IJR International Journal of Railway
Vol. 2, No. 2 / June 2009, pp. 60-69

The Korean Society for Railway

Presenting an Effective Model for Technology Transfer with the Maintenance Approach in Case of Tehran Subway

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Abstract

In recent years, technology developments in different countries, especially in newly industrialized countries, are extremely indebted to appropriate technology transfer by these countries. Nevertheless the technology transfer process in the present situation is complex, and its success is related to the coordination rate with the political, economic, social, and environmental objectives of countries. Today debates related to the transfer of the technical know how accompanied by equipment hardware has found remarkable importance such that countries seek increasing comprehensive capabilities in the field of transferred technology for which Preventive Maintenance (PM) is one of the aspects.

This research with the purpose to determine the technological capability level and to study the role of PM in the effective & appropriate technology transfer in subway industry is carried out for presenting a suitable model for the technology transfer in this industry with an attitude towards the effects of principal PM factors. For this purpose, after the study of different and relevant models existing in the field of suitable methods for technology transfer, some equipment PM theories and models were selected as the base for the compilation of the questionnaire. With the help of questionnaire, main PM factors that are effective in the field of technology transfer were extracted, and finally, their effects on technology transfer were analyzed, identified and a comprehensive model suggested in this connection.

Keywords : *Appropriate technology, Technology transfer, Preventive maintenance, Utilization operations*

Introduction

Nowadays, the PM of equipment in product and service section is very important, and applying suitable management science in this subject, will cause saving in the capitals and equipment. One of the important factors in the field of increased productivity in industries could be the implementation of proper, logical, and systematic PM. For perception the importance of the relationship between technology transfer and PM, we should recognize the main suitable factors in technology transfer, and to have an effective technology transfer, we must consider these factors in purchasing and application of modern railroad cars and equipment. These factors could classified in two internal and external sections, including culture, society, regulations, technologies, production resources, financing, supply of skilled manpower with higher technical know how, political and economic status of countries that recognition of the entire parameters in this connection is a difficult task. However, with the application of proper management science, and with the support of the policy makers, we can prevent from exit of millions dollars from the local country, and reduce the surplus PM expenses. Tehran Subway Co. is one of the state urban train organizations that use extended and advanced equipment for the secure, quick, and precise service, so study on proper and logical relationship between PM and technology transfer in this industry is a necessity. To provide and use of Railroad cars, repairing of defects during utilization and remove of existing delays, a special attention to the PM operations and used modern technologies, are necessary. Therefore, with the identification of the main parameters of PM files, which are effective in the technology transfer, equipment with higher quality, technical ability and effectiveness can be transferred in order to minimize the percentage of wastes and waste of spare parts as much as

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possible. In any case, the most crucial problem of the urban railway companies in Asian countries in particular is the lack of enough experience in the field of suitable utilization of the urban railways. Most of such subways are faced with various problems for the limitation of resources and lack of technical know how in the field of applied PM and this problem requires establishment of higher interaction among the planning-technology purchase and PM of technology. Therefore, study of the 4-element details of technology (hardware, human ware, info ware, and organizational ware) and the related capabilities in the state subway industry causes higher strengthening of this industry and the related organizations and waste of resources and capital will be avoided through presenting technology transfer solutions.

Definition of PM

Operations conducted for the preservation of health and permanent functioning of equipment and for avoiding emergence of damages in them and fully planned, which are under single management and include two PM (practice of cyclic and planned services) and repairs (execution of repair activities at the time of damage and emergency solution of main damages).

PM in industries and its benefits

Concept of PM and repairs today has turned to one of the effective and useful matters in the different production and service industries and, recently, even the science of maintaining and repairing is taught in most of the world universities. Followings are parts of the importance reasons of PM and repair.

A) Reduced rate of equipment damages

B) Keeping sensitive and emergency equipment running and operating

C) Suitable practice of trouble shooting

D) Avoiding emergence of damages

E) Increased reliability of the production lines

F) Increased productivity

Total Productive Maintenance (TPM)

Definitions of TPM

• TPM: a group and comprehensive effort throughout the Company that is launched for increasing the qualitative level of every equipment and improvement of the general effectiveness of equipment (Seyed Hosseini, Syed Mohammad, Systematic Planning of the Maintenance and Repair System, 2003).

