Developing a Timetable for Radiant and Circular Transport Organization with Implementation of the Transportation Requirements Planning Method

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This paper contains the results of preliminary research on the use of the Transportation Requirements Planning method to develop a timetable for radial and circular transport organization. It begins with a discussion on the method of Transportation Requirements Planning. Then the problem of developing a timetable in radial and circular transport is formulated. Successively results obtained by applying of the Transportation Requirements Planning method to develop the timetable under assumed conditions are presented. The summary and discussion of the perspectives for further research are the final part of the paper.

Keywords: Transportation requirement planning.

1. INTRODUCTION

Material Requirements Planning (MRP) method is the basic method used in modern logistics [Joh, 1986, pp.46 - 51]. In its basic version it is used for purchasing planning and production planning and control. In a modified version known as Distribution Requirements Planning (DRP), it is used by large distribution networks. Another variation of the Material Requirements Planning method is used in warehouses to designate storage locations under varying storage conditions - subsequent deliveries of various goods are placed in vacant locations. The interesting application of the Material Requirements Planning method is known as the Transportation Requirements Planning (TRP). It is used in transportation planning. The service that provides the customer with the results of the Transportation Requirements Planning method to facilitate the fleet management is included in the offer of many transport companies. The author searching the internet while preparing this article found about 150 such offers[1]. The Transportation Requirements Planning method is also implemented in modern ERP systems. It is usually linked to the Distribution Requirements Planning method. This solution was used for example in Baan [Baan] or SAP [SAP]. Although common, as it seems, interest in the Transportation Requirements Planning method, it is poorly developed from the scientific point of view. When collecting material for this article, the author has not found any scientific publication on the conditions of use and utilitarian properties of the Transportation Requirements Planning method. Since the author has been interested in the conditions of use and the usefulness of the Material Requirements Planning method in its various versions and variants [Fer, 2013], he has decided to undertake research in this field to satisfy his own curiosity. The results of the preliminary stages of this project are presented in hereby paper.

2. METHOD OF TRANSPORTATION REQUIREMENTS PLANNING (TRP)

The Transportation Requirements Planning method is defined as "utilizing computer technology and information already available in MRP and DRP databases to plan transportation needs based on field demand" [TRP]. This definition brings the essence of the Transportation Requirements Planning method closer, however, it does not say much about the procedure. To understand how the Transportation Requirements Planning method works, it is necessary to refer to

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data requirements in the Material Requirements Planning and Distribution Requirements Planning methods. The Material Requirements Planning method enables developing schedules of product manufacturing, materials and raw materials purchasing based on a plan including finished product. The Distribution Requirements Planning method enables developing distribution schedules. The requirements schedule is developed for each raw material, simple component of the product (part) or the subassembly or assembly. Schedule development starts with calculating gross requirements. This process is described in detail in [Orl, 1981, p. 121 - 123]. After calculating the gross requirements, the on hand inventory balance of the assortment item is calculated. The method of calculating on hand inventory balance is presented in [Orl, 1981, pp. 110 - 114] and [Fer, 2003, pp. 28-33]. The next step is calculating the net requirements. The method of calculating net requirements is discussed in detail in [Orl, 1981, p. 123 - 129]. Then on the basis of the calculated net requirements, the determined lead time, and the lot size, the dates and volume of planned deliveries and orders are determined. In the case of production, these refer to the due dates of production and start dates for production orders (releases).

The simple calculation process described above and its outcomes are subject to a number of important determinants. These determinants are related to the input data entered into the calculation process. Intuitively, it would appear that producing the same quantity of identical products at a certain time should result in the same material requirements. This assumption is true for the amount of material, but not for spreading the requirements over time! It is confirmed by many authors that the method of Material Requirements Planning method is "controlled" by the bill of materials and the results obtained depend on the bill of material used [Sch, 1994]. The Material Requirements Planning method in the version with computer-aided production control can be architected in many versions and variations. The selection of the version and variation for a particular company is made at the stage of implementation of the IT system and depends on particular production and organizational conditions. It is difficult to identify in the literature the version that could be used as a reference (recommended) version of the Material Requirements Planning method in production control, procurement and distribution. Practical experience with Material Requirements Planning in production control, procurement and distribution has led to the development of an effective procedure for updating material requirements schedules. It ensures the effective use of IT support provided by the IT system. At the same time, it provides the opportunity to respond quickly and flexibly to changes in the environment, to regulation of production, supply and distribution processes. This procedure consists in using the automatic update first to make changes resulting from changes in the production plan. This update is performed periodically (eg once a week or once a ten days) or as needed. This stage is called "top-down planning". Between automatic updates, changes to schedules are entered manually by the planner, whenever needed. This phase, in which planners use data from the environment to solve problems with the availability of materials or others, is called "bottom-up re-planning." The planner, based on available information evaluates the effects of potentially available solutions. The changes implemented in the schedules by the planners can refer to shortening the delivery cycles, reducing order size or production lots, changes in materials used and inducing changes in production plan. Simultaneous use of automatic updates and manual changes to material demand schedules in accordance with the procedure described above is considered by most professionals[2] to be the most effective way of utilizing methods of Material Requirements Planning in production control, supply and distribution.

