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ISSN 2150-4075 (Print) ISSN 2150-4083 (Online)
http://www.scirp.org/journal/ib

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Immigrant Entrepreneurs: The Face of the New Nashville

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Received September 27th, 2009; revised November 12th, 2009; accepted December 16th, 2009.

ABSTRACT

This paper examines the remarkable growth of the foreign-born population in Middle Tennessee over the past couple of decades and the significant role that immigrant entrepreneurs are playing in the economic development of the region. The largest segment of the foreign-born is Hispanic, with Mexico accounting for the greatest percentage, and sizeable numbers of Kurds, Somalis, Sudanese, and Laotians. The Chinese and Indian communities are prominent in business. At the same time, the issue of illegal immigration is working its way to the top of the legislative agenda in the U.S. Congress, making it all the more important for us to document this phenomenon. Middle Tennessee, comprising the greater Nashville metropolitan area, is now home to thousands of new residents from around the world, earning it the sobriquet as one of the nation’s New Ellis Islands. Since the 1970s research has confirmed the important contribution that the small business sector is making to the U.S. economy, accounting for a large portion of job creation and innovation. Richard Herman and Robert Smith, in their recent book entitled Immigrant, Inc., make the case that immigrant entrepreneurs are driving the new American economy and will save the American worker. The paper draws upon research conducted by faculty and graduate students in the College of Business at Tennessee State University during 2008-2009. With funding from the Tennessee Board of Regents, a College of Business team conducted a series of focus groups, face to face interviews, and an extensive questionnaire in the fall of 2008 and spring of 2009. On three occasions the TSU team hosted public forums in which the results of the survey were shared with those participating in it as well as public officials responsible for economic and community development. Team members relied upon the intermediary services of immigrant chambers of commerce and other community organizations with ties to foreign-born business owners. In the course of the survey the Metro Nashville government conducted a referendum on a proposal to require an English Only amendment on public documents. The Mayor’s Office and Nashville Chamber of Commerce lobbied against the amendment, which was roundly defeated. But it was a coalition of immigrant groups that rallied against the amendment, bringing them together in a common cause that made the difference. There is reason to believe that a New Nashville is taking form and finding its voice.

Keywords: Immigrants, Refugees, Entrepreneurship, Entrepreneurs, Nashville, Small Businesses, Foreign-Born Business Owners, Hispanics.

1. The Small Business Sector and the Foreign-Born in the U.S.

1.1 The Small Business Sector in the U.S.

For several decades students of the American economy have been aware of the important role that small businesses play in terms of job creation and innovation. While Fortune 500 firms have been losing jobs, companies with fewer than 500 employees have come to account for a greater share of employment. Indeed the so-called “gazelles”, small businesses that grow at a sustained rate of 20% or more a year for five years, account for much of the innovation in the economy.

The SBA Office of Advocacy regularly produces a series of working papers on the U.S. small business sector. In the fall of 2008 the staff prepared a paper for presentation at a conference in which the U.S. presidential elections were the focus of attention. In the paper Chad Moutray, Chief Economist in the Office of Advocacy, provided an overview of challenges and opportunities for entrepreneurship in the U.S. economy. Drawing upon data from the U.S. Census Bureau’s Statistics of Business, Moutray laid out reasons why small businesses play a key role in the economy. In the first instance, they provide much of the net new job growth; between 2004 and 2005, 83% of all the new jobs in the U.S. were in busi-
nesses with fewer than 20 employees. “High-impact firms” (those that experience doubling of sales and employment over a four-year period) accounted for almost all of the private sector employment and revenue growth in the economy.

Moutray outlined five challenges that small business owners were likely to face in coming years.

**Strengthening the Overall Economy.** The nation is in the grip of an economic downturn; since December 2007, 760,000 non-farm jobs had been lost and the unemployment rate stood at 6.1%. Small businesses in particular have struggled to weather the storm. To get the economy moving again small businesses will have to play a key role through innovation and employment. Construction, an industry overwhelmingly dominated by small businesses, has been particularly hard hit with the loss of 558,000 jobs since January 2007.

**Taxes and regulation.** Small businesses frequently cite tax and regulatory policies as a major concern. They face disproportionately higher compliance costs per employee than their larger counterparts when complying with federal regulations. A number of tax changes are wet to take place in the coming years that may be more palatable to small businesses. On the regulatory front, it is anticipated that there will be an influx of new regulations at the federal level on issues ranging from homeland security to health insurance to employees and increasing coverage the coverage they offer their workers, including sharing the costs with them or choosing not to offer health coverage at all. Of the 46 million Americans who do not have health insurance, many of them work for small businesses. Finding ways to control the cost of providing health insurance premiums have risen sharply in the past decade, forcing many small business owners to make changes to the coverage they offer their workers, including sharing the costs with them or choosing not to offer health coverage at all. Of the 46 million Americans who do not have health insurance, many of them work for small businesses. Finding ways to control the cost of providing health insurance to employees and increasing coverage will therefore likely remain a priority.

**Cost and availability of health insurance.** Health insurance premiums have risen sharply in the past decade, forcing many small business owners to make changes to the coverage they offer their workers, including sharing the costs with them or choosing not to offer health coverage at all. Of the 46 million Americans who do not have health insurance, many of them work for small businesses. Finding ways to control the cost of providing health insurance to employees and increasing coverage will therefore likely remain a priority.

**Attracting and retaining a quality workforce.** Small businesses must compete for labor with their larger counterparts. Firms that are able to offer benefits have a greater probability of retaining good employees than those who don’t. Demographic trends in the future are likely to exacerbate the challenges for small businesses in terms of employee recruitment and retention. With a growing number of employees retiring, small businesses will see a mass exodus of “institutional knowledge” that will be hard to replace in certain fields. This will also lead to labor shortages in some industries, especially in technology and health occupations.

**Global competition.** Not the least of challenges small businesses will face is globalization. Higher costs in the U.S. for taxes and regulatory compliance and energy expenditures have caused many firms to outsource abroad, thereby competing on price while focusing domestic production efforts in other areas. Even smaller businesses are being obliged to consider competing on a global scale. For some, advances in technology have allowed them to thrive in the global marketplace.

In sum, small businesses in the U.S. inject vitality and a competitive spirit into the economy that is not readily available from large businesses. They play a vital role in innovation, regional economic development, and the pursuit of new markets. They are responsible for half of the gross domestic product, employ over half of the private workforce, and generate the majority of new jobs. Furthermore, self-employment serves as an opportunity for many to better themselves by taking risks and generating new businesses.

### 1.2 Profile of the Foreign-Born in the U.S.

The Pew Research Center estimated that a record 12.7 million Mexican immigrants were living in the United States by 2008, a 17-fold increase since 1970. Mexicans now account for one-third of all immigrants living in this country. The second-largest nationality group of immigrants, Filipinos, account for just 5% of all immigrants in the U.S. [1].

More than half (55%) of the Mexican immigrants in the U.S. are unauthorized. Overall, Mexicans comprise about six-in-ten (59%) of the estimated 11.9 million unauthorized immigrants in the U.S. No other country in the world has as many total immigrants from all countries as the U.S. has immigrants from Mexico alone. Russia hosts the second largest number of immigrants, with 12 million foreign born, many of whom are natives of countries in the former Soviet Union.

Large-scale settlement in the U.S. by Mexicans began in earnest in the 1970s. By 1980, Mexico had the largest foreign-born population here with 2.2 million, or more than twice the second-place country (Germany at 850,000). The number of Mexicans immigrants to the U.S. doubled from 1980 to 1990 and more than doubled from 1990 to 2000. While the growth rate of the Mexican immigrant population has slowed considerably since 2006, the total number reached a record 12.7 million in 2008, or almost 17 times the number in 1970. Mexicans make up the largest number of undocumented immigrants in the U.S. (7.0 million, or 59%) as well as the largest number of legal immigrants (5.7 million, or 21%).

The current Mexican share of all foreign born living in the U.S.—roughly one third—is the highest concentration of immigrants to the U.S. from a single country since the late 19th century. But it is not unprecedented. Irish immigrants represented a third or more of the immigrant population from 1850 to 1870. Germans were 26% to 30% of the foreign-born population from 1850 to 1900.

The ACS data for 2007 shows that among the foreign-born those from India, Australia, South Africa and the Philippines have the highest median household in-
Immigrant Entrepreneurs: The Face of the New Nashville

comes. Residents born in India have the highest: $91,195. The foreign-born from Somalia and the Dominican Republic had some of the lowest median household incomes. Median household income is $50,740 for the total population, $46,881 for the foreign-born population and $51,249 for the native population. U.S. residents born in Somalia have the youngest median age (26.8). Nationally, the median age for the total U.S. population is 36.7. The total foreign-born population has a median age of 40.2 and the total native population has a median age of 35.8.

Some 81 percent of the foreign-born age 16 and over from Nigeria and Kenya are in the labor force, compared with only about 65 percent of the general U.S. population in this age group and 67 percent of the foreign-born population. U.S. residents born in India have the highest percentage of civilian-employed people working in management, professional and related occupations (69 percent). These occupations employ about 36 percent of the native civilian-employed U.S. population and 27 percent of the foreign-born. The foreign-born from Liberia and Haiti have the highest percentage of civilian-employed people working in service occupations (at 40 percent and 39 percent respectively, the differences are not statistically significant).

1.3 Contribution of Immigrant Business Owners to the U.S. Economy

Research conducted by Prof. Robert Fairlie under contract with the Small Business Administration [2] provides the most up-to-date summary of data available on the contribution of immigrant business owners to the U.S. economy. Fairlie draws upon three datasets: the Census 2000, 5 percent PUMS Sample, the Current Population Survey (CPS 1996-2007), and the Characteristics of Business Owners (CBO 1992). He presents several key findings from his study:

Immigrants are nearly 30% more likely to start a business than are non-immigrants; they represent 16.7% of all new business owners in the U.S.;

Immigrant business owners make significant contributions to business income, generating $67 billion of the $577 billion in U.S. business income, as estimated from the 2000 Census data. They account for one-quarter of all business income in California and nearly one-fifth of business income in New York, Florida, and New Jersey.

Immigrant business ownership is concentrated in a few states. Nearly 30% of all business owners in California are immigrants compared with roughly 12.5% of the population of U.S. business owners. In New York, New Jersey, Florida and Hawaii foreign-born business owners account for more than 20% of the total.

In California, immigrants are 34% of the new business owners each month, while 30% of all new business owners in New York Florida, and Texas are immigrants.

Immigrants own 11.2% of businesses with $100,000 or more in sales and 10.8% of business with employees.

The contribution of immigrant businesses differs across sectors of the economy. They own a large share of businesses in the arts, entertainment, and recreation as well as services and transportation.

Although business owners from Mexico constitute the largest share of immigrant business owners, total immigrant business ownership, formation, and income originate with immigrant owners from around the world.

Drawing upon 2000 Census data in his discussion of business ownership, Fairlie points out that the immigrant share of all business owners compares favorably to the immigrant share of the work force. Immigrants constitute 12.2% of the U.S. work force, suggesting a higher business ownership rate than the U.S.-born rate. In fact, 9.7% of immigrants own a business, compared with 9.5% of the U.S.-born work force. The source countries of immigrant business owners in the U.S. are quite diverse. The largest contributing country is Mexico, with 255,300 business owners representing 2.22% of all business owners in the U.S. Korean immigrant owners make up the second largest share of immigrant owners (78%) followed by Indian, Chinese, and Vietnamese.

Using education as a proxy variable for skill level, Fairlie concludes that immigrant business owners make up the largest share of the least educated business owners; slightly more than 28% of all business owners with less than a high school degree are immigrants. However, the largest educational group among immigrants is college graduates who constitute 31% of all immigrant business owners and 11.9% of all business owners with a college degree. Similar to the analysis by skill level, Fairlie notes that immigrant business owners make significant contributions to the U.S. economy in several industries. More than one-fifth of all businesses in the arts, entertainment, and recreation industry are owned by immigrants, double the portion of immigrant contribution to all industries. Immigrant-owned businesses also contribute substantially to other services (17.6%), transportation (16.9%), wholesale trade (15.9) and retail trade (15.5%). Geographically, immigrant businesses are heavily concentrated in four states: California, New York, Florida, and Texas. Immigrant contributions to business ownership in all these states are considerably higher than the national average of 12.5%.

Looking at business formation, Fairlie seeks to capture the dynamics of business creation among immigrants. To do so, he estimates the number of new immigrant business owners in the U.S. and makes comparisons to the total number of new business owners. Using data from the CPS (1996-2007), Fairlie notes that 81,000 immigrants started businesses each month, representing 16.7% of all new businesses in the U.S. for this period. This is higher than the share of all business owners or of the work force. Immigrants are found to be creating busi-
nesses at a faster rate than non-immigrants. The largest number of new businesses is created by immigrants from Mexico, who account for 4.8% of all business starts in the U.S. Business formation is distributed broadly across many other immigrant groups.

