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Research Article

DESIGNING A MATERIAL FLOW-NETWORK FOR MATERIAL REQUIREMENTS PLANNING (MRP) WITH SUPPLY CHAIN APPROACH

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ABSTRACT
The present study is an experimental-applied type and its main purpose is to reduce the supply and materials through designing a material flow network in order to balance the material requirements planning (MRP) in construction projects. For doing the research, first of all the researchers tried to understand the need of construction industry for MRP and its way of execution, by studying books, theses and articles that were written about the supply reduction and MRP. After reviewing the literature of the field on MRP in construction industry and analyzing the interviews with experts, considering the material flow design and MRP balancing, a linear model with a minimizing objective function was presented in order to reduce supply and the related costs. This model is designed and introduced to reach the following goals: a) Reducing the supply besides balancing MRP. b) Reducing the project time and costs.

Keywords: *MRP, Supply Chain, Linear Programming*

INTRODUCTION
In general, construction industry involves two sections of construction and services (designing is a part of this section) and unlike many other industries is not an integrated unit; rather it consists of different markets and industries. One can classify this industry into four sections as follows: building, construction engineering, maintenance and producing materials. Each of these four sections includes some subcategories. For instance, building section involves sectors such as residential buildings, industrial buildings or commercial buildings and markets. In other words, construction industry is a very large industry which, encompass many different industries and companies (Chegini, 2001).
Considering the increasing population growth of our country, one of the problems that will emerge in the future, is housing shortage. Currently, there are not enough houses and related facilities for many people, and the inflation and the rising housing costs, have made it difficult to buy a house. The reason is that the traditional housing strategy, which was designed for the static state of the construction industry in the past, is not compatible with the current situation and this industry needs modern and more technical strategies. In order to reduce the time and the costs of construction so that the strategies meet the current needs, it is necessary to design a material flow network, which can balance the MRP during the project. To pursuit such a purpose, a mathematical linear programming model or a minimizing objective function is used.
In order to balance the MRP through designing a material flow network and mathematical modelling, it is required that the materials meet the needs during the construction; thus, at the end of the project, the amount of the material will be zero. This means that there is no surplus material, which can speed the project process and will reduce the costs, by avoiding situations like having a dead capital (Mehregan, 2012).

Significance of the Study
In the previous years, more than 8 million models have been designed, restored and renovated in construction industry of the country. Although this number does not reveal a considerable construction mass compared to the neighbor countries, itshows a huge capital turnover in this sector compared to the other economic sectors of the country, highlighting more than ever the significance of construction and its effective role in the economy. Furthermore, the direct effects of construction industry on other production

sectors of the country is so much that the capital lock-up in construction, especially in building section, rapidly leads to stagnation in all industries, specifically the factory industries. In this regard, developments in construction can cause economic boom in other production sectors.
A definite and efficient techno-engineering system can prepare the necessary space for developing an industry. If this harmonic system is based on the industrial and professional requirements, then it can help us reaching the professional goals. Otherwise, this system not only can solve any problems, but also, it will become a problem among other issues, itself. Many experts believe that the techno-engineering must become an applied-scientific system, because it is directly involved with the executive sectors; however, asin our countries the construction engineers have not access to the administrative departments where the strategic policies of the construction industry are prepared and codified, they are less effective in executive affairs. The current system is based on a scientific-managerial idea, which is the inherent characteristics of political activists. Therefore, because of ignoring the technocracy, in the current laws and regulations, the trivial issues, which can facilitate the workflow or impede the process of project execution, are least considered (Shams, 2006).
In addition, in most cases the executive timings of the project do not match the financial plan and this problem leads to delays and lags in the construction projects. Problems such as the mentioned are the instances which highlight the need for conducting a research that should study the factors underlying issues like project cost and time extension.

Problem Statement

In construction projects, there are high amounts of raw materials (such as bricks, cement, iron, etc.) and compiling them in a place where they can be used whenever they are needed, may waste the total project budget, which consequently reduces the profits, in the long run. In addition, there are some construction materials, which cannot resist the climatic changes and expire in the course of time. If on one hand, we use these materials in construction, the building would lack the necessary quality and stability. On the other hand, not using these materials needs makes us to provide new materials and buying them again. In addition, storing the materials in the site space and transporting them again for utilization, causes duplication of works and spending extra costs and time.
In this research, the objective is to design a material flow network with a supply chain approach so that the MRP is balanced in construction projects and the supply is reduced.