• TPM: a kind of maintenance with planning and cooperation of the entire employees of the organization (Seyed Hoseeini, Syed Mohammad, Systematic Planning of the Maintenance and Repair System, 2003).

• TPM: a kind of result-oriented improvement assuming equipment as its axis which is one of the sub-branches of TQM or Total Quality Management and results in the increased reliability of equipment, continuation of the production process and reduced wastes (Nakajima, TPM and its Integrative models with Quality System, 2003).

Objectives of TPM

• To establish a suitable structure and beneficial designing in terns of security an quality of machinery

• Maximizing general effectiveness of equipment

• Creating new work environment in which higher motivation is established

• Development of human resources involved in maintenance

Definition of technology

Many definitions have been presented in relation with technology each of which are discussed from specific point of view that followings are some of the main definitions of technology:

• "Technology" has roots in Greek terminology and it is composed of Techne and Logie words. Techne means art and it is created by humanity and Logie means science and wisdom (Mahmoudzadeh, Ebrahim; "Management emerging with the future technology, 2001).

• "Technology" is a tool for changing the form of inputs to the products capable of being supplied to market (Navaz Sharif; "Management of Technology Transfer and Development, 1997).

• "Technology" is the practical execution of science. It is a tool contributing to the capacity increase of the humanity (Taregh Khalil; Technology Management, 2005).

Component of technology

Technology is classified in 4 sections and subsections (R.J. Watts and a.l. porter, innovation force sting, 1997), (Sharif, N. technology policy formulation and planning):

A) Techno ware: external physical facilities are called "techno ware". This subsection includes tools, machinery, transportation vehicles, and structures.

B) Human ware: capabilities such as skills, industrial works, and human creativity are called "human ware".

C) Info ware: documented and registered sciences are called "info ware". Info ware is related to realities and formulation, designing parameters, attributes, instructions, and technical know how and so on.

D) Organ ware: organizational frameworks epitomized in units are called "Organ Ware". Organ Ware is introduced with methods, techniques, organizational networks,

Table 1. Specifications Table of Urban Train in Iranian Metropolises

City	Population (million persons)	Length of entire designed lines (km)	Total N. of designed lines	Length of course approved in first phase (km)	Number of stations approved in first phase	Required credit (USD)
Mashhad	2.2	60	4	19	22	1,000
Esfahan	1.3	110	4	13	15	2,200
Shiraz	1.1	50	3	24	21	1,000
Tabriz	1.3	40	3	18	20	800
Ahvaz	1.2	60	4	24	25	1,000
Karaj	1.4	60	6	25	26	1,000
Total	8.5	380	24	123	137	7,000
Tehran	8	425	8 urban lines 4 express metro lines	103 42	52	1,000 3,000
Total	16.5	750	36	268	181	20,000

and management practices.

Technology Transfer Definitions

• Technology transfer means input of the technological factors acquired from developed countries to developing countries for enabling the latter countries to supply and apply new production tools and to develop existing tools (Unctad, 1964).

• Reaching technology at international market or at the compass of the national boundaries from one industry to the other, from one section to the other section, or from one organization to another organization is called technology transfer (Aghaee, Manuchehr, Technology Transfer, 1989).

Subway Industry in the World

Presently more than 200 cities of the world are using subway in its real meaning or they are establishing it among which 44 cities are located at America, 89 cities at Europe, 3 cities at Africa, 71 cities at Asia and 2 cities at Oceania. Currently, government and municipalities with the purpose of organizing urban transportation, frugality in fuel consumption, solution of the environmental problems, accidents and creation of a suitable system holding speed, precision, security and safety parameters have become more sensitive in dealing with designing, construction, and utilization of such systems and, in fact, such objectives have turned to prioritized plans for them. Therefore, approximately in entire developed countries, most cities with more than 1 million populations are equipped with tramway, metro, light urban trains, etc or they have such structures under construction. Such sensitivity is being transferred to developing countries. Currently, subway of New York City is one of the full-stationed subways of the world, London has the longest metro line, and Moscow has the higher passenger rate in the world.