How much do immigrant-owned businesses contribute to total business income in the U.S.? How much value do they create in the economy? Fairlie points out that this is a difficult question to answer because one must rely on the data from the 2000 Census and the 1992 Characteristic of Business Owners (CBO). According to the 2000 Census data, the total business income for immigrants was $67 billion, representing 11.6% of all business income in the U.S. which was $577 billion. The immigrant representation of total business income is lower than the representation of the total number of business owners, suggesting that immigrant-owned businesses have lower average incomes. Average Immigrant-owned business income was $46,614, compared with $50,643 for non-immigrants. Business income generally increases with the age of the owner and is also related to level of education.

Immigrants from Mexico provide the largest contribution to total U.S. business income, at 1.2%. Korean and Indian immigrants make relatively large contributions to total business income, but overall contributions are spread across a wide range of immigrant groups. Not surprisingly, most business income for both immigrants and the overall economy is produced by the most educated business owners. Among immigrants, the total business income of college graduate business owners represents 52% of all immigrant-owned business income, roughly the same as for all business owners.

On a subject of particular importance—employment generation—the Fairlie study provides very little information. Again, drawing upon the 1992 CBO data, he reports that immigrant-owned firms constitute 8.9% of all firms with no employees, whereas immigrants own 10.8% of all firms with some employees. Fully 77.8% of all immigrant-owned firms were reported as having no paid employees and 15% had fewer than five employees. Only 0.1% of immigrant firms employed more than 100 employees. It is fair to conclude that the overwhelming majority of immigrant businesses belong in the small business sector.

In their new book, Immigrant, Inc., authors Richard Herman and Robert Smith argue that immigrants constitute a culture of entrepreneurship. The authors describe a culture of hard work, education, thrift and innovation as well as a thirst for adventure that is characteristic of immigrant business owners. They note that immigrant entrepreneurs are twice as likely as native-born Americans to start a business. They established more than half of the technology companies in Silicon Valley and a fourth of those nation-wide. They file patents at twice the rate of American-born. Immigrant entrepreneurs are more likely to earn an advanced college degree than are American-born. And, as residents of the Cleveland area, the authors point out that immigrant talent is beginning to be viewed by some “rust belt” cities as a catalyst for economic revival. Relying less on a barrage of statistics than images, Herman and Smith paint portraits of foreign-born entrepreneurs from around the world who have enjoyed remarkable successful. A leitmotif of Immigrant, Inc. is the reminder that America is indeed a nation of immigrants who have provided the leavening for entrepreneurial achievement.

2. Nashville: A New Ellis Island

2.1 Center for Immigration Studies—New Ellis Islands—2001

In 2001 the Center for Immigration Studies undertook a study of trends in immigration in the U.S. in which they described the development of “new Ellis Islands” [3]. The authors noted that an estimated 1.3 million legal and illegal immigrants now settle in the country each year. In the past immigrant settlement was mostly confined to relatively few states, with California, New York, and Florida accounting for more than half of the nation’s foreign-born population. While immigrants still tend to be concentrated in a few states, the Center of Immigration Studies study revealed that there is growing evidence that immigrants are increasingly settling in areas that until recently were largely unaffected by immigration. Although Camarota and Keeley were not able to avail themselves of 2000 Census data, they attempted to identify new areas of immigrant settlement based on analysis of immigrant arrival data provided by the Immigration and Naturalization Service (INS).

The Camarota and Keeley study compared the size of the foreign-born population in the 1990 Census with the number of new legal immigrants (those receiving green cards) who arrived from abroad between 1991 and 1998, as determined by the INS. Excluding counties with very small immigrant populations, those counties in which the number of new legal immigrants (1991-1998) was equal or in size to at least 50 percent of the existing foreign-born population in 1990 were designated as “New Ellis Islands”. Some of the key findings from the study were:

One out of 14 counties in the United States—223 of the 3,141 that comprise the U.S.—met the criteria of a New Ellis Island. While these counties can be found throughout the United States, the new areas of immigrant settlement were mainly in the South with 131, and the Midwest, with 75 counties.

The state with the most counties identified as New Ellis Islands was Georgia, with 25, followed by Minnesota and Kentucky with 18 counties each. Virginia had 13 such counties, while Tennessee and North Carolina
had 12 each.

The new areas of immigrant settlement tended to be associated with either immigration from Mexico or India with refugee resettlement. Mexico was the leading sending country in 82 counties (37 percent) that qualified as New Ellis Islands. It was followed by India, the top-sending country in 35 counties (16 percent). Refugee-sending countries (primarily Vietnam and the former Soviet Union) were the leading sending countries in 50 counties (22 percent). Nashville ranked first in the number of new immigrants (1991-1998) relative to its foreign-born population in 1990 in the nation’s 100 largest metropolitan areas. Atlanta was second and Louisville third.

Table 1 (Metro Areas Ranked by Size) shows the top 25 MSAs ranked by the number of new immigrants (1991-1998) relative to the size of their 1990 foreign-born populations. The top city of new immigration was Nashville, followed by Atlanta and Louisville. Many of the cities were to be found in the South. Of the 25 metropolitan areas in the list, 13 were in the South. Analysis of the top sending countries showed that in most of these cities, refugee-sending countries lead the list. Vietnam or the former Soviet Union was the leading sending countries in 20 of the 25 metro areas. There is also significant diversity in legal immigration in most of these areas. In only three of the cities did the top sending country account for 25 percent or more of legal immigration. There were a number of major metropolitan areas that were experiencing significant immigration that until recently had been largely unaffected by immigration.

2.2 Vanderbilt Institute for Public Policy Studies: Immigrant Community Assessment 2003

In 2003 the Metropolitan Government of Nashville-Davidson County awarded a contract to the Vanderbilt Institute for Public Policy Studies (VIPPS) to conduct an Immigrant Community Assessment [4]. The study was to gauge the adjustment of immigrants in the Nashville community and to assess the level of services available to them. The research project was designed to accomplish five assessment goals identified by the Metropolitan Government. These included an understanding of the changing demographics and economic behaviors of the immigrant population, an analysis of available resources to the communities and methods of linking them to existing programs, and an assessment of how well immigrants were being integrated into Nashville. The study included a list of recommendations associated with each of seven themes intended to maximize mutual understanding between native and foreign-born residents. The VIPPS team consisted of researchers in various disciplines from several local institutions.

The assessment focused on themes for strengthening Nashville’s public and private social services. Those services discussed by the immigrants with greatest frequency included education (adult and children), employment, health, housing and safety. The ethnic groups that participated in the focus group sessions included Arabic, Hispanic, Kurdish, Lao, Somali, and Vietnamese. Each expressed needs unique to its community. Among the themes explored in the assessment was an increase in the availability of the curriculum of English-language instruction, the development of community-based social service agencies in areas where immigrants and refugees reside, and an increase in the accessibility of employment, housing, and service provided. A final recommendation was to establish an on-going organization dedicated to immigrant and refugee affairs. It is important to note that the VIPPS assessment did not pay particular attention to immigrant businesses or their concerns.

2.3 Building the New American Community—2003

Nashville was one of three American cities selected to participate in an experiment in public-private partnerships of immigrant and refugee integration primarily, funded by the U.S. Office of Refugee Resettlement. The project, known as Building the New American Community, sought to identify challenges to the integration of immigrants into the larger population [5]. Under project auspices, the Urban Institute prepared a demographic profile of the foreign-born population which included data on immigrant population growth, diversity, settlement patterns, English language ability, poverty, and citizenship trends. The profile of the Nashville Economic Market consisted of the Nashville Metropolitan Statistical Area (Cheatham, Davidson, Robertson, Rutherford, Sumner, Williamson, and Wilson) plus Maury and Montgomery Counties. Data for the paper were derived from the 2000 U.S. Census as well as the U.S. Immigration and Naturalization Service (INS) Statistical Yearbook.

Although the share of the Nashville Economic Market’s foreign-born population (5%) was less than half the national average of 11%, nevertheless the rate of immigration growth in the region grew rapidly. Between 1990 and 2000 the growth was 203%, four times the national average. For same period, the rate of growth for the state of Tennessee was 169%, placing it sixth in the nation in the rate of immigrant population growth. Even so, only 3% of the state’s population in 2000 was foreign-born. Latin Americans constituted the largest single geographic group among the foreign-born at 40%, although there were significant representations from other regions (Asia and Middle East 32%), Europe (16%) and Africa (6). Mexico was by far the largest country of origin of immigrants in the Nashville area with 27%, followed by Germany, Korea, Laos, Canada, India, and Iraq. The African significant portion of the Latin American immigrants
# Table 1. Metro areas ranked by relative size of 1991-1998 new legal immigration to 1990 foreign-born population

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<td>First Country Number</td>
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<td>1</td>
<td>Nashville, Tenn.</td>
<td>18,012.00</td>
<td>10,330.00</td>
<td>57% Vietnam: 1,325.00</td>
<td>Vietnam: 1,325.00</td>
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<td>2</td>
<td>Atlanta, Ga.</td>
<td>116,624.00</td>
<td>62,017.00</td>
<td>53% Vietnam: 11,251.00</td>
<td>Vietnam: 11,251.00</td>
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<td>3</td>
<td>Louisville, Ky.-Ind.</td>
<td>11,970.00</td>
<td>6,170.00</td>
<td>52% Vietnam: 1,420.00</td>
<td>Vietnam: 1,420.00</td>
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<tr>
<td>4</td>
<td>Minneapolis-St. Paul, Minn.-Wisc. Greensboro-Winston-Salem -Highpoint, N.C.</td>
<td>88,093.00</td>
<td>44,502.00</td>
<td>51% Vietnam: 5,345.00</td>
<td>Vietnam: 5,345.00</td>
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<td>5</td>
<td>15,318.00</td>
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<td></td>
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<td>Vietnam: 1,664.00</td>
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<td>6</td>
<td>Charlotte-Gastonia-Rock Hill, N.C.-S.C. Memphs. tenn.-Ark.-Miss Portland-Vancouver, Ore.-Wash Seattle-Bellevue-Everett, Wash. Seattle, Wash., D.C.-Md.-Va.-W.Va.</td>
<td>24,041.00</td>
<td>11,683.00</td>
<td>49% Vietnam: 2,142.00</td>
<td>Vietnam: 2,142.00</td>
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<td>7</td>
<td>13,907.00</td>
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<td>Vietnam: 1,344.00</td>
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<td>Minneapolis-St. Paul, Minn.-Wisc. Greensboro-Winston-Salem -Highpoint, N.C.</td>
<td>88,093.00</td>
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<td>51% Vietnam: 5,345.00</td>
<td>Vietnam: 5,345.00</td>
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<td>9</td>
<td>169,798.00</td>
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<td>Vietnam: 11,612.00</td>
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<td>10</td>
<td>489,668.00</td>
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<td>El Salvador: 21,858.00</td>
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<td>11</td>
<td>Baton Rouge, la.</td>
<td>10,458.00</td>
<td>4,257.00</td>
<td>40% Vietnam: 1,382.00</td>
<td>Vietnam: 1,382.00</td>
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<td>12</td>
<td>Indianapolis, Ind Raleigh-Durham-Chapel Hill, N.C.</td>
<td>21,597.00</td>
<td>8,725.00</td>
<td>40% Vietnam: 1,043.00</td>
<td>Vietnam: 1,043.00</td>
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<td>13</td>
<td>29,374.00</td>
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<td></td>
<td></td>
<td>China: 1,460.00</td>
</tr>
<tr>
<td>14</td>
<td>Denver, Colo.</td>
<td>81,334.00</td>
<td>31,721.00</td>
<td>39% Mexico: 7,876.00</td>
<td>Mexico: 7,876.00</td>
</tr>
<tr>
<td>15</td>
<td>Harrisburg-Lancaster-Lebanon-Carlisle, Pa.</td>
<td>11,911.00</td>
<td>4,633.00</td>
<td>39% Vietnam: 994.00</td>
<td>Vietnam: 994.00</td>
</tr>
<tr>
<td>16</td>
<td>Kansas City, Mo.-Kan. Greenville-Spartanburg-Anderson, S.C.</td>
<td>35,488.00</td>
<td>13,772.00</td>
<td>39% Vietnam: 2,085.00</td>
<td>Vietnam: 2,085.00</td>
</tr>
<tr>
<td>17</td>
<td>11,901.00</td>
<td></td>
<td></td>
<td></td>
<td>Vietnam: 532.00</td>
</tr>
<tr>
<td>18</td>
<td>49,021.00</td>
<td></td>
<td></td>
<td></td>
<td>Vietnam: 2,566.00</td>
</tr>
<tr>
<td>19</td>
<td>Wichita, Kan.</td>
<td>14,888.00</td>
<td>5,711.00</td>
<td>38% Vietnam: 2,154.00</td>
<td>Vietnam: 2,154.00</td>
</tr>
<tr>
<td>20</td>
<td>22,518.00</td>
<td></td>
<td></td>
<td></td>
<td>Vietnam: 1,505.00</td>
</tr>
<tr>
<td>21</td>
<td>Orlando, Fla.</td>
<td>82,042.00</td>
<td>30,381.00</td>
<td>37% Vietnam: 2,409.00</td>
<td>Vietnam: 2,409.00</td>
</tr>
<tr>
<td>22</td>
<td>Sacramento, Calif.</td>
<td>120,136.00</td>
<td>44,272.00</td>
<td>37% Vietnam: 10,746.00</td>
<td>Vietnam: 10,746.00</td>
</tr>
<tr>
<td>23</td>
<td>Baltimore, Md.</td>
<td>87,653.00</td>
<td>32,720.00</td>
<td>37% Vietnam: 5,802.00</td>
<td>Vietnam: 5,802.00</td>
</tr>
<tr>
<td>24</td>
<td>2,285,996.00</td>
<td></td>
<td></td>
<td></td>
<td>Dom.rep.: 153,790.0</td>
</tr>
<tr>
<td>25</td>
<td>Middlesex-Somerset-Hunterdon, N.J.</td>
<td>126,653.00</td>
<td>46,555.00</td>
<td>37% India: 4,772.00</td>
<td>India: 10,553.00</td>
</tr>
</tbody>
</table>

| Nation | 19,767,000.00 | 5,516,874.00 | 28% | Mexico: 766,162.00 | China: 427,348.00 | Soviet Union: 382,474.00 |        |