MRP

MRP was proposed as a computer approach for planning and preparing materials in the United States, in early 1960s, and it was in 1975 that Joseph Orlicky published a complete manual for this approach. Before World War II and before using the computer technique, MRP had been manually and synthetically used in different parts of Europe. However, Orlicky found that the computer can make it possible to use all the details of MRP technique and it will make this technique more effective in managing the working supply in production. Orlicky's original plan was designed for using MRP, through a computer, based on a bill-of-materials processor (BOMP) (Ghazanfari and Saghiri, 2004).
MRP, standing for the material requirements planning, refers to a method of planning and production control that in which a macro production-timing plan is used for determining the production orders and purchasing the materials dependent from the need (Davoodi, 2002).
Some of the features of MRP are as follows:

- MRP is a product-oriented system.
- MRP is a future-oriented system.
- MRP involves time-phased requirements.
- MRP involves prioritized planning (Jafarnejad, 2012).

How MRP Works?

In MRP, the time is assumed discrete and typically is divided in the week time intervals (Nevertheless, currently there are some systems that act in daily time intervals). The need for any piece can be computed according to the products or spare pieces in which that piece is used. An MRP begins its activities based on the main production plans as the input, and then uses some procedures for creating a timing plan for the net requirements of each piece (and the planned materials for covering these requirements) in order to execute the main production program (Ghazanfari and Saghiri, 2004). Explosion of the planned production amounts of the parent items to the net requirement by the use of the relations of bill-of-materials/ product tree.

Table 1: MRP Net Amounts Calculations

Gross Requirements
+ Allotments
- Predicted Supply
- Timed Receptions
= Net Requirements

MPS, the abbreviated form of Master Production Schedule, refers to the required amount of each end item in planning. In other terms, it involves the requirements of time-phased end items. However, the company also needs a series of time-phased requirements of raw materials and components of these end items.
The production orders are used for production timing in factories and purchase orders are sent from the unit, in order to make sure of the timely reception of the needed materials and amounts. Therefore, MRP acts as a go-between in the relation of planning operation and mid-term and short-term production timing (Jafarnejad, 2012).

Executing an MRP System

In general, one can say that the advantages of using MRP is maximized when a huge mass of materials are produced; the mean of BOM levels of the products are high; and the group sizes are large. Therefore, the best MRP performance can be observed in workshops with alternate and repetitive workflow where a huge volume of standard products are produced and stored (Davoodi, 2002).

Mathematical Programming

Using mathematical models and techniques in solving the decision-making problems, has created a branch of science called "Operations Research". In other words, operations research is a branch of mathematics that deals with the application of scientific methods in decision-making problems and reaching to the best or optimal answer. Mathematical programming is a part of operations research that is used for finding "the maximum" or "the minimum" function consisting of several variables, considering a series of constraints. Generally, one can claim that the mathematical programming insists on certain and non-probable issues (Mehregan, 2012).

Mathematical Models Components

Mathematical models usually have four key components: variables, constraints, objective or objectives, and data or parameters. Data or parameters are certain numbers or amounts.
All mathematical models possess three main components: consequence variables, decision variables and uncontrolled variables. These variables have a logical relation with one another (Figure 1).

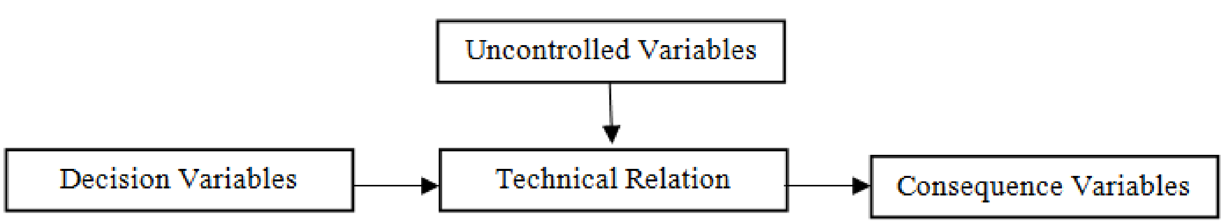

Figure 1: General Structure of a Model

Consequence Variables: These variables are dependent variables, which reflect the effectiveness level of the system, and they show the extent that the system can reach its goals. The system product, the performance and effectiveness rate, objectives and the income are the instances of consequence variables

Decision Variables: These variables express those elements of the problem on which the decisions are made and those that are selected. The decision-maker can control and manipulate these variables, if necessary. Some instances of these variables are the quantity of the products and the units that are ordered (Mehregan, 2010).