3. VARIANTS OF TRANSPORT LINKS. THE PROBLEM OF DEVELOPING TIMETABLE IN DIFFERENT TRANSPORT LINKS VARIANTS

Classification of transport variants has been introduced in Polish literature by L. Mindur [Min, 2014, p. 23]. L. Mindur distinguished four basic variants - linear, circular, pendulum and radial. It is obvious that in any real situation there may be any combination of basic variants. The two most complex - circular and radial – are to be analyzed in the paper.

[2] The author's conclusion is based on discussion during the conference on Industrial Systems (IS'2000). International ICSC Congress „Intelligent Systems & Applications. ISA' 2000, December 11- 15, University of Wollongong, Australia.

3.1. RADIAL VARIANT

The TRP method, like the MRP method, is controlled by the bill of material. For the TRP method, this structure maps the structure of the transport network. In case of a radial variant of transport the structure of the product includes information that controls the order of shipment. Such information may be:

a) The distance between the place of delivery and the source of supply. Sorting the data by increasing distance (from minimum to maximum) leads to the solution in which short deliveries are planned first. Ordering distances in descending order (from maximum to minimum) results in solution in which the long deliveries will be handled first. This approach provides better use of the capacity involved.
b) Priority of delivery. Ordering delivery locations according to the urgency of delivery (from maximum to minimum) leads to the solution in which the most urgent shipments will be scheduled first.
c) The location of the delivery site with respect to the source of supply. Supply locations can be grouped according to specified spatial criteria (location in the same region). If this is the case, an additional information will be needed for further development of the timetable - the order in which the regions will be handled (priority of each region). Arranging delivery locations according to their regional affiliation and prioritizing regions will result in a timetable where the regions are handled according to predefined priorities.
d) The time of travel between the source of supply and the place of delivery. Ordering by increasing travel time (from minimum to maximum) leads to the solution in which the shipments with the shortest travel time will be scheduled first. Ordering in descending order (from the maximum to the minimum delivery time) results in the solution in which the longest service will be handled first.
e) It is possible to place all of the above mentioned control information in the bill of materials that is used to compile the timetable. The timetable received will be a compromise between the control information used.

The issue of scheduling return trips (pendulum links) may be referred to in the timetable. This problem can be solved by developing a bill of material including the aspect.

Another issue could be the rhythmic transport, developing timetable for repeated trips between the source of supply and the place of delivery. This problem can be solved at the stage of data for the TRP method collection. It requires defining the planning horizon - the time period for which the timetable is developed for. For rhythmic transport it is necessary to determine the number of repetitions within the planning horizon. By dividing the long-term planning horizon by predetermined number of shipments, the rhythm of the transport is defined. Its longevity should be added to the travel time between the source of supply and the place of delivery.

3.2. CIRCULAR VARIANT

The TRP method, like the MRP method, is controlled by the bill of material. For the TRP method, this structure maps the structure of the transport. In the case of a circular transport variant the information that will control the order of shipments needs to be included in the bill of material;. Such information may be:

a) The distance between the place of delivery and the source of supply. Sorting the shipments by increasing distance (from minimum to maximum) results in the solution in which the shortest trips are scheduled first. Ordering distances in descending order (from maximum to minimum) results in solution in which the long deliveries will be handled first.
b) Distances between successive delivery locations. Sorting the shipments by increasing distance (from minimum to maximum) results in the solution in which the route begins with the transportation between the closest delivery locations. Ordering the shipments in descending order (from maximum to minimum) results in the solution in which the route begins with the transportation between the most distant delivery points.
c) Delivery priority. Ordering delivery locations according to the urgency of delivery (from the maximum to the minimum) results in the solution in which the route begins with the most urgent delivery.
d) The travel time between the various delivery locations. Ordering the shipments by increasing travel time (from minimum to maximum) results in the solution in which the route begins with the shortest trips. Ordering

the shipments in descending order (from maximum to minimum travel time) results in the solution in which the route begins with the longest trips.

e) Any other criterion. Ordering places of delivery according, for example, to their location along the railway will enable mapping the course of the line. On the other hand, ordering delivery locations according to the scheme obtained with the traveling salesman algorithm (TSP) results in the timetable with the shortest route length.