*Analysis limited to 100 largest MSAs. Figures for China include Hong Kong and Taiwan.*
Immigrant Entrepreneurs: The Face of the New Nashville

population (8%) was more than double the national average; the largest African groups were from Nigeria, Egypt, Ethiopia, and East Africa.

The 2003 Urban Institute paper noted the large discrepancy between the Census data and the INS admissions data; the latter includes only records for legal immigrants admitted in a given year. According to the Census data for the period from 1990 to 1998, 49% were born in Latin or North America, nearly three times the percentage indicated by the INS admissions data (legal immigrants). This was in sharp contrast to the other regions of the world. The conclusion to be drawn is that a significant portion of the Latin American immigrants were undocumented, whereas immigrants from the other regions were mostly legal.

The heaviest concentrations of the foreign-born population were to be found in the Davidson County (Nashville) neighborhoods of Glenview and Mercy Oaks (along Nolensville Road) where they comprised 25 to 34% of the total population. This was five times the average of 5% in the total economic market area. In addition, concentrations of Latin Americans were to be found in Ft. Campbell, Springfield, Gallatin, Columbia, and Murfreesboro. Asians were clustered in Ft. Campbell, Clarksville, Brentwood, and Murfreesboro.

Within the Nashville Economic Market some 31% of the immigrants were naturalized citizens, slightly lower than the national average of 40%. The lower rate may be explained by the fact that a large portion of the immigrants arrived after 1995. Of these, Asians (including Middle Easterners) comprised the largest group (41%), followed by Latin Americans (25%), Europeans (23%) and Africans (7%). Latin Americans had the lowest naturalization rate (19%) in the Nashville area and also lagged behind the national rate (30%). Fully 70% of Latin American immigrants are new arrivals. Furthermore, the INS data revealed that many were undocumented and therefore ineligible for citizenship.

2.4 Carnegie Reporter—Nashville: The Global Interior—2005

The Carnegie Reporter devoted a lengthy story to immigration in Nashville [6], noting that a city with a predominantly white population known for its country music, rhinestone cowboys and fried chicken and biscuits had suddenly morphed into a new Ellis Island! The article described Nashville as typical of the new, nontraditional settling grounds where foreign-born newcomers find an abundance of jobs, housing, lower prices and, sometimes, friendlier receptions. In the light of an unprecedented influx of foreign-born individuals and families, the city assembled businesses, government, religious and community organizations to grapple with its new role as a global destination. This made the city and region a national leader in superlatives: Tennessee was the first state to issue drivers’ licenses for documented and undocumented immigrants. The city housed one of five U.S. polling stations in America for Iraqi expatriate voters during the January 2005 Iraqi elections.

All of this provoked an anti-immigrant backlash and coalitions were formed to control the growth of undocumented immigrants. Nashville became part of a new American frontier sometimes labeled the “global interior” that runs from Minnesota to Texas where immigrants and refugees have moved in unprecedented numbers since 1990. Nontraditional communities have also become a haven for Iranians and Iraqis after the Persian Gulf War and terrorist attacks, Somalis and Sudanese evading political turmoil, Russian Jews seeking religious tolerance and Bosnians escaping ethnic cleansing. Tennessee’s foreign-born population grew by 169 percent between 1990 and 2000, and the state ranked sixth in the nation in the rate of its foreign-born population’s growth. It is the nation’s fourth fastest growing state in Hispanic population. Within Tennessee, most of the newcomer population flocked to Nashville in Davidson County and seven other adjacent outlying counties of middle Tennessee. By 2005 one-in-seven of Nashville’s 570,000 residents were foreign-born.

Nashville’s foreign-born population grew even more rapidly than the rest of Tennessee, almost four times as fast as the national average. And this rate was likely much higher because large numbers of undocumented immigrants are not counted by the census. Unlike previous generations, today’s immigrants and refugees simultaneously maintain cultural, political, economic and social ties to two or more societies. And one of their greatest challenges is integrating not only with the American culture, but also with the multiple cultures of other newcomers.

One of the first groups in Nashville to perceive the influx of immigrants and refugees were local businessmen who readily employed the newcomers arriving in the city looking for jobs. During the 1990s, the metropolitan area added 260,000 jobs, mainly due to the establishment of Nissan, Saturn and Dell manufacturing plants. Employers were happy to tap into the abundant supply of immigrants and refugees—even if they didn’t speak English—to work in factories, on construction sites and in restaurants and stores. Nashville-based Gaylord Entertainment—which has expanded its legendary Grand Ole Opry to include an entertainment division and a chain of hotels and resorts, including the 2,884-room Opryland Hotel in Nashville—houses its foreign-born workers at smaller, off-site hotels and provides English-as-a-Second Language (ESL) classes. One large Nashville construction company reported that one-fourth of its employees were Hispanic. A meatpacking plant near Nashville reported that 40 percent of its 1,600 employees were from foreign countries and spoke 13 different languages.
But the immigrant workers also brought problems with them: poverty, illegal status and language barriers all became issues. Currently, eighteen percent of the foreign-born population in Nashville lives below the federal poverty level ($17,050 for a family of four in 2000), almost double the rate for the total city population. Almost half of the foreign-born population speaks limited English. Three-fourths are not citizens and, therefore, are civically isolated and politically disenfranchised. The public school superintendent has increased the number of ESL classes for a student body that speaks 80 different languages, but the increases cannot keep pace with the demand and the number of classes and teachers is lacking.

2.5 Tennessee’s Population

The U.S. Census Bureau’s American Community Survey (ACS) estimated that in July 2007 Tennessee’s population had increased by an annual average of about 64,035 residents since 2000 (to 6,156,719 residents). Over that period net immigration was adding about 8,345 persons each year. During the same period there was a net annual average population gain of about 29,745 residents from net domestic migration (more native-born residents arriving than leaving). Net immigrant settlement accounted directly for more than one-eighth (13%) of the total population increase over this period and that does not take into account the children born to the immigrants after their arrival in the United States.

The 2000 Census found 5,689,283 persons resident in Tennessee, an increase of 812,098 persons above the 1990 Census (16.7%). The amount of increase was the 12th highest in the country. The rate of increase was the 14th fastest increasing population in the country. The 2000 population was about 32,000 more persons than the Census Bureau had expected to find in the state when it issued its most recent state population projections in 1996. The significance of this is that the Census Bureau concluded that much of the shortfall in their population estimates during the 1990s was due to an underestimation of the illegal alien population. Between 1980 and 1990 Tennessee’s overall population increased by 6.2 percent (from 4,591,023 to 4,877,185 residents).

2.6 Tennessee’s Foreign-Born Population

The Federation for American Immigration Reform (FAIR) is a national, nonprofit, public-interest, membership organization of concerned citizens who share a common belief that the nation’s immigration policies must be reformed to serve the national interest. Founded in 1979, FAIR seeks to improve border security, stop illegal immigration, and promote immigration levels consistent with the national interest—more traditional rates of about 300,000 a year. The FAIR website quotes statistics from the U.S. Census Bureau, providing its own estimates of demographic trends. FAIR is generally critical of the Census Bureau’s tendency to under-count illegal immigrants (http://www.fairus.org).

FAIR estimates that the foreign-born population of Tennessee was about 248,820 residents in July 2007, a four percent share of the total population. The amount of change since the 2000 Census indicates an average annual rate of increase in the foreign-born population of about 12,305 people, which is nearly one-fifth (19.2%) of the state’s annual average population increase. Since 2000, the foreign-born population has increased by 56.5 percent compared to a 6.8 percent increase in the native-born population.

Immigration also contributes to population growth through the children born to immigrants in this country. Nationally the share of births to the foreign-born is about double their share of the population. An eight percent share of Tennessee’s current births is large enough to account for about 6,415 births a year. Combining the increase in the foreign-born population and estimated immigrant births suggests that immigration may account for adding about 18,715 persons to the state’s population annually, i.e., nearly three-tenths (29.2%) of the state’s overall population increase. The 2000 Census recorded 159,004 foreign-born residents in the state (Table 2 Summary of Tennessee Demographic Data). That was 2.8 percent of the state’s overall population and an increase of 169 percent above the 1990 foreign-born population of 59,114 residents. That more than doubling of the immigrant population was much higher than the 14.8 percent increase in the native-born population. The amount

Table 2. Summary of Tennessee demographic data (and source)

<table>
<thead>
<tr>
<th>Category</th>
<th>Estimate/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (2000 Census):</td>
<td>6,156,719</td>
</tr>
<tr>
<td>Foreign-Born Population (2000 FAIR est.):</td>
<td>248,820</td>
</tr>
<tr>
<td>Share Foreign-Born (2007 FAIR est.):</td>
<td>4.0%</td>
</tr>
<tr>
<td>Share Native (2006):</td>
<td>31.7%</td>
</tr>
<tr>
<td>Legal Immigrant Admissions (DHS 1997-2006):</td>
<td>54,571</td>
</tr>
<tr>
<td>Refugee Admissions (DHS 1997-2006):</td>
<td>9,059</td>
</tr>
<tr>
<td>Illegal Alien Population (2007 FAIR est.):</td>
<td>100,000</td>
</tr>
</tbody>
</table>

Source: http://www.fairus.org
of increase was the 20th highest in the country. The rate of increase in the foreign-born population was the sixth highest in the country.

A comparison of the increase in the immigrant population from 1990 with the change in the overall population during the same period shows that immigrant settlement directly accounted for 12.3 percent of the state’s overall population increase over that decade. The share of the population increase due to immigration would be still higher if the children of the immigrants born here after their arrival were included with their immigrant parents in the calculation. The amount of the overall impact of immigration on population change (immigrants plus their children) is more likely to account for about 16 percent of the state’s population increase, based on the increase in the share of those who speak a language other than English at home in Tennessee.

The 2000 Census found that 57.7 percent of Tennessee’s foreign-born population had arrived in the state since 1990 (Table 3 Speakers of Foreign Languages at home). This demonstrates the effects of the current mass immigration, and it is a much higher share than the national average (43.7%). An indicator of the change in the immigrant population may be seen in data on the share of the population that speaks a language other than English at home. Between 1990 and 2000 the share of non-English speakers at home in Tennessee increased from 2.9 percent to 4.8 percent. Less than half (42.2%) of those who said they spoke a language other than English at home in 2000 also said they spoke English less than very well.

The Census Bureau’s American Community Survey found that in 2006, the foreign born population was 236,516 residents, an increase of 56.7 percent since 2000. By comparison, the foreign-born population changed from 59,114 to 159,004 residents between 1990 and 2000, an increase of 169.0 percent.

Ten countries constituted approximately 56.4% of the foreign-born population in Tennessee in 2006, (Table 4 Tennessee Foreign-Born Change 1990-2006). Of the total foreign-born population, Mexico alone accounted for nearly one third (31.9%). In 1990 the top five countries accounting for the foreign-born in Tennessee were Germany, the U.K., Canada, India, and Korea. Ten years later the top five countries were Mexico, Germany, India, Canada, and China.