A Glance on Construction Industry

Most of the recent developments in the construction industry concern the increase of project volumes, complication of their technical issues, complication of their structure, and the newly added state laws and needs. Shortage of resources such as materials, equipment, skilled workers, technicians and consultants, were the other effective factors underlying the problems and complexities. Every day, more and more state laws are issued about the construction planning security, projects environmental effects and personnel's occupational regulations. In addition, the cultural and economic issues caused by inflation, energy shortage, pattern changes and new standards, are the other realities that the construction industry faces today (Haami, 2004). Economic problems and the increasing shortage materials and other resources, play vital role in the issues which a project deals with , and in fact, it is very important that the project engineers' and managers' skills in planning and controlling the existent resources and consequently in overcoming the economic problems be improved.

Considering the mentioned notes, it can be observed that huge amounts of consuming materials in large buildings are surplus amounts and they can be cancelled altogether. Constructional materials and traditional systems of metal and concrete buildings weigh enormously and make the buildings heavy; while what stabilizes a building is having low weight.

In addition, as it was maintained before, the new materials essentially have a certain kind of energy and frenzy which can be used for constructing beautiful structures with artistic composition, and this feature makes the building façade more dynamic (Alimi, 2001).

Supply Chain

Various researchers and scholars have presented different definitions and ideas about the supply chain. Some have constrained supply chain to the relationship between the buyer and seller that such an idea only focuses on the first-rate purchase operation in an organization. Some others have expanded the supply chain notion more and regard it as an entity, which involves all the supply resources and bases for the organization. With such a definition, supply chain involves all the first-rate, second-rate, third-rate, etc. suppliers which confine the supply chain to the analysis of the supply network. The third view on supply chain, is Porter's value model in which supply chain consists of all the require activities for presenting a product or removing the end customer. Such an idea, adds the construction and distribution functions as a part of goods and services flow to the chain, and in fact based on such view, supply chain involves three areas:

1. Procurement
2. Production
3. Distribution

Considering the mentioned definitions, now we can present a brief but general definition of supply chain which is as follows:

"A Supply chain" consists of all the activities related to the flow of goods conversion from raw material "extraction" to the deliverance to the final consumer and all the related information flows (Jafarnejad, 2012).

The supply chain encompasses all the facilities, tasks, works and activities involved in producing and delivering a goods or service from suppliers (and their suppliers) to customers (and their customers), and generally includes planning and managing the supply and demand material procurement, production and timing plan of the product or service, storage, inventory control and distribution, and delivering to the customer (Azimi, 2001).

Investigating Supply Chain Management

A supply chain is a network of facilities and equipment, which is responsible for activities such as raw material procurement, converting them to semi-manufactured and manufactured products, and delivering the produced goods to the customers. Supply chain management involves coordinating production, supply and transportation among the components of a supply chain, so that the best possible combination of responsiveness and efficiency is attained for the market, which it feeds (Azimi, 2001).

Five main components of supply are:

1. Production 2. Supply 3. Position 4.Transportation 5. Information

MIT University's definition of supply chain management is that the integrated supply chain management (ISCM) involves an integrated process-oriented approach for procuring, producing and delivering the goods and services to the customers.

Considering Porter's Definition

Supply chain management is the integration of supply chain activities and the related information flows by improving the supply chain in order to gain a reliable and stable competitive benefit.

Supply Chain Management Processes

The processes of supply chain management consist of main work process along a network of organization that form the supply chain and it involves from the main supplier to the final customer. The Global Supply Chain Forum defines the main processes of supply chain management, as follows:

- Customer Relationship Management
- Customer Service management
- Demand Management
- Order Management
- Manufacturing Flow Management
- Supplier Relationship Management
- Product Development and Commercialization
- Return Management (Jafarnejad, 2012)

Supply chain management has three critical processes:

1. Information Management
2. Logistic Management
3. Relation Management (Jafarnejad., 2012)

Project Management

Project management is using the necessary knowledge, skills, tools and techniques in managing the flow and execution of activities, in order to fulfil the needs and expectations of the project managers. Project management uses two powerful instruments in order to reach such goal: planning and control (Haj-Shirmohammadi., 2001)

Project Planning

Planning process involves determining the sequence and parallelism of necessary activities in order to conduct a project, while considering the required time for doing each activity with the determined quality for that activity. In fact, the first step in planning is having a full knowledge of the activities and recognizing the most economical way in setting the main three factors of time, cost and quality.