4. DEVELOPMENT OF THE TIMETABLE FOR THE RADIAL TRANSPORT VARIANT

Requirements Planning method to develop a timetable for radial transport organization. In the Material Requirements Planning method several dozen of different forms of description of bill of material are used. The proper form of description of the bill of material to develop a timetable in radiant transport conditions is the phantom bill of material. "Phantom" is a non-physical location of the delivery site, to which a zero transit time between the source of supply and that location is assigned. The following is an example of how to prepare data for the transportation planning method to develop a timetable in radial transport organization. The organization includes both pendulum journeys and rhythmic movements.

Example:
- source of supply - A
- place of delivery - B, C, D, E, F, G, H, I, J, K,
- the variant of the order of transport is used – the travel time from the source of supply to the place of delivery in the increasing order.

Arbitrarily, the following interpretation was applied:
- short time - delivery locations B, C, D, E,
- average time - delivery locations F, G, H,
- big time - delivery locations I, J, K.
- phantom elements - α, β, γ, δ
- form of bill of material - phantom bill of material

A = {α, β, γ, δ}
α = {B *, C *, D, E *}
D = {δ}
δ = {A}
β = {F *, G, G1 *, G2 *, H *}
γ = {I *, J *, K *}
* - the lowest level code
n = 1

- the travel time between the place of delivery and the source of supply

Place of delivery	α	β	γ	δ	B	C	D	E	G	G^1	G^2	H	I	J	K
Time of travel from source A	0	0	0	0	1	1	1.5	2	3	11	19	5	6	7	8

The final form of timetable for the source of supply A:

Delivery location	Departure	Arrival	Time of Arrival
B	0.0		
C	0.0		
D	0.0	A	3.0
E	0.0		
F	0.0		
G	0.0		
H	0.0		
I	0.0		
J	0.0		
K	0.0		
G	11.00		
G	19.00		

5. DEVELOPMENT OF THE TIMETABLE FOR THE CIRCULAR TRANSPORT VARIANT

The main problem is the selection of the bill of material to be used in the Transportation Requirements Planning method to develop a timetable for circular transport organization. The choice is relatively simple. Realization of transport in the circular system consists in the fact that the carriage starts with the source of supply. All the delivery locations on the route should be visited. There is no problem of return trips, because each route ends at the source of supply. The simplest form of the bill of material to describe such situation is the parts list. More interesting from methodological point of view is to develop a timetable for circular transport in case there is a hierarchy of routes. In this case, there is the main route on which the nodes are located, which in turn are the sources of supplies for other routes - points of transshipment of goods or of passengers. To solve this problem, the modular bill of material

Table 2. Summary of figures of „Operator B” within a period of 12 months.

Lp.	Period	Number of pallets provided [pcs]	Number of used vehicles [pcs]	Number of completed deliveries [pcs]
1	Month I	24,790	780	1,687
2	Month II	25,600	827	1,870
3	Month III	25,630	826	1,722
4	Month IV	35,980	1,144	2,223
5	Month V	38,130	1,193	2,444
6	Month VI	35,740	1,118	2,444
7	Month VII	53,850	1,654	1,766
8	Month VIII	25,770	838	1,846
9	Month IX	25,780	834	2,185
10	Month X	39,020	1,230	2,835
11	Month XI	35,060	1,104	2,544
12	Month XII	23,420	754	1,683
	Sum	388,770	12,302	25,249

should be used. In this case, the parent module would be the main route, while the child modules would be representing the subsequent routes. In the case of circular transport, the bill of material for each module would be described as parts list. Combining different variants of transport organization is also be possible. Some of them could be organized as circular transport, others as radial.

6. SUMMARY

This paper illustrates only one of the applications of the method of Transportation Requirements Planning (TRP) - developing timetable in radial and circular variants. The characteristics of this method, as well as any specific method concerning requirements planning and derived from the Material Requirements Planning method (MRP), is that its application provides approximate and not optimal solutions, but its flexibility enables solving real problems of complexity of real business conditions within logistics area. Other issues not addressed in this article are the following problems that can be solved with the Transportation Requirements Planning (TRP) method:

– Just-in-Time delivery scheduling,
– planning the loading of vehicles with the scheduled timetable,
– planning the loading of vehicles with the criterion of the best use of their capacity.

If the Transportation Requirements Planning (TRP) approach is to address the problem of analyzing the use of available capacity, then the method is suitable for resource management, which is also the aspect poorly described in the literature of the subject.

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