2.7 Small Businesses in Tennessee

The small business sector in Tennessee mirrors its importance on the national level. According to the Small Business Administration’s Office of Advocacy, figures for 2006 indicate that Tennessee counted 100,607 small business employers (<500 employees), whereas large employers numbered only 2,952 (http://www.sba.gov/advo).

<table>
<thead>
<tr>
<th>Table 3. Speakers of foreign languages at home in Tennessee</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spanish</strong></td>
</tr>
<tr>
<td><strong>German</strong></td>
</tr>
<tr>
<td><strong>French</strong></td>
</tr>
<tr>
<td><strong>Vietnamese</strong></td>
</tr>
<tr>
<td><strong>Korean</strong></td>
</tr>
<tr>
<td><strong>Arabic</strong></td>
</tr>
<tr>
<td><strong>Chinese</strong></td>
</tr>
<tr>
<td><strong>Laotian</strong></td>
</tr>
<tr>
<td><strong>Japanese</strong></td>
</tr>
<tr>
<td><strong>Tagalog</strong></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Table 4. Tennessee foreign-born change since 1990: top ten countries 1990-2006</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rank</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td><strong>All Others</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Source: FAIR, www.fairus.org
There were 436,143 businesses that had no employees. Thus, small businesses represented over 97% of the state’s employers and 45% of its private-sector employment. The health care and social assistance industry was Tennessee’s largest small business employer while manufacturing was the largest overall employer. Small businesses created 39.7% of the state’s net new jobs from 2004 to 2005. Figures from 2002 showed that there were 7,241 Asian-owned businesses and 4,301 Hispanic-owned businesses in Tennessee.

3. Recent Immigration Issues in Middle Tennessee

3.1 Office of Research and Education Accountability—2007

In 2007 the Office of Research and Education Accountability (OREA) in the Tennessee Comptroller of the Treasury undertook a study of immigration issues in the state [7]. The primary focus of the resulting OREA briefing paper was on the scope and degree of the impact of unauthorized aliens on the state public policy and services. The OREA study also sought to address the question of what the role of the state should be with regard to the immigrant population. The OREA report noted that state-specific data of unauthorized aliens was limited. OREA relied primarily on U.S. Census data, which estimates the number of unauthorized aliens based on a residual methodology taking figures for foreign born and subtracting counts for those with a legal status from the Department of Homeland Security.

Drawing upon data from the 2000 and 2005 U.S. Census American Community Survey, the OREA report observed that 45% of the 2005 foreign-born population in Tennessee was from Latin America, of which 29% was from Mexico. About 29% were from Asia and 13% from Europe. Seventy percent of the state’s foreign-born population resided in the metropolitan (MSA) counties. The Nashville MSA accounted for 36% while the Memphis MSA had 22%. Relying upon data from the Pew Research Center, the OREA study reported estimates of between 100,000 and 150,000 unauthorized aliens in Tennessee in 2005, representing only about two percent of the total population. Most of the unauthorized aliens have come from Mexico (56%) and another 22% from the rest of Latin America, mainly Central America.

The OREA briefing paper described some of the costs to state government from unauthorized aliens, but did not attempt to provide a specific estimate of the overall impact on the economy. However, it noted that unauthorized aliens are not eligible for most public benefits, with the exception of elementary and secondary education and emergency and public health care. In terms of higher education, unauthorized aliens may be admitted to public colleges and universities in the state but are not eligible for in-state tuition or financial aid. The OREA paper ventured only a couple of modest recommendations. Among them was the suggestion that state agencies such as the Department of Safety and Health continue to assist in providing the federal government with means of worker verification. This could make it easier to identify unauthorized aliens and exclude them from jobs and services as currently required by federal law.

American Community Survey figures for 2006 show a total of 60,854 foreign-born in Davidson County, of whom 45,076 were not U.S. citizens and only 15,778 were naturalized citizens (see table below). Of these, 35,874 entered the U.S. before 2000 and the remainder thereafter. The Latin American region accounted for 26,140 of the foreign-born population, whereas Asia accounted for 15,833 and Africa 11,769. Within the population five years and older, a substantial number of the total population, nearly 33,000 spoke Spanish at home.

4. Profiles of Selected Refugee and Immigrant Groups in Middle Tennessee

Nashville’s refugee population has grown in both size and diversity since the 2000 Census (Table 5).

Davidson County, Tennessee Selected Social Characteristics. State Department figures show that Nashville ranks 28th in the nation in refugee resettlement, with at least 3,100 placed here since 2002—about 1 percent of the national total. The Administration for Children and Families in the Office of Refugee Resettlement (ORR) in the U.S. Department of Health and Human Services (http://www.acf.hhs.gov/programs/orr) manages refugee resettlement. ORR was established in the belief that newly arriving populations have inherent capabilities and thus provides those in need with critical resources to assist them in becoming integrated members of American society. ORR serves those persons outside the U.S. who are unable or unwilling to return to their country of origin because of persecution or a well-founded fear of persecution on account of race, religion, nationality, membership in a particular social group, or political opinion. Persons granted refugee status overseas by the U.S. Department of Homeland Security is brought to the U.S. for resettlement by the U.S. Department of State. Voluntary agencies assist with their resettlement and integration into the U.S. Refugees are eligible to receive ORR benefits and services from the first day they arrive in the U.S.

Newcomers are becoming so diverse that the former Somali Community Center was recently renamed the Center for Refugees and Immigrants of Tennessee since the Center caters to refugees from many countries. Catholic Charities Refugee Resettlement Program, a local affiliate of the United States Conference of Catholic Bishops’ Migration and Refugee Services, provides core
Table 5. Davidson county, Tennessee selected social characteristics data set: 2006 American community survey

<table>
<thead>
<tr>
<th>Place of Birth</th>
<th>Total population</th>
<th>U.S. Citizenship Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>578,698</td>
<td>Foreign-born population</td>
</tr>
<tr>
<td>Born in United States</td>
<td>517,844</td>
<td>Naturalized U.S. citizen</td>
</tr>
<tr>
<td>State of residence</td>
<td>512,467</td>
<td>Not a U.S. citizen</td>
</tr>
<tr>
<td>Different state</td>
<td>313,162</td>
<td></td>
</tr>
<tr>
<td>Born in Puerto Rico, U.S. Island areas,</td>
<td>199,305</td>
<td></td>
</tr>
<tr>
<td>to American parent(s)</td>
<td>5,377</td>
<td></td>
</tr>
<tr>
<td>Foreign born</td>
<td>60,854</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year of Entry</th>
<th>Population born outside the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>66,231</td>
</tr>
<tr>
<td>Entered 2000 or later</td>
<td>526</td>
</tr>
<tr>
<td>Entered before 2000</td>
<td>4,851</td>
</tr>
<tr>
<td>Foreign born</td>
<td>60,854</td>
</tr>
<tr>
<td>Entered 2000 or later</td>
<td>24,980</td>
</tr>
<tr>
<td>Entered before 2000</td>
<td>35,874</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>World Region of Birth of Foreign Born</th>
<th>Foreign-born population excluding population born at sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign-born population, excluding</td>
<td>60,854</td>
</tr>
<tr>
<td>born at sea</td>
<td>+/−3,889</td>
</tr>
<tr>
<td>Europe</td>
<td>5,600</td>
</tr>
<tr>
<td>+/−1,616</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td>15,833</td>
</tr>
<tr>
<td>+/−1,561</td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>11,769</td>
</tr>
<tr>
<td>+/−3,008</td>
<td></td>
</tr>
<tr>
<td>Oceania</td>
<td>121</td>
</tr>
<tr>
<td>+/−141</td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>26,140</td>
</tr>
<tr>
<td>+/−2,081</td>
<td></td>
</tr>
<tr>
<td>Northern America</td>
<td>1,391</td>
</tr>
<tr>
<td>+/−599</td>
<td></td>
</tr>
</tbody>
</table>

Source: U.S. Census Bureau, 2006 American Community Survey (www.factfinder.census.gov)

Immigrant Entrepreneurs: The Face of the New Nashville

resettlement services to newly arrived refugee individuals and families (http://www.cctenn.org). Through its Reception and Placement Program refugees secure housing, food, clothing and other basic needs; assistance in accessing education, social services and health care; and employment services. Within 90 days, most refugees are on their way toward self-sufficiency. The city’s refugee services have provided refugees with English and citizenship classes and helped them find jobs. The Metro school system has guided their children to the International Newcomer Academy to learn simple aspects of American life, such as standing in line and using modern bathrooms.

Refugees fled the Khmer Rouge in Cambodia, the theocratic regime in Iran, political oppression in Africa, and the civil war in Iraq [8]. Refugees have arrived in the Nashville area from all over the globe, largely because of the U.S. government’s resettlement program decides where to send them. The Nashville area now has the largest Kurdish community in the U.S. (estimates vary from 8,000 to 12,000), primarily from Iraq. Somalis and Sudanese represent the next-largest groups, numbering more than 3,500 each. Refugees have suffered political persecution and hardship and are accorded resident status by the State Department. More recently refugees are coming from new places. For example, several of the 60,000 Bhutanese being admitted to the U.S. over religious tensions have landed in Nashville and more are expected. Myanmar, formerly known as Burma, is also the point of origin for new refugees.

4.1 Hispanics

By far the most important segment of the foreign-born population in Middle Tennessee is that comprised of Hispanics. There is considerably more data available on Hispanics than other groups, owing to the work of the Pew Hispanic Center which tracks Hispanic population trends throughout the U.S. Founded in 2001, the Center is a nonpartisan research organization that seeks to improve understanding of the U.S. Hispanic population and to chronicle the growing impact of Latinos on the nation. The Center does not take positions on policy issues. It is a project of the Pew Research Center, a nonpartisan “fact tank” in Washington, DC, that provides information on the issues, attitudes and trends shaping America and the world. It is funded by the Pew Charitable Trusts, a public charity based in Philadelphia. The Center provides the following figures for the Hispanic population in Davison County/Nashville.

The Pew data recorded a veritable explosion in the Hispanic population in Davidson County from 4,775 in 1990 to 46,546 in 2007 (see table below). During the period from 1990 to 2000 the Hispanic growth rate was 446% while from 2000 to 2007 it was 78%. The Hispanics represented 5% of the county population in 2000, increasing to 8% in 2007. The Pew data, covering all 3,141 counties in the U.S., showed that Davidson County was among the highest in the country both in terms of absolute number of Hispanics and rate of growth (Table 6 Davidson County Hispanic Population 1990–2007), (www.pewhispanic.org).

The Hispanic community is also fortunate to have a strong non-profit organization dedicated to serving its population. Conexión Américas was founded in 2002 to address some of the most pressing challenges and opportunities created by recent demographic changes in the region as an increasing number of Latino families in search for a better quality of life. The name speaks to our desire to connect and build bridges that come between the Latino and the native-born communities. The founders of Conexión Américas—María Clara Mejía, José...
Today Conexión Américas is recognized as a leading Hispanic force in the Middle Tennessee region and in the entire state. In 2005, Conexión Américas was named the recipient of the Best Innovative Partnership Award from Neighbor Works America for its Puertas Abiertas homeownership program. In 2007, Conexión Américas received both the national Strengthening Families Award presented by the Annie E. Casey Foundation and the National Council of La Raza (NCLR) and the Bank of America Neighborhood Builder Award.

### Table 6. Davidson county Hispanic population 1990–2007

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2000</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hispanic Population&lt;sup&gt;1990&lt;/sup&gt;</td>
<td>4,775</td>
<td>26,091&lt;sup&gt;151&lt;/sup&gt;</td>
<td>46,546&lt;sup&gt;190&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total County Population</td>
<td>510,784</td>
<td>569,892</td>
<td>619,626</td>
</tr>
<tr>
<td>Hispanics as Percent of County Population&lt;sup&gt;2000&lt;/sup&gt;</td>
<td>5%&lt;sup&gt;753&lt;/sup&gt;</td>
<td>8%&lt;sup&gt;753&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Change from 1990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic Population Change&lt;sup&gt;2000&lt;/sup&gt;</td>
<td>21,316&lt;sup&gt;475&lt;/sup&gt;</td>
<td>20,455&lt;sup&gt;98&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Percent Change in Hispanic Population&lt;sup&gt;2000&lt;/sup&gt;</td>
<td>446%&lt;sup&gt;238&lt;/sup&gt;</td>
<td>78%&lt;sup&gt;405&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Note: Ranks are among all 3,141 counties in the United States. Source: Pew Hispanic Center (www.pewhispanic.org); accessed 06-23-09.

González and Renata Soto—understood that void and its challenges. They teamed up with an existing small non-profit group, the Hispanic Family Resource Center (HFRC), that was exclusively dedicated to providing information-and-referral services on health-related matters. The merger allowed for the implementation of a holistic approach to help Latino families.

