)343+(.06)192}$$

$$= \frac{2509}{273.5}$$

$$= 9.18$$

$$N = \frac{(.03)(3.6)(1800)+(.03)(3.6)(3600)+(.06)(142)(5.9)+(.06)(190)\ (4.8)+(.06)(186)(5.9)+(.06)(134)(6.1)+(.06)(264)(6.9)+\ (.06)(310)(0.0)+(.06)(49)(3.2)+(.06)(943)(1.8)+(.06)(192)(2.7)}{273.5}$$

$$= \frac{1011.1}{273.5}$$

$$= 3.7$$

From this analysis it can be determined that the new plant should be located at 9.18 east and 3.7 north, This is the ton-mile center and it considers the difference in freight rates between raw materials and finished product.

Students can be give the following grid analysis assignments:

1) Calculate the simple mile center for the PROLOG market area. What are the major implicit assumptions of your analysis?

2) Calculate the tone mile center for the PROLOG market area. Why would this be a better location for a warehouse to serve the market area than the one you calculated in 1 above?

3) Determine the location for a new plant which would minimize transportation costs of both raw materials and finished products. Assume that Cincinnati is old and needs to be replaced.

ROUTING

The problem of routing shipments is one that is often raised in logistics classes. There are several techniques that are fairly simple and straightforward. One that can be taught to both undergraduates and graduates, and happens to be a very accurate and flexible method as well, is the savings or lockset method [3]. This technique, like the others, can begin at a very simple or elemental level and made progressively more complex. This technique is used to solve the traveling salesman problem where the vehicle must originate and terminate at the same point, and make stops with a minimum of travel time or distance. While this is not the exact problem presented to students in PROLOG it is a Common one in logistics and the PROLOG market area and transportation network provide a good basis for such an exercise.

The specifics of the technique will not be presented here but the reader can find descriptions from several sources. Table V provides the mileage grid for the PROLOG network and Table IV presents the distance saved coefficients. Students can be given the mileages but to truly understand the technique they should be required to calculate the distance saved coefficients.

Using the distance saved coefficients the optimum route through the PROLOG network is Cincinnati Toledo - Cleveland - Buffalo New York – Baltimore -Roanoke - Charlotte - Charleston - Cincinnati. This problem assumes that the vehicle has the capacity to hold all the freight for all the markets, A more realistic example is to assume that each market will receive either the average demand for that point or the actual demand from a past period.

Let's assume that deliveries must be made from the Cincinnati warehouse to the markets in the amounts for period one (top number in each column) from Table I. Thus, Baltimore gets 21 units, Toledo 242, Cleveland 117, etc. Truck capacity is 400 units and the minimum weight is 30,000 pounds, or 300 units. Using the distance - saved coefficients (DSC) from Table IV the following routes can be constructed. Cincinnati - Baltimore - New York - Cincinnati has a DSC of 1293 and a total quantity of 389 units enough for a complete route. The next highest DSC is Cincinnati Roanoke - Charlotte - Cincinnati. Total quantity is 520 units so 120 are left at Roanoke, the closer point to Cincinnati. All of the DSC's involving New York, Baltimore. Charlotte and Pittsburgh with zero demand can be eliminated from consideration, The next highest DSC is Cincinnati Charleston - Roanoke - Cincinnati. Total demand is 434 (120 at Roanoke) therefore 34 units remain at Charleston. The next highest DSC is Buffalo/Cleveland with total demand of 196. Adding in Charleston results in a load of 230 units. Then Toledo would be the only point left. The routes are as follows:

1) Cincinnati-New York-Baltimore-Cincinnati
2) Cincinnati - Roanoke - Charlotte . Cincinnati
3) Cincinnati - Charleston - Roanoke - Cincinnati
4) Cincinnati - Cleveland - Buffalo - Charleston Cincinnati
5) Cincinnati - Toledo - Cincinnati

Other routings are possible depending on the decision rules. In the above examples the pair with the highest DSC was added to the route and if the demand exceeded the capacity of the vehicle the excess was left at the market closest to Cincinnati to be included in a subsequent route, A decision rule could be used such that any point with over 300 units would not be paired with any point unless all of the units could be picked up. Half the class could be assigned one decision rule and the other half the other decision rule and the quality of the routes calculated and compared. Quality could be defined as coat or miles.

The assignment for the routing problem is:

A) Using the savings (lockset) method calculate the shortest path through the PROLOG network, originating and terminating at Cincinnati,

B) Using the same technique, design routes to deliver the quantities demanded in period one of the history of demands. Vehicle capacity is 400 units and the minimum weight is 300 units.

CONCLUSION

This paper has presented three exercises which can be used to integrate the simulated logistics system of PROLOG into the undergraduate logistics course, The value of these exercises is that the student is familiar with the PROLOG environment and has been making decisions in it. Throughout the course, exercises such as the three presented here, are offered to the student as ways to solve problems that they have actually confronted. They are therefore much more receptive than when presented with them as a lecture or exercise assignment only.

Obviously, many other exercises can be developed to use with PROLOG and it is hoped that this paper will stimulate such development.

REFERENCES

[1] Gentry, James, George Jackson and Fred Morgan "Demonstration: A Computerized Logistics Game for Micros" in Alvin C. Burns and Lane Kelley (editors), Developments in Business Simulation and Experiential Exercises (Stillwater, OK: ABSEL, 1985).