Subway Industry in Iran

The step for the intercity rail transportation was established at the time of Nassereddin Shah between Teheran and Abdolazim Holy Shrine in 1888 which had been known as Ghatar Doodi (Smoky Train). However, Municipality of Tehran assigned the problem of analyzing the urban transportation in 1971 to Sofretu-Ratp Companies. This institute based on the gathered data and statistics as well as the predictions related to the urban development of Tehran presented a comprehensive report in 1974 under the title of "Tehran Transportation Comprehensive Plan". As a result, "street-subway" system leaning on solving traffic of Central Tehran through establishing 7 subway lines with the length of 147 km was approved and Tehran's subway system commenced its activity in 1975 as the first state urban railway. With the utilization of the first subway line (Line 5) and with the transfer of a large number of passengers between Karaj and Tehran and, in the continuation of this, with the establishment of Line 2 (Sadeghiyeh- Imam Khomeini), state policy makers and planners applied some changes on their strategies and development of subway lines was granted with special attention in Tehran.

Subway Project in Metropolitans of Iran

Based on the latest macro planning in favor of the establishment of state urban railway projects, number, and length of total lines are according to the following table and volume of its investment is more than 20 Milliard Dollars (Hashemi, Mohsen, Tehran Subway, Corrections, Financing, Initiation, International Management Conference, 2006).

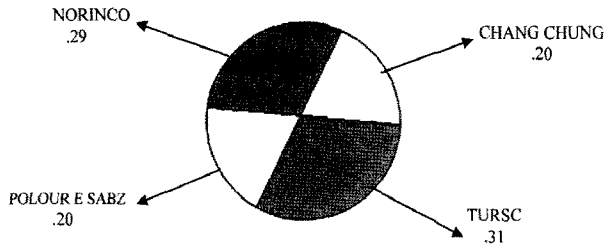

Fig. 1 Percentage of Foreign Investment in Technology Transfer of Subway Wagon

Method of supplying equipment and technology transfer in Tehran Subway

In the past situations most of the activities under process of Subway Company are focused on building activities, which are allocated to private section. With the review of such proceeding, execution of the construction activities is assigned to the contractor and the attention of the Subway Company is drained to the complex and more expensive activity such as technology transfer and fabrication of wagons in local country, which is not possible without the special support.

Foreign investment and technology transfer

Considering the governmental policies in supporting the local industries and absorbing the foreign investments to the local country with regards to the heavy investments made in the establishment of parking and repair stations of subway lines making use of the substructural facilities in repair stations decided to fabricate and import a part of the required wagons. In other words, these repair stations are used both for overhauls and assembling wagon. Since this experience is practiced in most of the world subways, Subway Company has taken action in the establishment of a legal company with the investment of the foreign partner and use of existing facilities of Tehran Subway Company including building, area, and facilities existing in the repair stations of Tehran Subway Co. Therefore, the foreign investment is also entered the country and required wagons will be produced resulting in the employment and transfer of advanced technology and prosperity of the local industry. Fig. 1 show the percentage of foreign investment in technology transfer of subway wagon.

The effort for fabricating mostly used spare parts in Iran, such as producing of inverter in Sharif University of Technology, producing of repulsion engines by JAMCO and producing of process show by the Defense Industry is commenced and fructified as well (Hashemi, Mohsen, Corrections, Financing, and Initiation of Tehran Subway, 4th International Conference on Management, 2006).

Research Methodology

The research domain here covers PM Deputy of Tehran Subway that is for the recognition of the main PM factors and its effects in the technology transfer of Subway Industry. Since this research is not about to interfere in the affairs of the said deputy, it just studies the current status and besides identification of the main PM factors effective in the field of technology transfer, effects of such factors on the due technology transfer are identified. In addition, Friedman's Non-parameter Test will be used for the prioritization of the main PM factors.

