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Consumption Forecasting of Iran Plywood Industry with Respect to its Substitution Rate in Building Applications

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Abstract: Supplying of plywood industry has a special place in wood industries because of plenty of applications in different building contexts, industrial backgrounds, furniture and etc. To facilitate making a development planning structure and operation in different sections of wood industries especially plywood, considering of the replacement by another products, including particleboard, fiberboard and aluminum profile have attained importance in building applications because of various factors such as raw material shortage and other problems and difficulties. Therefore, precise prediction of production, consumption, import as well as development and operation of plywood will be conducted if the rate in which it is replaced by other substituted industry would be identified. A ten year period products prediction was made by using exponential smoothing method and then based on population growth and per capita construction, the rate in which plywood was replaced by other products was identified. The results show that based on the growth of population, only particleboard would replace the plywood while fiberboard and aluminum would not replace it because of the descending trend of consumption curve. Furthermore, based on per capita construction development all three products would equally substitute the plywood.

Key words: Substitute, forecasting, exponential smoothing, plywood, building construction, consumption

INTRODUCTION

Considering the ever increasing rate of Iran population and increased demands in different social classes on the one hand and the available restricted natural resources and limited possibilities to transform these resources into worthy value added products on the other hand, it is necessary to seek an option in cases where the national natural sources and shifted industries are used in order to insure that the least amount of damages are laid to these sources while we are satisfying the maximum needs. Such things are made possible if the output and productivity of first shifted industries are increased and second the utilization of forests is made possible in an advanced scientific way, the forests are revived and expanded by due forestation. Unfortunately, nothing effective has so far been done in order to achieve the above mentioned aims because, on the one hand, all the plywood factories are involved in production less than their rated capacity and also they face a wide range of damages such that in recent years the rate in which the plywood is produced was 42.2% of the whole nominal capacity. On the other hand, as regards forests, only about 33% of the whole area of them have been used and the rest remained stagnant. As Iran has many extensive forests with excellent hardwood, there are, thus, plenty of possibilities to expand plywood industry, But there is not new research in field of plywood consumption with respect to its building applications in the country, accordingly programming for development of the industry will not be accurate. In this development as plywood is mainly used in construction and since there is a possibility for it to be replaced by particleboard, fibreboard and aluminium profile, it is inevitable to determine how much we can exercise this replacement in building applications as inferred by the said industries. It is in this way that the production, consumption, import and investment on plywood industry will be predicted and foreseen more accurately. With regard to above mention, hypothesis of the research are as follows:

- The plywood industry has replacement products in building applications.
- The rate of the plywood replacement in building applications by particleboard is higher than another products.
- With respect to increasing of plywood consumption in future there will be need more development in the industry.

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There is not researches that compeletly similar to the present research but some of researches that their subject are approximately close to the field be referred. Estimated consumption for lumber and plywood in Hawaii indicates if the predicted consumption by the year 2000 is realized the present industry in Hawaii will have to grow to about 2.5 times its present size to maintain its relative position in the hardwood lumber market. The expected consumption in 2000 provides a base for expanding industry in terms of its present level. If the Hawaii timber products industry is to take part in this expected increase in market demands, it must (a) provide the species and products desired by the market; (b) provide these products at an accepted level of quality and in the amounts desired by the market; and (c) provide these products at competitive prices (Frazier, 1965). Statistics are presented about 4 wood based panel industries in North America, viz. particleboard, oriented strand board, fiberboard and plywood. Items highlighted are trends in manufacturing and new plants costs, industry manufacturing capacity and location. Recent data show the greatest amount of growth taking place in the oriented strand board sector. Modest rates of growth are taking place in the other 3 sectors (Spelter, 1994). A study undertaken by USDA forest service and forestry Canada assessed the prospects for timber supply and demand in North America to 2005. The research discusses the North America forest resource in terms of size, location and ownership distribution by both area and volume. Trends and prospects are indicated for raw material supply and forest product demand and the implications of the forecast demand are considered (Darr and Boulter, 1991). An introduction defines the 3 main classes of reconstituted panel produced: plywood, particleboard and fiberboard; and outlines various subdivisions within these categories.