Since then, the original information-and-referral service of the HFRC has evolved into the Spanish Help Line for Middle Tennessee and Conexión Américas’ programs serve over 2,500 families per year. In addition, new programs in the social, civic and economic integration areas have been developed and implemented successfully. The organization’s funding base has been also greatly diversified. The need Conexión Américas is addressing in the Nashville community is best understood in the context of the demographic changes taking place in Nashville. The 2000 Census showed a 446 percent growth of the Hispanic population in Nashville from 1990. By 2000, public agencies and nonprofit organizations were dramatically challenged by this wave of newcomers. Although a few programs in large nonprofit organizations were addressing particular and isolated areas of these newcomers’ needs by 2000, no organization was fully focused on Latino families in a comprehensive way. Furthermore, no organization had full cultural competence to work effectively with our community’s newest neighbors coming from Mexico and other Latin American countries.

Today Conexión Américas is recognized as a leading Hispanic force in the Middle Tennessee region and in the entire state. In 2005, Conexión Américas was named the recipient of the Best Innovative Partnership Award from Neighbor Works America for its Puertas Abiertas homeownership program. In 2007, Conexión Américas received both the national Strengthening Families Award presented by the Annie E. Casey Foundation and the National Council of La Raza (NCLR) and the Bank of America Neighborhood Builder Award.

#### 4.2 East Indians

Sarita Prabhu, a columnist for the Tennessean, has given voice to the Indian immigrant community for several years. She frequently writes about Nashville through the eyes of an Indian immigrant, having moved here some 14 years ago from India. Ms. Prabhu recently described how the first trickle of immigrants from India began arriving in the area 35 years; now they number more than 5,000 [9]. The first to arrive were mainly doctors who came with few restrictions during the Nixon era. Medicare had been established and there was a shortage of native-born doctors. The overwhelming majority of Indian immigrants from the very beginning were professionals—software engineers, doctors, hotel and restaurant managers and owners, and academics—and more recently real estate and life insurance agents as well as immigration lawyers.

Today there is a prominent presence of Indian faculty and students at Vanderbilt University and other local universities, especially in the sciences and engineering. The Indian immigrants are hardly a monolithic group. Rather they represent the diversity that is Indian society—Hindus, Muslims, Christians, Sikhs, and Jains—from all corners of rural and urban India. Elsewhere in this report it has been noted that immigrants to the U.S. born in India have the highest percentage with a bachelor’s degree (74 percent) of any other group. And they also have the highest median household income ($91,195) of any immigrant group.

As the Indian community grew in number and affluence, they began to establish their own institutions and cultural traditions. For example, a group of Hindus pooled their resources and established the Sri Ganesha Temple, part of the Hindu Cultural Center of Tennessee. The temple is now housed in a magnificent edifice in Bellevue. The temple complex, carved out of the hillside, houses the priests and their families and will soon include a school as well. The temple is open for service daily from 9:00 AM to 7:00 PM. Priests are available for special poojas (prayers) and occasions such as weddings and religious functions. The temple hosts frequent musical and theatrical presentations open to the public throughout the year.

A new monthly magazine known as JanDarpan, has come along to reflect on the Indian cultural scene. JanDarpan is one of the first publications of its type in the Nashville area, focusing primarily on the Indian commu-

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Major employers who require low skilled workers, like Tyson’s, took advantage of these changes. Tyson was prodded by Federal criminal cases brought against it by the US Department of Justice for hiring illegal Hispanic aliens. The hiring of legal Somali immigrants was facilitated by federal cash stipends and social assistance administered by state social services agencies with the contractual assistance of voluntary agencies like Catholic Charities, Lutheran Relief, Church World Services and others.

There have subsequently been reports of a culture clash between the locals and the highly visible Somali who are totally isolated and with no interaction between them and the locals. The large influx of Somalis has only added to frustration of the locals with the plant and the government. Three major industries have been shut down in Shelbyville and 700 to 800 locals have lost their jobs and are trying to find any kind of work they can. As they see it, the U.S. government is shipping people from overseas to come in and take their jobs. The Tyson plant generated national controversy in the fall of 2008 when it dropped Labor Day as a paid holiday in favor of the Muslim holiday Eid al-Fitr.

Among the refugees from Somalia there was a minority group known as Bantu [11]. Beginning in May 2003, some 200 Somali Bantu were flown to 22 cities across the United States, the first wave of one of the U.S. government’s largest recent refugee resettlement efforts. Officials planned to resettle nearly 13,000 Bantu. Nashville was one of several cities that received the Bantu refugees. The Bantu in Somalia, an ethnic minority, were forcibly transported there from Mozambique, Malawi and Tanzania by Arab slave traders two centuries ago. In Somalia, they were often denied access to education and jobs. They were enslaved and persecuted for generations in Somalia until civil war scattered them to desolate and violent refugee camps in Kenya in the early 1990’s.

As refugees, the Bantu farmed, cooked, cleaned and labored in construction jobs in the refugee camp in Kenya. But most had never flipped a light switch, operated a stove, opened a bank account or flown in an airplane. They then began the long process of adapting to a new culture when the International Organization for Migration began familiarizing them with English, American culture and modern appliances while they waited in the camp for overseas to come in and take their jobs. The Tyson plant generated national controversy in the fall of 2008 when it dropped Labor Day as a paid holiday in favor of the Muslim holiday Eid al-Fitr.

4.3 Somalis

Somali refugees from East Africa have poured into Middle Tennessee. The resettlement program is one part of a taxpayer-funded refugee aid program with a billion dollar budget. Immigrants are chosen from UN refugee camps. The selected refugees then undergo a few days of cultural orientation and are soon on their way to America. Although most of the refugees are repatriated to their home countries, the U.S. takes in more refugees than any other nation—with a cap of about 80,000 this year. The transition to life in the U.S. is not always a smooth one, however [10]. Most Somalis came as refugees to escape the chaos of their homeland, which is located in the Horn of Africa. Beginning in 2004, hundreds of them (estimates vary between 400 and 1,000) landed in Shelbyville, Tennessee, a town of about 17,000 population located about an hour’s drive from Nashville. At first glance, Shelbyville is your typical sleepy southern hamlet in middle Tennessee where the walking horse is king. Somalis in other cities were drawn to Shelbyville by the jobs offered at the local Tyson’s chicken processing plant. Previously the plant had come under fire from the Department of Justice in 2001 for hiring illegal Hispanic immigrants.

Somalis came to America under a legal humanitarian immigration program established by the 1980 Refugee Act, controlled by the UN High Commissioner for Refugees (UNHCR) and by the US State Department Bureau of Population, Refugees and Migration with a budget of over $1 billion. In 2007, there were an estimated 70,000 plus Somali legal immigrants in the US. Major centers of Somali refugees included, Minneapolis and Columbus, Ohio. This was facilitated in the 1990’s when the Clinton Administration, through the US Office of Refugee Resettlement, decided to vector Somalis and other humanitarian refugees away from major coastal cities and into the interior of the American heartland.
went into exile with many of his followers to the U.S. where he died in 1979. In 1992 another wave of Kurds was accepted into the U.S. as refugees after living in "refugees camps in Turkey for four years. They had fled their homeland in Iraq after the Iraqi government’s genocidal campaign of 1987 and 1988 in which thousands of Kurds were killed. The lucky ones escaped across the border into Turkey. The third group of Kurdish immigrants came in 1996 when Iraq troops crossed into the Kurdish controlled area to recapture it. Many of the thousands of Kurds who fled then were professionals and college graduates who came to the U.S. as asylees and refugees. They settled throughout the U.S., but especially in the Nashville area. Today there is no official statistics of the Kurdish population in the U.S., although the estimate is around 40,000, the majority of them from Iraq. Others have come from Iran, Turkey, and Syria. The Kurdish Yellow Pages estimates that 10,000 Kurds reside in the Nashville area.

Business Week recently (June 29, 2009) devoted a cover article to the U.S. housing market, profiling eight cities including Nashville, known as Music City USA. Some of the cities have suffered from the economic downturn while others appear to be keeping their heads above water. In the Nashville area immigrant homebuyers are reported to be having a positive impact on the market, where the median home price declined only slightly from $159,490 in 2007 to $153,000 in 2008. For example, the city’s Kurdish immigrants are helping stabilize the local economy. As a group, Kurds increased their homeownership rate from 46.5% in 1995 to 53% in 2008, according to the Pew Hispanic Center.

The immigrant population has been a stabilizing force in Nashville, where mosques and markets occupy a stretch of Nolensville Road south of downtown. Already, housing is showing signs of life: home sales topped 1,300 in April 2009, up from 850 in January. Toxic mortgages, so common in recent years, have not been an issue for home buyers would drag down home prices. But the immigrants have had the opposite effect: Overall property values in Providence Park have increased, boosting Nashville’s tax coffers by $230,000 a year. Nashville Mayor Karl Dean says: “The cities that are going to do well are cities that are attracting new people and reinventing themselves.”

The Kurdish community is very homogeneous and well organized. The religious and cultural center of Kurdish life is the Salahadeen Center of Nashville, a non-profit, tax exempt, faith-based organization founded in 1998 to serve the Muslim and specifically Kurdish communities. It is located just off Nolensville Road in the heart of the Kurdish business sector. The business community is reflected in the second edition of Kurdish Yellow Pages (2008) which provides an alphabetical listing of Kurdish businesses and advertisements.

4.5 Bhutanese

Bhutanese refugees began arriving in the United States in March 2008, the first wave of what the United Nations describes as one of the world’s largest resettlement efforts. The refugees are ethnic Hindu Nepalis who were forced into exile, according to human rights groups. The U.S. offered to resettle 60,000 of the estimated 107,000 refugees living in seven U.N. camps in southeastern Nepal—their home for the past 17 years. Six other nations have offered to resettle 10,000 each (CNN, March 25, 2008). Over the summer of 2008, a contingent of the Bhutanese became the most recent wave of refugees resettled in Middle Tennessee [12]. Seventy-two of them were brought to Nashville by Catholic Charities, the first of what could become several thousand.

Wedged between China and India, Bhutan is a Buddhist kingdom about half the size of the U.S. state of Indiana. It is considered one of the world’s most isolated countries. The government strictly regulates foreign influences, including tourism, to preserve the country’s Buddhist culture. According to Human Rights Watch, Bhutan stripped the Nepalis of their Bhutan citizenship and forced them into exile in the early 1990s, allegedly in an attempt to ensure a homogenous Buddhist culture. Some of the Nepalis took up arms and joined with Maoist rebels. The refugees claimed they were forced to leave Bhutan by security forces, but Bhutan disputed whether all were truly refugees. Several rounds of talks between Nepal and Bhutan failed to resolve the issue.

The United States’ resettlement plan has divided the refugee community, as members disagree over whether it is best to resettle in the United States or hang onto hopes of returning to Bhutan. Bhutan became the world’s newest democracy in 2008 when an election ended more than 100 years of royal rule in the South Asian nation. Officials in Bhutan declared the first elections in the Himalayan kingdom a resounding success.

4.6 Nigerians

Nigeria is by far the most populous nation in Africa and is blessed (cursed?) with an abundance of oil reserves.
The country is multi-ethnic and multi-religious, with the northern half populated primarily by Muslims and the southern half by Christians. Nigerians are known throughout Africa for their business acumen. In the Nashville area Nigerians seem to have carved out a niche for themselves in the home health sector [13]. For example, Alternative Care is an Antioch, TN-based firm that provides 24-hour care for elderly persons. The company prepares meals, see that the patients take their prescribed medicine, and plan outings. And Alternative Care is just one of several local Nigerian-owned businesses providing nursing and residential care for the elderly and mentally challenged adults. Health care operations do not require a lot of start-up capital. Some full-service firms arrange for a home for the patient. The costs of care and other living expenses are paid for by the state, the patient’s relatives or by Social Security. Other providers simply send in workers to lend personal assistance in the home. Home health care involves providing nurses for medical care in the home, programs that are highly regulated.

5. Immigrant Entrepreneurs: Face of the New Nashville

5.1 The Primary Research Conducted by TSU Faculty and Graduate Students

Despite the burgeoning growth of the immigrant community in Middle Tennessee and the importance of immigrant entrepreneurship to the local economy, there has heretofore been little systematic study of the nature of foreign-owned businesses. There is a distinct lack of information regarding the patterns of entrepreneurship of the various immigrant groups in Nashville and the constraints faced by each group in creating, operating, growing and planning for the succession of their businesses. The research described here was a first step towards the collection and analysis of primary data on this subject.

The Tennessee State University College of Business team that surveyed immigrant entrepreneurs in Middle Tennessee began operations in the summer of 2008 solicited the active participation and support from the immigrant-based chambers of commerce and other community organizations that represented foreign-born business constituencies. At the time there were five chambers (two Hispanic, one Chinese, one Asian, and soon after an African chamber). The team began by researching relevant literature on the minority enterprises and immigrant communities and establishing a database. In the fall invitations went out to two groups of ten business owners to participate in a focus group. The issues raised in these sessions were used to inform the eventual design of a questionnaire. A public forum was held, bringing university and community partners together to explain and discuss the nature of the study.