Indicatives for the Identification of Main PM Factors

A questionnaire was designed for the recognition of main PM factors for due technology transfer and after the recognition of main indicatives, effects of these factors in the due technology transfer in four technological domains were identified that followings are the designed indicatives in this regard:

Human Ware

1) Educational level and compatibility of the educational field of the personnel employed in PM section

2) Participation of employees in research and development and reengineering process

3) Work experience rate of employees and appointment of skilled employees in PM section

4) Educational and skill rate of employees in applying PM equipment

5) The introduction rate of employees to the equipment

6) Employees being able to analyze the breakage and damage reasons

7) Familiarity rate of personnel with computer

8) Flexibility of personnel in comprehending changes of PM process

9) Tending to group work and flexibility of personnel for understanding changes in the PM process

Info Ware

1) Utilization rate of the information technology instruments (local network, website, and information systems)

2) Creation of a comprehensive system for the maintenance, repair and registration of PM activities

3) Establishment of a planning and due scheduling system for the execution of PM operations

4) Coding instructions, technical maps, and authenticity of technical archive data, compiling the technical ID of entire equipment in the PM section

5) Content of the contracts concluded with the technology giver

6) Information rate and technical know how for the exe-

6) Information rate and technical know how for the execution of the PM operations and exchange of information and technical science between university sections

7) Familiarity rate of the receiver with technology and its market

Hardware

1) Suitable designing and management of equipment for avoiding occurrence of emergent damages

2) Equipping workshop with various instrumentation for the optimal execution of the PM activities

3) Waste rate of spare parts

4) Lifecycle and newness of equipment

5) Compatibility rate of equipment in terms of ergonomics

6) Consumption rate of energy

7) Compatibility rate of equipment with the state environmental and geographical conditions

8) Halt rate of equipment during utilization

9) Advancement rate of the control equipment of PM operations

Organ Ware

1) Capability of the organization in managing control of stocks and supply of spare parts

2) Endeavor of the organization in implementing the qualitative standards in the PM section

3) Concentration rate on objectives of the organization in the PM section

4) Effort of the organization in improving the efficiency and effectiveness of the PM operations

5) Designing organizational structure in terms of the structural PM specifications

6) Competitive effects of technology in the PM operations

7) Organization trying to outsource and privatize the PM section

8) Influence rate of the technology giver company on the receiver company

9) Innovation and development of R&D by the receiver

10) Communication rate of the organization with the manufacturer companies of equipment

11) Development of local construction policy

12) Allocating enough budget for the purchase of equipment

Identification of main PM factors

Besides launching some library studies the technical documentations and reports of the PM section were studied and then a single interview was made with the experienced elites of this industry and, finally, a group interview was made with elites for final summing up and the following results were acquired.

Table 2. Frequency of Scores Given to Human Ware Questions

Score	Frequency								
	1	2	3	4	5	6	7	8	9
Very low (1)	0	0	1	0	0	1	0	0	1
Low (2)	1	3	2	2	2	7	1	7	1
Medium (3)	6	14	5	9	12	9	19	14	14
High (4)	17	14	20	12	18	9	12	8	15
Very High (5)	11	3	7	12	3	9	2	6	4
Total	143	119	135	139	127	123	117	118	125

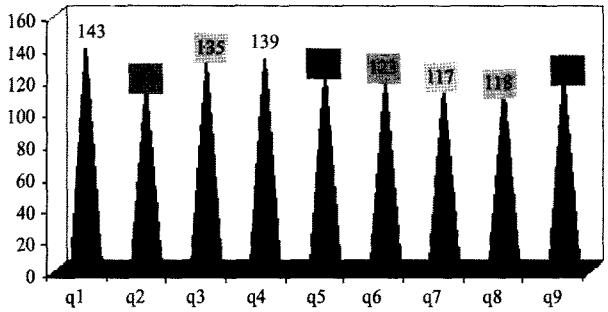

Fig. 2 Frequency of Scores Given to Human Ware Questions

Table 3. Prioritization of Human Ware Questions

	Mean Rank
q 1	6.91
q 2	4.41
q 3	5.85
q 4	6.40
q 5	4.81
q 6	4.29
q 7	4.15
q 8	3.62
q 9	4.54

Human Ware Indicatives

Frequency table resulted from completing and scoring questionnaire concerning human ware indicatives is covered in Table 2.