The industry is compared with that world-wide and within the European countries and data for 1976-86 illustrate import/export of particle boards and or raw materials. The industry is dependent on foreign supplies of raw material. In order to ensure future timber supplies to the sector, it is recommended that agreements between wood supplies and panel producers be made, which would safeguard supplies and enhance economic development (Alvisi *et al*., 1989). Substitution models usually assume that the potential market size is known and that products can freely substitute for one another. A small but growing literature concerned with the diffusion of new innovations also exists within the domain of forest products. This diffusion literature typically focuses on factors affecting consumer acceptance for product innovations and forecasting the level of demand growth without constraining the potential market size. In the study, researchers examine the dynamic sales behavior of three and four successive generations of structural wood panel products using varying forms of a multi generation diffusion model. The multi generation diffusion model introduced here, which encompasses the elements of diffusion and substitution modeling, assumes that a new structural wood panel product will diffuse through a population of potential consumers over time and that market share competition will be introduced with successive generations of structural wood panels. Estimation results indicate that market share competition between various structural wood panel products are differentially affected by substitution and diffusion effects. The model results also suggest that structural wood panel products act as complements rather than as substitutes to one another. In the near-term, the multi generation diffusion model suggests that the southern pine plywood market has reached its peak production level over the past five years, with production forecast to decline slowly but steadily over the next decade. Western plywood is forecast to continue its downward production and market share trend. Oriented strand board is expected to remain entrenched in a growth phase over the next five to ten years (Steven *et al*., 1998). Evidence shows that in Germany extensive researches have been made regarding the plywood market (Mantel, 1973). In Iran the production, consumption and import trends of plywood industry and the problems that are faced by the available plywood industries were identified and necessary strategies were introduced (Amiri, 1991). The positions of raw materials used in Iran wood industries including plywood were studied and the rate of production and level of importation of wood raw material to improve the industry were determined (Amiri, 1990). Fisette presented the rate of replacement of plywood by OSB(oriented strand board). The result showed OSB is unceremoniously pushing plywood aside as the structural panel of choice. The increase in OSB production is expected to depress the price of all structural panels. Also, strong supplies reduce price volatility. Prices remain stable when the distribution chain expects adequate supplies. Market data show that conversion from plywood to OSB among builders is irregular (Fisette, 2005). Three residential builders cut callbacks, improve customer relations and meet code requirements using wood structural panels. This publication describes how three builders in Idaho, Texas and Ohio gained a competitive edge by fully sheathing the walls of their homes with plywood or OSB. Although each house which has been built is customized Oliver Custom Homes always use plywood for the flooring and oriented strand board (OSB) for the walls and roofs. They prefer to use plywood or OSB because they

get a better structure out of it (APA, The Engineered Wood Association, 2005). The aims of the present research are as follows:

- Determination of the replacement percent of plywood by particleboard, fiberboard and aluminum in building applications.
- Forecasting of plywood consumption with respect to per capita construction and population growth.
- Determination of the raw material required by plywood industry in the future.

MATERIALS AND METHODS

Librarian method of study: Based on the available data in both the national Iranian statistics institute and ministry of industry, the capacity of production of plywood, particle board, fiberboard and aluminum profile as well as the level of these products imports was provided for a ten year time (Iran National Statistical Yearbook and Iran Ministry of Heavy Industries, 1990). Then, the rate in which such products are consumed was calculated. As for construction trend the related statistics were obtained from the concerned entity (Iran Deputy for Housing Affairs, 1992). The research has been done at University of Tehran, Tehran- Iran, between 1999 to 2000.

Exponential smoothing method for predicting the level of products consumption: This method was found suitable to predict the economic indices that used to fluctuate in a period of time and correct the trend. This method first smooths the amounts of products in different years and provides us with a definite trend. Then, this trend continues The special formula to calculate a smoothed growth is as follows (Hajji, 1983; Rein and Silver, 1984):

$$F_{t+1} = \alpha A_t + (1-\alpha)Ft \quad (1)$$

F_{t+1} = Period predicted t+1
α = Smoothed growth coefficient $0 \le \alpha \le 1$ (In this research =0.1)
F_t = t-period predicted
A_t = observed real amount in t period

In order to predict the amount of products consumption such that of plywood, particleboard, fiberboard and aluminum profile, first of all the amount in which per capita consumption of products occur is calculated based on this amount and national population statistics in a ten year time, 1991-2000 and prediction of a ten year period is made by using the exponential smoothing method. On the other hand, the population rate is predicted in that period of time based on the growth rate of population and the level in which a product is foreseen based on growth rate of population and by multiplying the per capita consumption of a product.