[2] See for example Coyle, John J. and Edward J. Bardi, The Management of Business Logistics, (West Publishing; 1986) and Johnson, James C. and Donald Wood, Contemporary Physical Distribution and Logistics, (MacMillan; 1986).

[3] See Clarke, G, and J.W. Wright, "Scheduling of Vehicles From a Central Depot to a Number of Delivery Points," Operations Research, July - August 1964, pp. 568-581.

Table I
Fifteen Week History of Demand

Baltimore	Toledo	Cleveland	Charleston	New York	Pittsburgh
21	242	117	314	368	0
141	30	152	140	265	109
127	102	213	187	235	141
119	140	186	277	121	43
140	108	187	146	69	304
100	182	219	274	84	368
131	0	129	109	202	364
84	160	162	287	153	117
115	104	111	246	0	0
19	215	264	32	12	329
113	139	248	97	105	298
10	191	268	199	51	315
101	203	148	183	0	415
72	89	215	267	124	0
175	110	176	118	346	52
1468	2015	2795	2876	2135	2855

Buffalo	Charlotte	Roanoke
79	216	304
352	266	552
452	318	466
260	429	435
187	482	278
340	456	631
289	395	325
117	355	343
280	354	379
340	304	370
413	235	224
195	66	334
187	257	279
417	510	0
52	0	226
3960	4643	5146

Average Total Demand per Week = 1859.5

Table II Tabular Comparison of EOQ's

Order Quantity	Number of* Orders per year	Annual** Transportation Costs	Annual*** Inventory Costs	Annual**** Ordering Costs	Total
165	206	$825,030	$4,125	$4,120	$833,275
300	113	452,565	7,500	2,260	462,325
400	85	453,900*****	10,000	1,700	465,600
653	52	453,313	16,325	1,040	470,678

* 33,935 divided by the order quantity

** .03 per unit multiplied by 445 miles by the number of units

*** $50 per unit multiplied by 1/2 the order quantity (average inventory)

**** $20 order cost multiplied by the number of orders placed annually

****** This is different from the 300 order quantity because of rounding the number of orders

Table III
Grid Locations and Market Demand

Market	Grid Location (E,N)	Average Weekly Demand
New York	5.9, 5.9	142
Pittsburgh	2.4, 4.8	190
Cleveland	1.3, 5.9	186
Toledo	0.0, 6.1	134
Buffalo	3.0, 6.9	264
Charlotte	2.0, 0.0	310
Baltimore	4.7, 3.2	98
Roanoke	2.9, 1.8	343
Charleston	1.4, 2.7	192

Table IV Distance-Saved Coefficients

Pairing		Distance-Saved Coefficient			
Market1	Market2	Cinci-Mkt1	Cinci-Mkt2	Mkt1-Mkt2	DSC
PITTS	NY	303	848	447	704
CLEVE	NY	262	848	593	517
CLEVE	PITTS	262	303	146	419
TOLEDO	NY	208	848	706	350
TOLEDO	PITTS	208	303	259	252
TOLEDO	CLEVE	208	262	113	357
BUFFALO	NY	466	848	405	909
BUFFALO	PITTS	466	303	225	544
BUFFALO	CLEVE	466	262	204	524
BUFFALO	TOLEDO	466	208	317	357
CHARLOTTE	NY	555	848	688	715
CHARLOTTE	PITTS	555	303	553	305
CHARLOTTE	CLEVE	555	262	680	137
CHARLOTTE	TOLEDO	555	208	675	88
CHARLOTTE	BUFFALO	555	466	778	243
BALT	NY	651	848	206	1293
BALT	PITTS	651	303	348	606
BALT	CLEVE	651	262	494	419
BALT	TOLEDO	651	208	607	252
BALT	BUFFALO	651	466	356	731
BALT	CHARLOTTE	651	555	589	617
ROANOKE	NY	461	848	497	812
ROANOKE	PITTS	461	303	394	370
ROANOKE	CLEVE	461	262	540	183
ROANOKE	TOLEDO	461	208	653	16
ROANOKE	BUFFALO	461	466	626	301
ROANOKE	CHARLOTTE	461	555	191	825
ROANOKE	BALT	461	651	398	714
CHALRESTON	NY	225	848	623	450
CHALRESTON	PITTS	225	303	223	305
CHALRESTON	CLEVE	225	262	350	137
CHALRESTON	TOLEDO	225	208	345	88
CHALRESTON	BUFFALO	225	466	448	243
CHALRESTON	CHARLOTTE	225	330	555	0
CHALRESTON	BALT	225	651	524	352
CHALRESTON	ROANOKE	225	461	236	450

Table V

	NY	Pitt	Cl	Tol	Buf	Char	Balt	Ro	Ch'n	Cin
New York	0									
Pittsburgh	447	0								
Cleveland	593	146	0							
Toledo	706	259	113	0						
Buffalo	405	225	204	317	0					
Charlotte	688	553	680	675	778	0				
Baltimore	206	348	494	607	386	589	0			
Roanoke	497	394	540	653	626	191	398	0		
Charleston	623	223	350	345	448	330	524	236	0	
Cincinnati	848	303	262	208	466	555	651	461	225	0

Figure I

PROLOG Market Area