Considering the results acquired from the Fig. 2, fillers of the questionnaire have suitably scored the related questions and they believe that factors of this dimension of maintenance are effective on the due technology transfer in subway industry. Now we classify and identify effect of each one of the human ware factors of maintenance through Friedman's Non-parameter Test.

Therefore each one of indicatives is prioritized based on their effects that questions 1, 4, and 3 have higher priority.

Table 4. Frequency of Scores Given to Info Ware Questions

Score	Frequency						
	10	11	12	13	14	15	16
Very low (1)	2	0	3	1	0	0	2
Low (2)	4	3	3	8	5	5	5
Medium (3)	14	8	11	13	10	16	10
High (4)	11	15	14	7	15	11	14
Very High (5)	4	9	4	6	5	3	4
Total	116	135	118	114	125	117	118

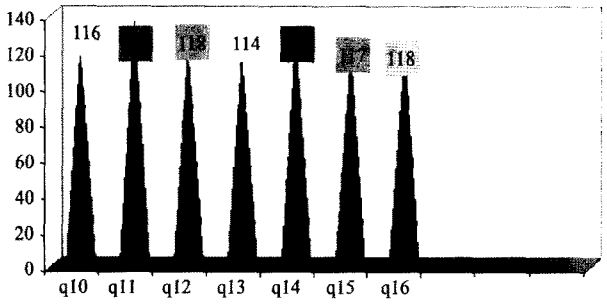

Fig. 3 Frequency of Scores Given to Info Ware Questions

Table 5. Prioritization of Info Ware Questions

	Mean Rank
q 10	3.56
q 11	5.46
q 12	3.76
q 13	3.36
q 14	4.46
q 15	3.66
q 16	3.76

Info Ware Indicatives:

Frequency table resulted from completing and scoring questionnaire concerning info ware indicatives is included in Table 4.

Considering the results acquired from the Fig. 3, fillers of the questionnaire have suitably scored the related questions and they believe that factors of this dimension of maintenance are effective on the due technology transfer in subway industry. Now we classify and identify effect of each one of the human ware factors of PM through Friedman's Non-parameter Test.

Therefore, each one of indicatives is prioritized based on their effect rate that questions 11, 14, and 12 have higher priority.

Maintenance Hardware Indicatives:

Table 4: frequency table resulted from completing and scoring questionnaire concerning maintenance hardware

Table 6. Frequency of Scores Given to Hardware Questions:

Score	Frequency						
	10	11	12	13	14	15	16
Very low (1)	2	0	3	1	0	0	2
Low (2)	4	3	3	8	5	5	5
Medium (3)	14	8	11	13	10	16	10
High (4)	11	15	14	7	15	11	14
Very High (5)	4	9	4	6	5	3	4
Total	116	135	118	114	125	117	118

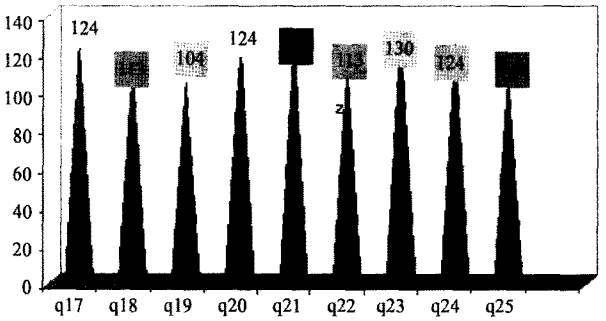

Fig. 4 Frequency of Scores Given to Hardware Questions

Table 7. Prioritization of the questions of Info Ware Indicative

	Mean Rank
q 17	5.50
q 18	4.71
q 19	2.96
q 20	5.49
q 21	5.76
q 22	4.04
q 23	6.85
q 24	5.50
q 25	4.19

indicatives is included in Table 6.