Table 1: Rate of consumption of the products in one square meter of construction building per ton

Product	Consumption
Plywood	0.00064
Particleboard	0.0017
Fiberboard	0.00122
Aluminum	0.00112

Steps in which the percent of plywood replacement by three other products is identified: To obtain the percent of plywood replacement we applied case study process. There are 4 steps to calculate of the replaced percent that are as follows:

Step 1. Indicator of products consumption in building construction
Step 2. Per capita consumption
Step 3. Prediction of products consumption by replacing similar products based on per capita construction growth
Step 4. Determine the replaced material percent

Note: All of formulas (2-10) that have been used are case study. We describe indicators as follows:

R_i : Index of a product consumption
C : The level in which a product is used in a square meter.
C_t : Total products consumption in a square meter (m^2), (Table 1)
C_W : Suggesting consumption with no other products replacement in a target year
S : The rate in which construction is made in a target year
C_s : Consumption by replacing the similar products in building construction
R_i : Product consumption index
C_a : Product per capita consumption (in ton)
C_o : Total product consumption
P : Number of population (in million)
S_a : Per capita building construction (man)
S_{ac} : Cumulative statistics building construction in a target year
C_s : Products consumption by replacing similar materials in construction in a year
S_a : Per capita construction building
C_{ss} : Product consumption by replacing similar materials based on per capita construction growth in a year.
C_p : Annual consumption of particle board, fiberboard and aluminum based on population growth
C_{pp} : Annual consumption of plywood based on population growth
M : Annual varied consumption of every products in addition to plywood

M_1 : Year passed
M_2 : Year to come
L : Replaced amount
C_M : Percent of replaced materials for plywood in the year passed

$$R_i = \frac{C}{C_t} \quad (2)$$

$$C_w = C \times S \quad (3)$$

$$C_s = R_i \times C_w \quad (4)$$

$$C_\alpha = \frac{Co}{P} \quad (5)$$

$$S_a = \frac{Sac}{P} \quad (6)$$

$$C_{ss} = S_a \times C_s \quad (7)$$

$$M = C_p - C_{pp} \quad (8)$$

$$L = M_2 - M_1 \quad (9)$$

$$C_M = \frac{L}{M_1} \times 100 \quad (10)$$

There is an example about calculating of the replaced percent in Annex 1.

Annex 1: An example about calculating of the replacement percent

C_{sb} : Consumption by replacing similar particleboard products in building construction in 1982.
C_{sp} : Consumption by replacing similar plywood in building construction in 1982.

C_t= 0.00064+0.0017+0.00122+0.00112 = 0.00468

$$R_b = \frac{0.0017}{0.00468} = 0.364$$

$$R_p = \frac{0.00064}{0.00468} = 0.136$$

R_b : A code suggesting how much particleboard is consumed.
R_p : A code suggesting how much plywood is consumed.

R_l : A code suggesting how much aluminum is consumed
R_f : A code suggesting how much fiber board is consumed

$$R_f = \frac{0.00122}{0.00468} = 0.26$$

$$R_l = \frac{0.00112}{0.00468} = 0.239$$

C_{sb}= 0.0017088×32340000=55262
C_{sp}= 0.136×55262=7515.6
C_{ap} : plywood per capita consumption in 1982
C_{ab} : particle board per capita consumption in 1980
C_{af} : fiberboard per capita consumption in 1980
C_{al} : aluminum per capita consumption in 1982

$$Cap = 473$$

$$Cab = 2355.5$$

$$Caf = 773.2$$

$$Cal = 979$$

$$S_a = \frac{32340}{4200000} = 0.76$$

This prediction has been conducted in order to give effect to the construction parameters and population factor. It has the following formula:

For example the plywood replacement percent by particleboard in 1991 is as follow:

$$C_{pb\ 91} - C_{pp\ 91} = M_{91}$$

157726-23629=134097

$$C_{pb92} - C_{pp92} = M_{92}$$

161506.6-23883=137623.6

$$M_{92} - M_{91} = L_b$$

137623.6-134097=3526.6

$$\frac{3526.6}{134097} \times 100 = 2.63\%$$

The plywood replacement percent by particleboard in 1991(2.63)

Table 2: A predicted of the plywood replacement percent by particleboard, fiberboard and aluminum profile

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Particleboard (%)	27.26	29.19	31	32.94	34.83	36.33	38.22	40.12	41.8	43.67	45.56
Fiberboard (%)	7.82	8.1	8.28	8.33	8.36	8.36	8.36	8.36	8.36	8.36	8.36
Aluminum (%)	7.82	8.1	8.28	8.33	8.36	8.36	8.36	8.36	8.36	8.36	8.36

Table 3: A predicted consumption of plywood based on population growth and per capita construction building and its mean (Ton)

Year/Consumption	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Per capita building construction (Ton)	33567	33761	33944	34074	34107	34131	34104	34027	33899	33685	33496
Population growth (Ton)	29053.5	29628	30199	30765.6	31511	32249.8	32797.8	33592.6	34415	35120.8	35958.7
Mean Consumption (Ton)	31310	31694.5	32071.5	32419.5	32809	33190	33450.9	33809.8	34157	34402.8	34727.4

$C_{pb\,91}$: Consumption of particleboard in 1991 (Ton) based on population growth

$C_{pp\,91}$: Consumption of plywood in 1991 (Ton) based on population growth

M_{91} : Varied consumption of particle board in comparison with that of ply wood in 1991 (Ton)

L_b : The amount of replaced particleboard

Determining the percent in which plywood is replaced by Particleboard, fiber board and aluminum profile (based on per capita growth of construction building)

The same as said before but here what replaced is the per capita growth rate of construction building rather than population growth factor. For example, as regards the process of plywood being replaced by particleboard, the calculation is made based on per capita growth of construction building in 1991:

$$C'_{pb91} \quad C'_{pp91} \quad M'_{91}$$

$$77406 - 28975 = 48431$$

$$C'_{pb92} \quad C'_{pp92} \quad M'_{92}$$

$$79245 - 29608 = 49637$$

$$M'_{92} - M'_{91} = L'_b$$

$$49637 - 48431 = 1206$$

$$\frac{1206}{48431} \times 100 = 2.48\%$$

RESULTS

Prediction of the plywood replacement percent by particleboard, fiberboard and aluminum profile: If we assess the replacement percent by particleboard in two positions of population growth and per capita building construction, there is an increment linear trend in replacement percent by particleboard from 2001 to 2011. As regards fiberboard and aluminum profile, there is an increment linear trend in the replacement percent from 2001 to 2005 then the trend is fixed until 2011(Table 2).

Comparison between different consumptions of plywood based on population growth and per capita building construction: The predicted consumption based on per capita building construction is more than population growth base from 2001 to 2008 then the predicted consumption trend is inversed, otherwise from 2009 to 2011 the amount based on population growth is more than per capita building construction. Also there is an increment linear trend in the mean consumption from 2001-2011(Table 3).

The raw material required by plywood, particleboard and fiberboard industries by 2011: As far as the estimated logs (round wood) and firewood in the industries are concerned, if we consider the conversion coefficient as the same introduced by FAO for plywood, particleboard and fiberboard 2.3, 1.3 and 1.9 m^3 round wood, respectively, the plywood manufacturers would need by 2011 about 159744 m^3 of logs and those of particleboard and fiberboard about 488090 m^3 of firewood and extra cut off products, based on the mean consumption.