The Supplies and its Various Types

The most important goods inventory that can be available in the productive, industrial and commercial institutes and organizations are:

1. Raw material
2. Semi-manufactured goods or the goods being manufactured
3. Manufactured goods
4. Spare pieces and accessories 5. Necessary supplies

Basics of Modeling

Considering the research topic which is designing a material flow network in order to balance the MRP, first of all, we have drawn a material network flow according to the number and types of raw materials, semi-manufactured materials and products, and then noting this flow network, a mathematical model of linear programming type has been presented whose objective function is minimizing type.

Figure 2 shows the relation of the model-maker, the model and the real world, which shows the following sequence:
- A reality is transferred via the sense and reason to the person.
- The person interprets the data according to his thoughts.
- The person presents his interpretation (perception) as a reality.

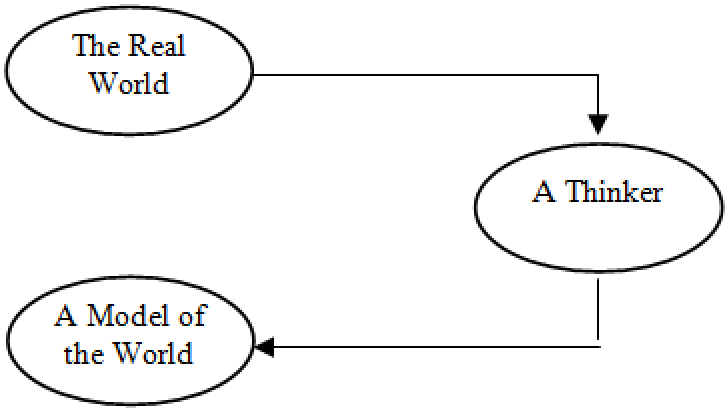

Figure 2: Interpretation of the world according to our perception

Therefore, this model-making procedure is a process, which begins with thinking in the nervous system networks of the brain, and then continues by perceiving the realities, formulating the experiences, processing and representation of the outside world data. The result of this process is called a "model" (Mehregan, 2012)

Objective Function

In case of real problems, selecting the objective is not always clear. In the present study, due to the following reasons, the objective function is of minimizing type:

1. In this study, we want to reach a model thatmakes the costs of supply to the least possible amount. Therefore, it is necessary that the objective function be of minimizing type.
2. By balancing the MRP exchanges flow, the material costs and the supply amount has been minimized.

The objective function not only involves the production and purchase costs, but also it includes the costs of storing and keeping the available supply. The cost of each material has been estimated for all the periods in the objective function. Also all the costs have been imposed at the beginning of each period.
In this research, the indexes, parameters, decision variables, series and other factor are as follows:

1. Costs

PCp: The cost of each square or cubic meter of the activity of p which involves all the production costs save the costs of raw and semi-manufactured materials.
CCc: The cost of each kilogram of prefabricated materials
RCr: The cost of each kilogram of raw material
Php: The cost of transporting each square or cubic meter of p
Chc: The cost of transporting each kilogram of prefabricated materials
Rhr: The cost of transporting each kilogram of raw material
Pihp: The cost of keeping each square or cubic meter of p during the period
Cihc: The cost of keeping each kilogram of prefabricated materials during the period
Rihr: The cost of keeping each kilogram of raw materials during the period

2. Decision Variables

PPpj: Amount of each of the activities (concrete wall, concrete casting, and plastering) per square or cubic meter which should be done in each period.

CPc.j: the amount of c (prefabricated material) per kilogram, which should be prepared in period j.
RPr,j: the amount of raw material that must be prepared in each period, per kilogram.
Pip.j.j: cubic or square meter of each activity which is transferred from period i to period j.
CIc,I,j: the semi-manufactured material c per kilogram transferred from period i to period j.
PISp,i: the amount of each activity , which should be completed in period i per cubic or square meter.
CISc,i: the amount of raw material i per kilogram which is used from the primary supply in period i.
RISr,s: the amount of raw material i per kilogram which is used from the primary supply in period i.
PFSp,i: the amount of each activity , which should be completed in period i per cubic or square meter.
CFSc,i: amount of c per kilogram which is stored beyond the time limit of the program, in period i.
RFSr,i: amount of raw material per kilogram which is stored beyond the time limit of the program, in period (precautionary saving)
PSp,i: the amount of supply of each activity in period i
CDp,c,i: the amount of each semi-manufactured material c per kilogram which is needed for manufacturing each activity in period i.
RDc,r,i: the amount of raw material which is needed for manufacturing each semi-manufactured materials in period i.