Considering the results acquired from the table 6, responders to the questions included in this questionnaire have suitably scored the related questions and they believe that factors of this dimension of PM are effective on the due technology transfer in subway industry. Now we classify and identify effect of each one of the human ware factors of PM through Friedman's Non-parameter Test.

Therefore, each one of indicatives is prioritized based on their effect rate that questions 23, 21, and 20 have higher priority.

4-2-4-Mainteance Tools Organization Indicatives:

Frequency table resulted from completing and scoring

Table 8. Frequency of Scores Given to Organ Ware Questions

Score	Frequency											
	26	27	28	29	30	32	32	33	34	35	36	37
Very low (1)	0	0	0	0	1	0	2	1	4	0	3	0
Low (2)	2	6	4	1	4	7	5	5	2	5	3	4
Medium (3)	4	10	13	13	15	8	4	6	14	13	9	4
High (4)	17	16	14	15	8	14	10	14	9	12	9	12
Very High (5)	12	3	4	6	6	6	14	8	5	5	10	15
Total	144	121	123	131	116	124	134	125	111	122	122	143

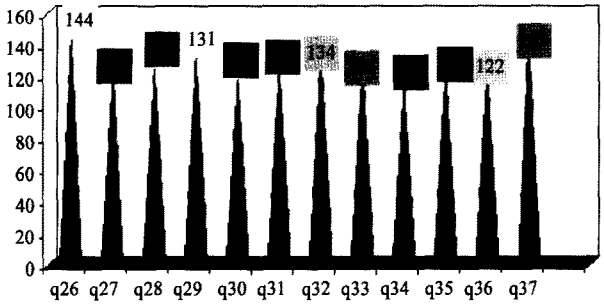

Fig. 5 Frequency of Scores Given to Organ Ware Questions

Table 9. Prioritization of the Questions of Organ Ware Indicative

	Mean Rank
q 26	9.25
q 27	5.26
q 28	5.62
q 29	6.94
q 30	5.26
q 31	5.81
q 32	7.59
q 33	6.85
q 34	4.46
q 35	5.44
q 36	6.37
q 37	9.15

questionnaire concerning PM organ indicatives is covered in Table 8.

Considering the results acquired from table 8, responders to the questions included in this questionnaire have suitably scored the related questions and they believe that factors of this dimension of PM are effective on the due technology transfer in subway industry. Now Friedman Non-parameter Test is used for the classification and identification of the effect of each one of the human ware factors of PM through.

Table 10. Frequency of Scoring Questions

Indicator	Total questions	Total indicator scores	Average of indicator scores	Mean % of indicators
Human Ware	9	1146	3.7	% 74
Info Ware	7	843	3.5	% 70
Hardware	9	1067	3.4	% 68
Organ Ware	12	1516	3.7	% 74
Total	37	4572	3.6	% 72

Summing up indicatives and questions of the questionnaire related to the second questions of the research, table and frequency Figure resulted from filling and scoring questionnaire concerning total indicative is shown in table 10.

Identification of Main PM Indicatives:

Therefore, for the continuation of the research and for responding to the next questions of the research, 3 factors, which have obtained the highest score in Freidman's Test, were selected as factors having the highest effectiveness and their effect on the due technology transfer will be studied. Then library researches were launched and technical documentations and technology transfer contracts were investigated and individual interviews were made with the experienced elites of this industry and, finally, a group interview was made with elites for final summing up and the following results were acquired.

Furthermore based on the findings of the second question of the research, main PM factors are classified in four sections including human ware, info ware, hardware, and organ ware and indicatives were prioritized based on Freidman Test that due to the time limit of the research and the possibility of reaching a general framework, the expected response of three indicatives that had the highest prioritization were selected for being studied.