DISCUSSION

Percent of replaced plywood: Taking into consideration the results, the mean percent in which the plywood is replaced by particleboard has been estimated far more than fiberboard and aluminum profile. Two factors affects on the replacement, 1) total products consumption in a square meter of building construction, 2) the consumption trend of the products in past years. As we showed (Table 1) application of particleboard in building construction is higher than another products, also trend

of particleboard consumption showed increment linear trend in past years. Accordingly these factors affects on the replacement percent and the rate is high the trend will be increment linear trend in future. With respect to above mention factors both of fiberboard and aluminum profile had similar situations. Application of fiberboard and aluminum in building construction is close together and significantly are less than particleboard applications, as well as, trend of fiberboard and aluminum consumption in past years had lower increment linear trend with comparison to particleboard. Therefore replacement percent trend of them will be approximately increment linear trend and then is fixed, as well as, replacement rate of them becomes very lower than particleboard. Thus, it can be most easily observed that how much plywood industry depends on particleboard. Therefore, on the one hand as population growth and the particleboard can naturally and essentially replaces the plywood, it is necessary to accelerate its production in order to respond to the domestic demands (Table 2).

With regard to the predicted consumption of plywood, the trends were affected from consumed plywood of past years and building construction trend in recent years. What generally commands in consumption trend based on the population growth, because of short raw materials is supply and demand. The price rises as influenced by supply and demand and inflation factors and what eventually increases is the price index. In consumption trend, the supply and demand notion does not command as per capita building construction growth shows. It influences the prices constantly. In other word, the prices index is constant and only inflation causes the prices rise. As mean consumption trends show both supply and demand and per capita consumption factors (per capita building construction) influence the price and the price index would show a rise but this rise does not occur based on population growth and it is, thus, a little less (Table 3).

Raw material: With respect to the results, if we select the year of 2000, production of logs (319116 m^3) as basis, only 15% out of it, that is 47860 m^3 in plywood industry, have been used (Shafiey and Nakhaie, 1989). Now, comparing the quantity of logs in 2011, that is 159744 m^3, with that of 2000, only 29.9% of raw material of plywood industry can be supplied from domestic sources. This shows how much the said industry depends on logs import. However, there would be no difficulty in supplying raw materials for particleboard and fiberboard because they can be easily obtained from firewood or cut-off's. As it is known from the anticipation there would exist cases of deficiencies in plywood industry in supplying the required raw material in the future, such that taking into consideration the nature of usable raw material, that is to say, logs of 1st and 2nd grade and excellent species in the forest, it is necessary for the industry development to put the stagnant projects into operation, utilization of the forests would be made in a scientific way, forests are revived and expand by necessary a forestation.

Also some of the researches verify the present results. Results of the multi generation diffusion model shows the estimations of various structural wood panels affected by replacement effects in the forecasting period (Steven *et al*., 1998). The OSB industry research results indicates the plywood have replacement industry (OSB) and plywood consumption trend affected by the rate of replacement. Also the plywood development depends on the replacement industry situations in the future (Fisette, 2005). The builders surveyed reported shows wood structural panels, compared to other non-structural products can replace each other in building applications (APA, The Engineered Wood Association, 2005). The research on Hawaii timber products showed to encourage the continued development of the products requires a forestry program that provide the raw materials needed in the quantities desired by the industry (Frazier, 1965).

Accordingly all of the hypothesis which mentioned in first part of the research is confirmed.

Generalization: It will be possible that the methods which includes exponential smoothing and case study formulas be generalize to calculate the replacement percent of the another industries which can be substitute each other in deferent applications. Since, in the future, raw material resources to produce various products will decrease in all of the world, we can programming to develop the industries with respect to its substitution rate in deferent applications, accurately.

Limitations: In the present research, there were some limits. In building applications, the plywood, which can be used as doors and windows of the building has replacement industries. The scope of this study was using plywood density of 0.45-0.6 g cm^{-3} , fiberboard of 0.496 g cm^{-3} and particleboard of 0.4-0.8 g cm^{-3} (Parsapajouh, 1984) and low weight aluminum. Another limitation was value of Alfa in exponential smoothing formula.

CONCLUSIONS

In the present research we found tree objects which related to the aims of research. They are respectively: Replacement percent of plywood by particleboard, fiberboard and aluminum in building applications,

Forecasting of plywood consumption with respect to per capita construction and population growth, Raw material required by plywood industry in the future.

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