The next phase of the project involved conducting face-to-face interviews with 32 individual entrepreneurs, selected along region-of-origin of immigrant groups within the area as well as business types. Ten of those interviewed were Hispanic, of whom seven were originally from Mexico; six were from the Middle East; eleven were from Asia; two from Africa, and two from Europe. Nine of them were restaurant owners; eight were in services such as beauty salons and clothing stores, two were in trade; two newspaper and magazine; three in trade and distribution; and six were in technology and computer services. While not a statistical representation of business types, this was a fair representation of common businesses in the area.

5.2 Profile of Immigrant Entrepreneurs Interviewed

A draft survey instrument was refined several times through a series of four trials and a final version emerged by January 2009. Survey responses were obtained from 114 respondents, collected both in person and online. The results of this survey are summarized in charts and graphs in the Appendix. One of the most important purposes of the survey was to ascertain the concerns and needs of immigrant entrepreneurs. The following list emerged from the survey:

- English lessons, focused on business needs
- Assistance in financing and business planning
- Assistance with tax records preparation
- On-call assistance; services at unconventional times
- Human resource training, skill development, supervisory skills
- Networks for material sources, legal assistance, accessing sources of funding
- Services in local immigrant communities

From the questions posed to the entrepreneurs themselves the following profiles emerged. The two main reasons for their having migrated to the U.S. which they listed were the unfavorable economic conditions and political instability in their country of origin. A majority of the respondents indicated that they bought the business they now manage, as opposed to creating it themselves. Those who started the business themselves began alone and not with partners. Most of them are in fact sole proprietors, some are partnerships, and a few are incorporated. None indicted that they were franchisees. Nearly all of the respondents began their business primarily with personal savings, quite a few of them using personal credit cards. Most of them also indicated that they also relied upon family and friends for financing. No more than ten percent of them, however, had received bank financing.

As for their products or services, most respondents said that they had to adapt quite a lot to the American
taste. We were interested to learn the extent to which the immigrant entrepreneurs managed to do business with the government, either as contractors or sub-contractors. Only seventeen percent said that they had done business with the government, mainly because they were unfamiliar with government agencies and contracting. However, most of the respondents felt that there was no government bias against foreign-born businesses. Immigrant entrepreneurs rely heavily upon personal, social and business networks for the success of their business as well as hard work and reliable employees.

5.3 Distribution of Businesses by Region of Origin, Type of Business and Location in Nashville Area

A final phase of research focused on the distribution of businesses by region of origin or language grouping. The Office of the Davidson County Clerk maintains a database of all businesses that operate within its jurisdiction. That database includes several data fields: name of the business, type of business, name of the owner, and mailing address (including zip code). The list is updated monthly and is available to the public for a fee. We purchased the database with a view toward trying to determine which of the businesses might be run by foreign-born owners. The list we examined contained a total of 39,226 businesses, all of them in the service sector. Manufacturers are not obliged to have the same business license.

Admittedly, this was a very unscientific process! The first question was what criteria to use. How could we be at all certain that a business owner is in fact foreign-born? Basically, this would be an exercise in guesswork. We identified six categories, based on the family name of the owner. These were somewhat arbitrary, but provided a means of getting a handle on the extent of diversity among businesses in the Nashville area. The categories we identified were as follows:

- Hispanic: language group consisting primarily of persons from Latin America
- Muslim: religious group, identified primarily by Muslim names, mainly Middle Eastern
- Indian: geographic group of the Indian subcontinent including Pakistan, Bangladesh
- African: geographic group, often overlapping with Muslim names
- Asian: geographic group, consisting mainly of Chinese, Koreans, Japanese and Thais
- European: geographic group covering Eastern and Western Europe and Turkey

Granted, there is much room for error in such an exercise. There is no proof that many of businesses identified were really owned by the foreign-born. There are numerous Garcias on both sides of the Rio Grande! And a person with a Muslim name could be from many parts of the world, including Indonesia (with the largest Muslim population in the world) as well as North or West Africa. The vast majority of names on the Davidson County business tax list of course have names of European origin (native born, assumed not to be foreign-born). So most of those we identified for the European category were of Eastern European origin with mostly Slavic names.

Therefore, the best we could hope for was a ballpark estimate, until a more scientific methodology is devised. By the very nature of the database (licensed businesses), businesses in the informal sector (unlicensed) are excluded. We are thus probably missing quite a sizeable segment of immigrant-run operations. Nor were we able to obtain such important information as the size of the business, the date of establishment, or number of employees.

Besides names of owners, we were interested in two other data points: type of business and location within the Nashville area. The objective here is to be able to map out region of origin with zip code and business type. Of the 39,226 businesses in the Davidson County Business Tax Database we identified a total of 4588 as possibly being foreign-born, or roughly 12% of the total. Not surprisingly, the largest category of foreign-born businesses was Hispanic (1428) followed closely by Muslim (1104), Asian (684), African (630), Indian (377), and European (365). When we look at the distribution of registered businesses by type of business we see a significant variance among the six groups. For example, by far the largest concentration of African businesses are under the heading of taxi drivers, accounting for nearly half of all those in this category (630). Furthermore, they account for roughly half of all businesses listed in the Business Tax Database as taxi drivers.

When we examined the types of businesses owned in each of the six categories there were certain patterns that emerged. Unfortunately, the coding of businesses types by the County Clerk’s office left something to be desired, since a very sizeable proportion of businesses in all categories were coded 99, which simply means “undefined”. The prevalence of this code applied across all of our categories. Several business types were also preceded by the term “miscellaneous”. Both African and Muslim businesses are coded highest on TaxiCabs. In fact, together they account for the vast majority of taxi drivers in the Nashville area. The Indian, Hispanic, European and Asian categories all score either highest or second highest on Eating Places. (Only Indians are coded as Liquor Store owners). The next most popular type of business among Africans, Asians, and Hispanics is Services to Buildings, followed closely by Muslims and Europeans. Although Indians are not listed at all in this business type, they were very prominent in Hotels, Motels, and Tourist Courts. All are engaged in Special Trade Contracting, and all except Hispanics are engaged in General Building Contracting businesses. All groups
except Indians are in Services to Buildings. Hispanics tend to specialize in Painting & Paper Hanging, Masonry Stonework, and Carpentry while none of the other groups are coded in these businesses.

Not surprisingly, all categories of business owners are listed as owners of Grocery Stores and all are coded for Retail Stores. The Used Car Business is a common denominator among the Africans, Indians, Muslims and Europeans, but not the Asians and Hispanics. However, Hispanics, Europeans and Africans are engaged in General Auto Repair. Beauty Shops show up regularly among Asians, Europeans, and Hispanics, but not Indians, Africans, and Muslims. All groups are engaged in Other Business Services, but only Europeans and African are in Management Consulting and Public Relations.

As for location within the Nashville area, we found heavy concentrations of nearly all six groups of foreign-born entrepreneurs in the southeastern part of the city along the Nolensville Pike corridor (zip codes 37211, 37217, 37013). This also coincides with the distribution of the general population of these groups.

6. What Does the Future Hold for Immigrant Businesses?

6.1 Immigrants Leaving the U.S.

As the debate over H-1B workers and skilled immigrants intensifies, it is becoming clear that the U.S. is no longer the only land of opportunity. If the immigrants who have fueled innovation and economic growth are no longer wanted in the U.S, they now have options elsewhere. Immigrants are returning home in greater numbers. New research shows they are returning to enjoy a better quality of life, better career prospects, and the comfort of being close to family and friends. A research team composed of scholars at Duke, UC Berkeley and Harvard conducted a survey funded by the Kauffman Foundation through the professional networking site LinkedIn [14]. They located 1,203 Indian and Chinese immigrants who had worked or received education in the U.S. and had returned to their home countries.

The study concluded that a crisis is brewing because of a burgeoning immigration backlog. At the end of 2006, more than 1 million skilled professionals (engineers, scientists, doctors, researchers) and their families were in line for a yearly allotment of only 120,000 permanent resident visas. The waiting time for some people ran longer than a decade. In the meantime, these workers were trapped in “immigration limbo”. If they changed jobs or even took a promotion, they risked being pushed to the back of the permanent residency queue. Given these circumstances, skilled foreign workers may very well get fed up and return home to countries like India and China where the economies are booming. This issue looms large as the debate over immigration policy gains steam.

Meanwhile, Richard Herman who lives in Cleveland, Ohio, is on a crusade to promote immigrants as the vanguard of a new American economy [15]. Herman says that the rust belt—traditionally tied to the Old Economy—progressively depopulating, under-educated, with massive job loss, and not too keen on start-ups—is beginning to see that new partnerships are needed to compete in the global, knowledge-based, New Economy. According to Herman, global connections such as those ushered in by immigrants will be the key to the rust belt’s revitalization and new era of job-creation, start-ups, new industries and neighborhood renewal. Herman reports on business and civic leaders in the region from Cleveland to Detroit pursuing an immigration stimulus. He argues that world-class universities in the region are leading the way in innovating biomedical, polymer, liquid crystal, energy, advanced manufacturing and other technology frontiers. Perhaps high-speed rail could accelerate the regional collaboration already percolating between these cities and their institutions.

Herman suggests that one important way of promoting the Tech Triangle anchored by Detroit, Cleveland, Pittsburgh and Columbus would be to enact a new federal immigration policy that grants immigration incentives to companies, foreign talent, and investors that locate in economically distressed metro areas—what the Metropolitan Chambers of Commerce coalition is calling “High Skill Immigration Zones”. Finalized in February, 2009, this immigration policy proposal, crafted by the Greater Cleveland Partnership, and adopted by 30 Metropolitan Chambers of Commerce from Chicago to Vancouver due to U.S. immigration barriers to talent, proposes that immigration law reform include the creation of “High Skill Immigration Zones” (HSI Zones) in struggling metro areas. The HSI Zone proposal would facilitate significant international talent attraction, integration and retention, in order to accelerate the development of emerging industries such as renewable energy technology, biomedical and nanotechnology as well as other emerging sectors. The HSI Zone would allow companies to locate in these regions to take advantage of relaxed visa restrictions in hiring high-skilled workers. For example instead of opening up an R&D facility in Vancouver due to U.S. immigration barriers to talent, Bill Gates could open up the same facility in Cleveland or Detroit. Foreign talent would be less likely to return back home to India or China due to 5 to 10 year waits for their green card; there could be an elimination of green card quotas for workers in HSI Zones.

Foreign investors, investing $500,000 to $1,000,000 and creating 10 new jobs under the existing Foreign Investor Green Card program, would have greater opportunities to invest in HSI Zones. International Students seeking to study in HSI Zones would receive expedited
visas from U.S. embassies. Foreign nurses with proper 
licensure would be permitted to access a revived H1A 
non-immigrant nursing visa for hospitals and health care 
facilities in the HSI Zones. International Welcome Cen-
ters would be established in HSI Zones to facilitate 
community and employer engagement with immigrants. 
The region’s universities already attract some of the most 
brilliant minds in the world—only to see them depart 
from the region or the U.S. due to not feeling welcomed, 
visa restrictions, barriers to job advancement, and insuf-
ficient entrepreneurial infrastructure and support system. 
Similarly, foreign direct investors could be better re-
cruited and welcomed to the region in order to provide 
much-needed capital for rebuilding the economy.

While Middle Tennessee is not thought of as a “rust 
belts”, immigrant entrepreneurs are helping to re-make the 
economic landscape of the region. As a New Ellis Island, 
the Nashville area continues to attract immigrant and refu-
gees from all over the world. Their entrepreneurial energy is 
being clearly felt and for the most part appreciated.

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Time and Risk Entrepreneurial Characteristics of Growth: The Case of Persisted Light Industrial Prototypes

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Received October 15\textsuperscript{th}, 2009; revised November 27\textsuperscript{th}, 2009; accepted December 31\textsuperscript{st}, 2009.

ABSTRACT

This article is about the role of entrepreneurial perception of time and risk vis à vis structural change and growth. Entrepreneurship is a basic constituent element of social capital which in turn is a productive lubricant of the growth process. Different structural entrepreneurial prototypes with respect to time and risk have different structural change effects. Those structural changes (and any structural changes) are not neutral as far as the implications of growth rate changes are concerned. Therefore the time and risk characteristics of active entrepreneurship are reflected in the growth process either in the form of structural change and/or in the form of growth rate change.