A) Human Ware:

• Level of education and compatibility of the educa-

tional field of the personnel employed in the maintenance section

- Proper prioritization of tasks and determination of domains for the employees of the PM section
- Work experience rate and application of skilled employees in the PM section

B) Info Ware:

- Creation of a comprehensive system for the PM and for the registration of PM activities
- Importance of coding instructions, technical maps, and authenticity of the technical archive data and compilation of the technical ID of entire equipment in the PM section
- Content of contracts concluded with the technology giver

C) Hardware:

- Adjusting equipment with the state environmental and geographical conditions
- Lifecycle and newness rate of equipment
- Compatibility rate of equipment in terms of ergonomics

D) Organ Ware:

- Capability of the organization in managing control of stocks and supply of spare parts
- Allocating enough budget for the purchase of equipment
- Organization trying to outsource and privatize the PM section

Presentation of suggestive model:

Since due technology transfer requires attention to the entire effective factors on such transfer, technology transfer shall be done depending on the activity type and attributes of every organization in order to acquire the required efficiency and effectiveness avoiding waste of resources. Technology transfer in the subway industry has been done based on the experience and comments of the skilled individuals and no specific unified and systematic and scientific model. In this connection, the following model which has been extracted from this research has been presented as a suitable technology transfer model in the subway industry.

Conclusion

Subway has allotted to itself 10 per cent of the intercity travels in a short-term period and 50 per cent in a long-term period. These travels generally will happen in the most trafficked urban transportation axles and in the most crowded districts of the city. Doubtlessly, attendance of subway has applied many evolutions on the life of the citizens residing in the Iranian metropolises and it will result in the waste of time and energy, increased physical and mental health, reduced mortalities, and dangers resulted from driving accidents and reduced depreciation of the personal transportation vehicles. Tehran Subway Company simultaneous with the utilization of the first intercity subway line in 1998 has presented some suitable guidelines and solutions for minimizing the travel expenses and reduction of the time waste factors and energy consumption in order to promote citizens to use subways and government to invest in the subway industry through increasing productivity and continuous value generation in traveling with subway. In addition, considering the sensitivity of the PM operations in the subway industry and with the true implementation of PM, damages at the time of utilizing equipment was minimized. This action will result in the customer (passengers) satisfaction and effectiveness of the applied technologies. As you know, intercity rail transportation system has found special position in metropolises and it is regarded as the most secure, comfortable, quick, and frugal public transportation mean. Therefore, considering that this industry is newly established in Iran and interest of the senior managers of this industry in the level and scale of compatibility of these technologies with the state conditions and with the consideration of state conditions as well as issues related to the technology transfer process, this industry will result in higher frugality in the expenses resulted from the default of the PM operations and effectiveness of the transferred technology.

Suggestions

Considering the practiced studies, followings are suggestions presented t other organizations and researches for paying attention to the role of PM in the due technology transfer:

1) Since definition and recognition of technology transfer in Iran is most of the times related to the purchase of equipment and machinery, therefore, exploration and identification of the effective factors in the technology transfer seems necessary.

2) Due technology transfer is under the influence of the technical ability rate of the organization and environmental conditions like state political and economic situations having effect on this matter and they must be considered in the due technology transfer.

3) PM has an inseparable relation with technology. Therefore, its main factors should be identified and it must be considered in the due technology transfer.

4) Effect of main PM factors in the technology transfer is one of the main strategies of the organization in having successful technology transfer.