Objective Function

Objective function not only includes the production, purchase and procurement, but also it involves the maintenance and transport costs. The cost of each item is planned for all the planning period in the objective function, in such a way that all the costs are estimated in the beginning of each period.

min:

$$\sum\sum \mathrm{pc_p pp_{p,j}} + \sum\sum \mathrm{cc_c cp_{c,i}} + \sum_{\mathrm{rc}}\sum \mathrm{rc_r RP_{r,j}}$$
$$+ \sum\sum \mathrm{ph_p PI_{p,i,j}} + \sum\sum\sum \mathrm{ch_c cI_{c,i,j}}$$
$$+ \sum\sum \mathrm{rh_p RI_{r,i,j}}$$
$$+ \sum\sum \mathrm{ph_p PFS_{p,i}}$$
$$+ \sum\sum \mathrm{Ch_c CFS_{c,i}}$$
$$+ \sum\sum \mathrm{rh_p RFS_{r,i}}$$
$$+ \sum\sum \mathrm{ph_p IS_{p,i}}$$
$$+ \sum\sum \mathrm{ch_c CIS_{c,i}}$$
$$+ \sum\sum \mathrm{rh_r RIS_{r,i}}$$
$$+ \sum \mathrm{rih_r TRIS_r}$$

Rc_r: The cost of procuring each kilogram of raw material except the maintenance and transport costs.
Chc: The cost of maintaining each kilogram of semi-manufactured material r
Rh_r: The cost of maintain each kilogram of raw material r
Cih_c: The cost of transporting each kilogram of semi-manufactured material r
Rih_r: The cost of transporting each kilogram of raw material r

Limitations

ST:

$$\mathrm{PS_{p,i}} + \sum \mathrm{PI_{p,i,j}} + \mathrm{PFS_{p,i}} - \sum \mathrm{PI_{p,i,j}} - \mathrm{pp_{p,i}} - \mathrm{PIS_{p,i}} = 0$$
$$\mathrm{PS_{p.i}} \geq \mathrm{PD_{p.i}}$$

$$\sum \mathrm{PIS}_{p,i} + \mathrm{TPIS}_p = 0$$
$$-\sum \mathrm{PFS}_{p,i} + \mathrm{TPIS}_p = 0$$
$$\mathrm{CD}_{p,C,i} - \mathrm{CU}_{p,c} + \mathrm{Pp}_{p,i}$$
$$\sum \mathrm{CD}_{p,C,i} + \sum \mathrm{CI}_{c,i,j} + \mathrm{CFS}_{c,i} - \sum \mathrm{CI}_{c,j,i} - \mathrm{CP}_{c,i} - \mathrm{CIS}_{c,i} = 0$$
$$\sum \mathrm{CIS}_{c,i} - \mathrm{TCIS}_c = 0$$
$$-\sum \mathrm{CFS}_{c,i} - \mathrm{TCFS}_c = 0$$
$$\mathrm{RD}_{c,r,i} - \mathrm{ru}_{c,r}\mathrm{CP}_{c,i} = 0$$
$$\sum \mathrm{RD}_{C,r,i} + \sum \mathrm{RI}_{r,i,j} + \mathrm{RFS}_{r,i} - \sum \mathrm{RI} - \mathrm{RP} - \mathrm{RIS}_{r,i} = 0$$
$$\sum \mathrm{RIS}_{r,i} - \mathrm{TRIS}_r = 0$$
$$-\sum \mathrm{RFS}_{r,i} - \mathrm{TRIS}_r = 0$$

RESULTS AND DISCUSSION

Results

Considering the presented results from the model solution by Lingo Software, the following notes can be mentioned:

- The optimal amount of min. objective function, gives the least total project cost, considering the modelled variables and limitations.
- Of the total model variables, 138essential, secondary and lateral decision variables were predictable, since the variables related to $PI_{p,I,}$ must be zero. The reason is that each activity of p1, p2 must be completed in their own periods, and are not transferrable to next periods.
- Also in case of the variables related to $\mathrm{CI}_{c,i,j}$, it should be noted that we cannot transfer the semi-manufactured materials to the next period , considering the corruptibility of the combinational materials. Hence, the value of these variables must be zero.
- Also, the variables related to $\mathrm{RI}_{r,i,j}$, must become zero as the raw materials have to be consumed only in the periods related to them, so that no surplus would remain from the previous periods to the next.
- After solving the model, the model should have the capability of sensitivity analysis. The real problems are dynamic and alive; the price of raw materials and the demand rate is constantly swinging, so concepts like the shadow price and lost opportunity cost are used.
- By solving the model and by having the shortage and losses at the least rate, the prime cost of the housing reduces, and the efficiency and also the enthusiasm increases for investments in housing and construction.

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