Keywords: Time, Risk, Entrepreneurship

1. Introduction

This article is about the role of the entrepreneurial perception of time and risk vis à vis structural change and growth. Entrepreneurship is a basic constituent element of social capital which in turn is a productive lubricant of the growth process. Different structural entrepreneurial prototypes with respect to time and risk have different structural change effects. Those structural changes (and any structural changes) are not neutral as far as the implications of growth rate changes are concerned. Therefore the time and risk characteristics of active entrepreneurship are reflected in the growth process either in the form of structural change and/or in the form of growth rate change.

The analysis of the growth process, based on the Schumpeterian tradition of real economic structure change, with the development of endogenous models and the introduction of research [1] and knowledge [2] effects of human capital contribution to growth has found a respectable and well-spread acceptance. At the same time growth models have been found to be in line with developments in the real economy [3], increasing their acceptability.

However, the present mature stage of economic growth in developed countries and the challenge of sustainable growth patterns, together with the observed persisted light industrial prototypes in a number of peripheral countries (Balkans etc.) may reopen the discussion on the growth process with ‘reasoned history on the time and space particularities of growth dynamics’ [4].

The reopening of the discussion will be facilitated with the introduction of the extended concept of social capital as being broken down into human capital, entrepreneurship and networks effects [5].

The paper is developed as follows: Section 2 focuses on social capital, entrepreneurship and growth relationship; Sections 3 and 4 relates to the analytics of risk and time; Section 5 clarifies the time and risk dimensions of entrepreneurship; Section 6 analyses the effects of entrepreneurial time and risk on structural change. Finally conclusions will be drawn.

2. Entrepreneurship, Social Capital and Growth

The relation between growth and entrepreneurship appears to be easily accepted. However until now this has not yet been fully scientifically supported. First, this is because the phenomenon of entrepreneurship lacked a conceptual framework by itself [6]. Also for a very big period of time the significance/meaning of entrepreneurship had been excluded [7] from the picture with equilibrium approaches in economics [8].

Adam Smith [9] formed the conditions of introducing entrepreneurship as an engine of growth since he recognised that the only restriction on sustainable growth is division of labour and the extent of the market. Thus entre-
Entrepreneurship (innovation) extends the market and increases productivity and therefore causes economic growth. Moreover if we accept that entrepreneurship opportunities already exist but were unnoticed [10] and profit, as a reward of entrepreneurship, is the engine that moves the system away from equilibrium (Schumpeter [11] and in a decentralised context, Hayek [12], then we may have a logical consequence of growth. On the other hand, Ricardo [13] set the principles of growth as they were organised in the model of Solow [14]. Only by investing in capital (K), can production (Y) be increased and thus productivity will increase. The restrictive terms will emanate from fixed factors of production and the diminishing marginal factor productivity. Any other influences in the productive process should be searched in the Solow residual [15].

Lucas [2] rearranges the neoclassical model and introduces the idea that attention should be on the labour factor l and the external effects of human capital. Romer [1,15] adds that additional investment in research could produce increasing returns through knowledge spillover embodied in human capital. The aspect of knowledge that is crucial is alertness [10], that is the 'knowledge' of where to find market data [16]. The entrepreneurial discovery process is associated with the actor's interpretation framework, or the stock of knowledge, which is derived from everyday life experiences [17].

The concept of social capital has been put forward alongside the traditional concept of financial, real and human capital during the 1990s [18] and it has recently been related to entrepreneurship [19]. According to Bourdieu and Wacquant [20] social capital is an individual or group-related resource that accrues by possessing a durable network of more or less institutionalised relationships. According to Coleman [21,22] it is to be found in the relations between individuals and it includes obligations, expectations, information channels and social norms [5], like high-trust and low-trust attitudes (Fukuyama 1995) or family-based social trust vs community-based trust [23]. Social capital should be regarded as the most diversified of capital forms. The extent of the diversification will largely depend on how its basic nature is analysed: Coleman's [22] endogenous phenomenon of social relations vs Fukuyama's [23] view that it is the result of society's trust and cooperation.

Woolcock [24] and Federde et al. [25] proposed that we should see in the concept of social capital two interacting dimensions: ‘transparency’ (the transaction-cost-lowering functions of social capital) and the rationalisation potential of maintaining increasing returns to scale, i.e. delaying the onset of diminishing returns. Two more notes were added to this by Piazza-Georgi: a) social capital operates to a significant extent through human skills capital and entrepreneurial skills by lowering their creation costs; b) there may be a significant substitution effect between human and social capital (towards human capital) through the increased cost of human time. If we then accept that investing in human capital is more efficient than investing in social capital we could have another reason for delaying the diminishing returns process. Thus growth and social capital are positively connected since the accumulation of the latter is fuelling the growth process.

Yu [17] utilising Kirzner's theory of entrepreneurial discovery, Schumpeter's two types of economic responses (extraordinary and adaptive) and the Austrian theory of institutions as building blocks, constructs an entrepreneurial theory of institutional change and social capital accumulation. Yu and others do not use the concept of social capital and institutions alternatively. However, the concept of social capital as it is defined [19] can be very closely compared with Yu's definition of institutions [17,26]. The process of institutional change is the continuous interaction between entrepreneurial exploitation and exploitation of opportunities [27]. Institutions (stock of knowledge) emerge as a result of human agents attempting to reduce structural (vs neoclassical static) uncertainty. Therefore, entrepreneurship enlarges institutional development and social capital accumulation. It is obvious that there are second-round effects where social capital accumulation reinforces entrepreneurship through the production of externalities which promote the distribution of information and generate asymmetric information. At the same time institutions reinforce entrepreneurial alertness and the discovery process [26]. Thus we may accept that entrepreneurship enlarges social capital accumulation. Therefore, entrepreneurship positively affects growth.

3. Entrepreneurship and Risk

Although as Knight proposes there is considerable difference between the concept of uncertainty and the risk (measurable) from now on we will use the two terms alternatively because there is no added value in the scope of the paper.

In our attempt to establish the positive theoretical relationship between entrepreneurship and uncertainty we may approach the subject from four different angles. The first refers to the role of social capital and the Knightian uncertainty as presented by Brouwer [28]. The second will be based on the entrepreneurial perspective of institutional change [17]. The third utilises the basic financial relationship of (entrepreneurial) return and risk [29–31] proposed by Petrakis [32]. Finally the fourth can be based on the concept of distribution of risk through the division of labour process.

According to Brouwer [28] in Knight's view, true uncertainty is the only source of profits, since profits would disappear as soon as change became predictable or it can be hedged and they will be changed into costs. Brouwer shows how the introduction of Knightian uncertainty can
abate diminishing returns of innovative investment. This can be done by R&D cooperation, that is, by creating social capital through R&D networks. So we can conclude that uncertainty makes perpetual innovation more likely. Thus growth and uncertainty are positively related. Knight saw rates of return on entrepreneurial investment vary around an average and it is the relative entrepreneurial ability that is rewarded.

Entrepreneurs also create a great deal of uncertainty through Schumpeterian innovation which creates confusion in the market. Lack of entrepreneurship means that we are locked up in old structures, interpretations and understandings [17]. Thus, entrepreneurial activation is positive concerned with uncertainty.

The portfolio theory, as shaped by Markowitz [29], Tobin [30] and Sharpe [31], recognised the positive relationship between expected return and risk. When an individual creates a portfolio, optimisation is based on the risk and return relationship: risk is the result of either systematic risk or, in the case of imperfect unsystematic risk, diversification due to project indivisibility or project interrelationships [33] or a combination of both. Given these prerequisites, the risk premium that the economic agent enjoys is the entrepreneurship premium that we come across in entrepreneurship theories.

The relationship of risk and growth can be approached from a more general point of view. This can be done if we consider the growth process as facilitated by divisions of the labour process. Thus, the division of labour not only increases developments in specification and broadens labour skills expertise and therefore increases rates of returns but also by necessity distributes the risks around different economic activities. The distribution of risk, and thus the lowering of the prevailing risk levels, increases the discounted (by risk) rates of returns.

From the above analysis, irrespective of the angle we approach the issue under discussion, we can conclude that entrepreneurship and uncertainty are related with the latter positively affecting entrepreneurship. Finally, we may conclude that growth and uncertainty are related with the latter positively affecting growth.

Risk reflects the degree of uncertainty and potential loss associated with the outcomes which may follow from a given behaviour or a set ofbehaviours [34]. Yates and Stone [35] identify the basic element of risk construction: potential losses and the significance of those losses. The point of research focuses on how entrepreneurs cope with the risks inherent in their decisions, what determines the way they perceive the riskiness of their decisions, whether they possess character traits which predispose them to engage in uncertain behaviour or whether they assess opportunities and threats differently from non-entrepreneurs [36].

In any case entrepreneurs’ risk-taking decisions are extremely complex [37]. This is quite an obvious conclusion and has been stated very clearly from Knight [38] to Baird and Thomas [39] with their contingency model of strategic risk-taking.

Sitkin and Weingart [40] summarise the whole framework of risk decision in two main sub-domains: outcome history and problem framing [41] as mediated in two crucial entrepreneurial variables: entrepreneurial risk propensity and perception of risk. Problem framing refers to whether a situation is presented to decision-makers as an opportunity or a threat. Outcome history is a person situation interaction characteristic defined as the degree to which the decision-maker believes that previous risk-related decisions have resulted in successful or unsuccessful outcomes [40]. Correspondingly risk perception is defined as an individual’s assessment of how controllable that uncertainty is [39] and risk propensity is defined as an individual’s current tendency to take or avoid risk.

The concept of meditation on risk perception has also been stated in the work of Hean Tat Keh et al [42]. Their model also recognises four independent variables (over-confidence, belief in the law of small numbers, planning fallacy and illusion of control) and two control variables (demographics and risk propensity). The researchers have been utilising the work of Simon et al [43] who found that the significant relationships are illusion of control belief in the law of small numbers with risk perception (negative relationship). Illusion of control and belief in the law of small number affects uncertain decisions positively and risk perception negatively. The same authors identify that flexibility, optimism and risk propensity affect a decision-maker’s tolerance of risk.

Derived from the above analysis is the fact that risk perception mediates the relationship between cognitive biases and decisions under risk. Although enough theorisation has been developed about these associations [44–46] the question about how cognitive biases i.e. common types of mental stochastics used to make judgments [43] lead individuals to perceive different levels of risk in the same decision situation needs further classification. This is despite the empirical evidence on the role of overconfidence, illusion of control etc. produced by Simon et al. [43] mainly because those approaches are partial equilibrium approaches. In other words, when we study such a complex phenomenon it is very difficult to isolate the influences of even basic factors that influence the decision under risk. This point should be taken into account when we examine well-supported evidence [47,48] that risk tolerance or ambiguity tolerance do not reside differently in entrepreneurs. However, there is a discussion [49] that risk and ambiguity have different and distinguished effects on entrepreneurial behaviour and specifically that the presence of ambiguity accentuates the perception of risk.
4. The Entrepreneurial Perception of Time

According to Shane and Venkataraman [6], entrepreneurship also means the process by which opportunities to create future goods and services are discovered, evaluated, and exploited. In the framework of a well-structured theory for tracing and developing entrepreneurial opportunities [50], two levels of analysis appear. The first includes the process of tracing and developing entrepreneurial opportunities (development, recognition, perception, discovery, and evaluation) while the second includes the factors that influence this process (entrepreneurial alertness, information asymmetry, and prior knowledge, discovery versus purposeful search, social networks, and finally personality traits).

The individual according to his or her sensitivity alertness [10,51] reacts to the information s/he receives and recognises the entrepreneurial opportunity. At that moment, the entrepreneurial opportunities are continuously evaluated either within a formal or informal process [52]. The individual informsally collects information until it becomes more formal and particularly when the collaboration of third parties is necessary in the search for essential resources. If the result of this process is satisfactory, then a feasibility study is produced. The personal trait of preference of time has its role through the Stage–Gate procedure [50] or, alternatively, through the Passage via the Knowledge Corridor [53]. Thus, the process of the evaluation of time acts upon entrepreneurship as one continuous screening procedure.

Entrepreneurs develop their entrepreneurial alertness either on the grounds of backward or forward interpretation [17] of incoming information and only to the level that they pace with their time preference. For example, they exclude from their evaluation all information (in this case preference for short-term entrepreneurship) connected to long-term entrepreneurship. Thus entrepreneurial alertness is not a complete process but a unilaterally developed sensitivity which is biased in favour of short-term actions. Note that in cases where a long-term perception of time prevails in society, then the long-term entrepreneurial trap can arise where no immediate results come of a linear or non-linear approach towards time perception; furthermore, whether it is a state of the world situation or an event (or a sequence of events); and finally whether this is an objective or a subjective perception.

In any case, we can accept that how the present is determined depends on the subjective perceptions of the entrepreneur [58,59]. Moreover, the concept of the average ideal duration of entrepreneurial commitment can be considered as the outcome of a linear or non-linear approach towards time perception; furthermore, whether it is a state of the world situation or an event (or a sequence of events); and finally whether this is an objective or a subjective perception.