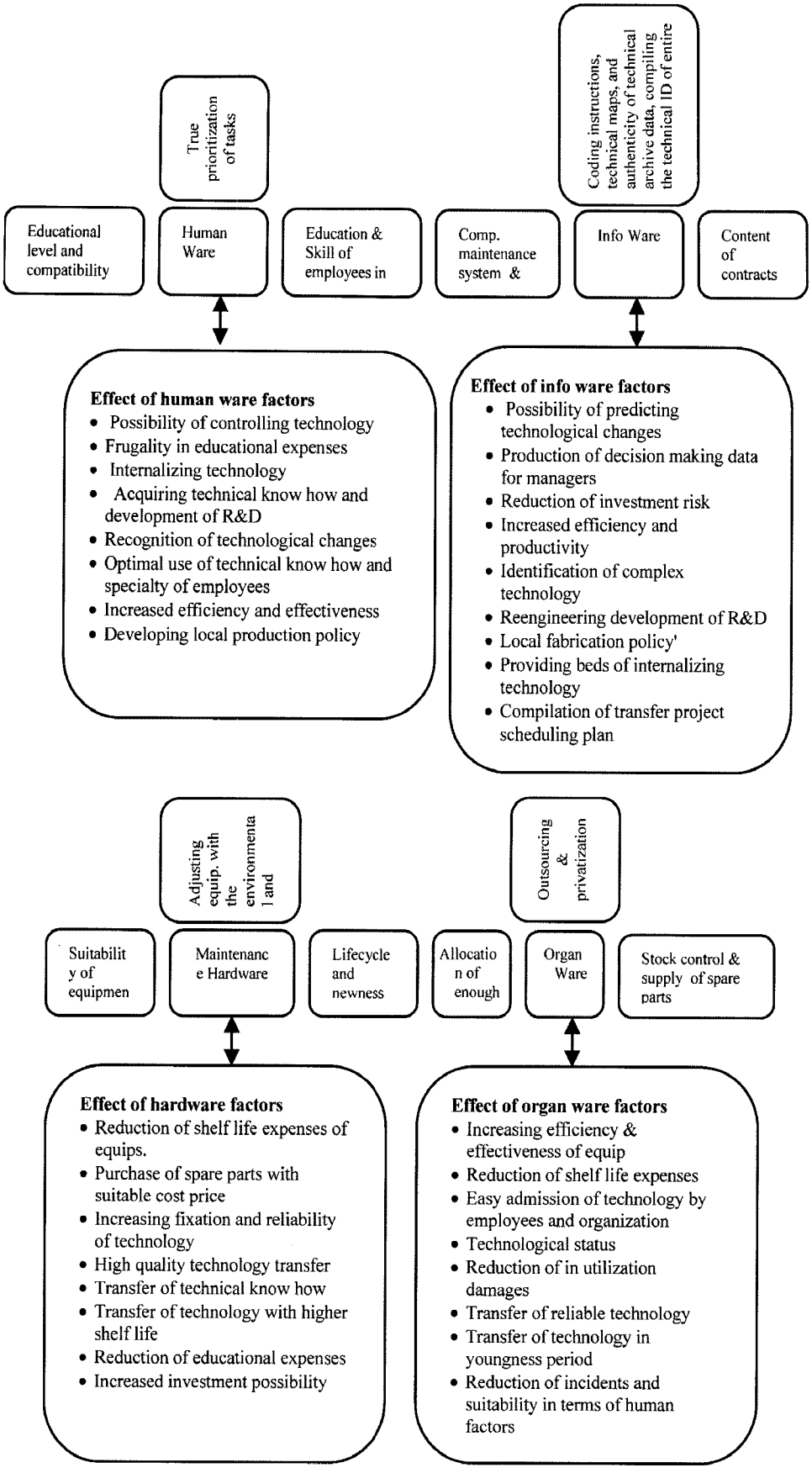

Fig. 6. Suggestive Model for the Due Technology Transfer in Subway Industry with PM Approach

5) Organization pays less attention to the education and development of manpower; special policies should be adopted concerning the improvement of the educational level.

6) No concentrated, stable and applied relation is observed between subway industry and university section.

7) No enough attention is paid to outsourcing matter of PM and use of private mother companies. Outsourcing of PM shall become one of the priorities of the organization.

Suggestion for the future researches

1) Since in this research the due technology transfer solutions are based on main PM factors, therefore, researchers may improve this model through studying other models and with the investigation of the other effective factors in the field of due technology transfer.

2) The future researchers can carry out researches concerning the role and effect of IT debates in the field of due technology transfer.

3) Future researchers may study other PM parameters in the due technology transfer.

4) Future researchers may study this model in other industries and domains.

5) Future researchers may carry out researches about the role of outsourcing in PM and its effect on due technology transfer.

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