5. Entrepreneurship, Time and Risk

The development of the decision-making investment process within the standard neoclassical model has shaped time into a simple, mono-dimensional factor of decision-making. This happened with the same simplicity that also forced out the entrepreneur’s role from the function of the economic system [7].

But the question of preference of time is too important for the process of entrepreneurship and, therefore, for us to ignore. Temporal dynamics are at the heart of entrepreneurship [60]. Anything that involves an entrepreneurial organisational process (including the decision of resource commitment) has its time-dimensional character. When the process of evaluation is conducted in terms of excessive preference for the present over the future, very few or no entrepreneurial plans are going to materialise. Additionally, it is very unlikely that specialised markets of time and risk are going to help the investor to materialise his or her investment. Moreover, it is known that very few similar markets exist. Even if they exist, very few entrepreneurs have access to them.

The inclusion of time can be connected with significant aspects of the growth process. Time is introduced by the dynamic models and therefore it brings up the issues
of equilibrating vs. non-equilibrating growth paths. Thus, disequilibrium based on growth (evolutionary theory) can emerge. It is also related to convergence issues. However, according to the scope of the present paper the issue of time is related and defined as the ideal duration of entrepreneurial commitment. This concept is directly related to the structural prototype prevailing in space and time since it can distinguish between short-term entrepreneurship and long-term or future-oriented entrepreneurship [61].

Decision risk is defined here, according to the extended Sitkin and Pablo [41] definition, as the extent to which there is uncertainty about whether potentially significant (satisfactory) and/or disappointing outcomes of decisions will be realised. Thus, risk reflects the degree of uncertainty and potential loss associated with the outcomes which may follow from a given behaviour or set of behaviours [34]. Yates and Stone [35] identify the basic element of risk construction: potential losses and the significance of those losses. The point of research focuses on how entrepreneurs cope with the risks inherent in their decisions, what determines the way they perceive the riskiness of their decisions, and whether they possess character traits which predispose them to engage in uncertain behaviour or whether they assess opportunities and threats differently from non-entrepreneurs [36].

In order to do so, we should clarify the meaning of the two basic risk concepts: risk perception and risk propensity. Thus, risk perception is a subjective concept about the controllability of uncertainty [39,41]. This subjective concept generally speaking is developed according to how the problems are framed (how the problem is presented to the entrepreneur, positively or negatively), the outcome history [40], the problem under consideration and the cognitive process of risk perception development. This concept could be connected with general society’s sense of uncertainty controllability as a social value and it is formed at a personal level. When we speak about low (high) risk perception we are referring to a situation where the individual believes the uncertainty of outcomes is highly uncontrollable (strong controllability). Risk propensity is defined as an individual’s current tendency to take or avoid risks [40,41]. It is a clear personal trait which can also be influenced by general social values (as they can influence all aspects of entrepreneurial behaviour).

Drawing and extending the work of Sitkin and Pablo [41] and Forlani and Mullins [34] we can imply that the entrepreneur’s perception of risk and decisions involving risk are distinct and separate cognitive processes. Moreover the risk propensity is a separate cognitive process from risk perception. Following Sitkin and Weingart [40] and in contrast with previous researchers [62] we do not consider risk propensity as a stable personal attribute. Thus, we employ a trait-based definition which is constructed as a cumulative tendency to take or avoid risks and can be changed as a result of experience. Risk and uncertainly is about future and therefore is about time. Thus it is generally agreed that time plays a crucial role in risk [63]. Researchers such as Vlek and Stollen [64] observed that several risk behaviours are related to time and the notion of discounting in time.

Das and Bing-Sheng Teng [61] analyse the interrelation of risk and time given that risk is inherently embedded in time. First they put forward the notion of the risk horizon differentiating short-range risk from long-range risk and examine the risk behaviour of entrepreneurs in terms of their individual future orientation in connection with their risk propensity.

Short-range risk refers to variations in outcomes in the near future, while long-range risk relates to the distant future [65]. However, when people make decisions about the distant future they may be engaged in either low-risk or high-risk long-range risk behaviour. The same individual may well exhibit low-risk behaviour regarding long-range risk and high-risk behaviour regarding short-range risk or vice versa.

Thus Das and Bing-Sheng Teng develop different entrepreneurial types by employing their distinct risk behaviour in the short run and in the long run. They suggest that craftsman entrepreneurs can be identified by their short-range high risk behaviour, while opportunistic entrepreneurs can be identified by their long-range low-risk behaviour. Their distinction has received empirical support although the findings are far from conclusive [66]. According to Smith [9] a craftsman entrepreneur is characterised by narrowness in education, low social awareness and involvement and they do not offer innovative products. In contrast, an opportunistic entrepreneur is one who typically has breadth in education and training as well as high social awareness and who is involved in providing novel products/services.

It may appear in two cases that an entrepreneurial attitude cannot be developed: when short-range orientation and low-risk behaviour manifest in the same individual as well as when long-range high-risk behaviour also manifest in the same individual.

Does entrepreneurial risk attitude affect entrepreneurial time perception or vice versa? How distinct are the cognitive processes of development of risk attitude and time perception? So far we have seen a situation where the combination of the two attitudes produced particular types of entrepreneurial attitudes. The prevailing of long-lasting attitudes towards the formation of one or other type of entrepreneurship (or some in between forms) may affect the industrial structure permanently or at least for a long period of time. More interesting would be the case where the cognitive process of developing the risk attitude may affect the cognitive process of developing the perception of time. These interrelations may develop not only be-
cause the cognitive process may be interrelated but because of cultural and social economic factors which determine that the one process may affect the other.

The important point arises when we come to the type of interrelation. If for instance the correlation of the two types of behaviour is positive then there will be a tendency for risk-loving behaviour to be developed in parallel with long-term perception of entrepreneurial commitment which will have serious consequences on the type of entrepreneurial attitude behaviour since, as we have seen, a non-entrepreneurial behaviour is expected to be observed under these circumstances. The interrelation of risk and time attitudes can also affect the entrepreneurial intertemporal rate of substitution. Long-range and risk-loving entrepreneurship may be connected with large intertemporal rate substitution while short-range and risk-averting behaviour are connected with a small intertemporal rate of substitution.

Another important point arises as to how the cognitive process of time and risk attitude is developed in relation to entrepreneurial decision-making. In other words the important points are related to the way those attitudes interfere with the entrepreneurial opportunities identification and development. Following the alertness perspective where entrepreneurs may assess opportunities and threats based on a Bayesian probability [36], differing assessments of prospective outcomes may be attributable to differences in prior information as they are filtered by the risk and time attitudes. Therefore time and risk consideration will not enter within entrepreneurial decision-making as any type of investment criteria but as particular types of cognitive attitudes towards the assessment of entrepreneurial decision-making. These attitudes are developed and embodied in entrepreneurial behaviour through a long-lasting procedure originating in the general economic environment as it is mediated by personal traits and cognitive factors.

6. Structural Change, Time and Risk

Montobbio [67], in his critical and concentrated literature review, presents three main trends in structural change thinking:

1) endogenous growth models assess the determinants of aggregate growth in a multi-sectoral economy [15,68] which incurs difficulties in explaining major processes of structural changes;

2) the life-cycle models of growth, maturity and decline [69] when they do not have a role for demand pressures and how growth is linked with the declined sectors;

3) the supply and demand side factors approach. This last approach seems to have attracted most of the recent work done in the field.

The supply side was first proposed by Schumpeter [70]. Kuznets [71] in the same vein stressed the importance of different impacts of technological innovations and a selection mechanism based on the competitive advantage. Pasinetti [72,73] shows that growth rates depend on productivity rates. Baumol [74] and Baumol et al. [75] follow the same reasoning, arguing that stagnant sectors in return of productivity tend to absorb a relatively higher share of employment. Metcalfe [76] also stresses the importance of sectoral differences in productivity without affecting the relative industrial shares in terms of employment. Finally Montobbio [67] shows that positive aggregate productivity growth can be achieved without technological change at the level of firms. This can be achieved, as far as the supply side is concerned, through the effect of sectoral output growth of selection on firm’s unit costs.

The demand side approach is also used, usually in connection with the supply side, to explain structural shifts. Kuznets [71] pinpoints the different income elasticity of domestic demand. Pasinetti [72,73] stresses the importance of trends in demand and differentiation of income elasticities. Montobbio [67], as far as the demand side is concerned, emphasises the importance of sorting procedures according to elasticity of substitution of sectoral demand which depends on the institutional characteristics of the market.

From the previous analysis it follows that there are four types of situations which can cause different types of structural change as they arise, all with different possible combinations of time and risk perception:

1) short-term future orientation and risk aversion;
2) long-term future orientation and risk aversion;
3) short-term future orientation and risk loving;
4) long-term future orientation and risk loving.

We may also consider the economy to be characterised by two separate sectors: the equilibrating sector where entrepreneurship produces products and services which match demand and supply and the innovative sector where new creative products are produced. As we have seen, generally speaking we expect that the innovative sector will be characterised by long-term future orientation and risk-averting attitude (the b situations) while the equilibrating sector will expand to two of the above situations (b and c).

The risk–return relationship holds if the innovative sector equilibrates at a higher level than in the equilibrating sector. The resources move intersectorally according to a) risk-return relationships prevailing in both sectors and b) the time and risk characteristics of entrepreneurship activated in the sectors. Thus it follows that when time and risk influences reduce the intertemporal rate of substitution while risk and return on innovative sectors are higher than the equilibrating sector, then the innovative portfolio share will be increased. The opposite is true under conditions of enlargement of intertemporal rate of substitution (see Figure 1).

The analysis shows that it can be the case where socie-
ties develop entrepreneurship which can be classified in one or more of the above two (II, III) quarters depending on a number of factors which have been identified in previous sectors of the paper. Depending on the type of entrepreneurship that is developed (with respect to time and risk characteristics) it is clear that we may have a different type of structural changes growth process which in turn may result in growth rate change.

Is it probable that a growth rate change neutral process may result? It is very unlikely to be the case. There are two reasons for this: a) the two sectors (equilibrating and creative) do not enter under identical (equivalent) conditions of portfolio shares participation and rates of return and risk relationship. Therefore any departure from the initial non-equivalent position in the economy will result in a (probably) non-equivalent continuity in the evolution of the portfolio of relative shares; b) the rates of returns of two sectors which reflect the time and risk entrepreneurial consideration are different with the innovative sector characterised by larger levels. This difference in conjunction with the entrepreneur’s intertemporal rate of substitution will result in different patterns of portfolio shares expansion.

7. Conclusions

The activation of one of the most important components of social capital, which is entrepreneurship, with particular effects through its time and risk characteristics, can be used in order to understand the growth prototypes prevailing in space and time. At the same time we can very well understand that those characteristics are long-lasting accumulated cultural and personal characteristics which cannot be altered through the interference of short-term policies. As a matter of fact the history, political and geo-strategical procedures responsible for the establishment of these values should be affected if the structural change process is to be altered. We expect that entrepreneurial risk and time elements will have significant influence on basic growth structural elements such as the portfolio shares of distinct types of entrepreneurial events, the rate of returns on them, and thus the way markets operate.

Finally those basic structural elements will affect the growth rate of the economy itself since there is no reason to suppose that structural changes offset each other.

The risk and time elements interfere with the entrepreneurial identification process and shape the actor’s interpretation framework by influencing the stock of knowledge and everyday life. Thus, those factors are not acting as a type of criteria of entrepreneurial decision but are more activated as filters of incoming signalling and information. Most of the institutionalised relationships between individuals, including the derived obligations (and thus expectations as well), are developed in such a way that they are inherent in the particular time and risk horizons and limits prevailing for the entrepreneurial society. By referring to trust issues we may notice that it is very difficult to develop high-trust attitudes under short-term risk-averse behaviour. It is also very probable that under specific conditions the family-based social trust will be prevailing at the expense of community-based trust. It is also clear that entrepreneurs will develop a high perception of risk (irrespective of whether they are characterised with social capital and refers to its transparency the transaction costs and thus will affect or reinforce the corresponding rate of social capital. Thus if the institutionalised forms reflect short-term risk-averse attitudes they will tend to enlarge their bureaucratic institutions in order to control this type of attitude. For the same reasons the rationalisation potentiality will cease.

The above analysis pinpoints the fact that it is no longer enough to accept that entrepreneurship enlarges social capital accumulation and vice versa. The important thing lies in what type of social capital is developed under the influence of time and risk entrepreneurial considerations.

Uncertainty affects entrepreneurship. However, what is now evident is that uncertainty affects the way that entrepreneurship is developed, which is the way that the time and risk elements are developed. At the same time, the entrepreneurial time and risk elements affect uncertainty in the economy as entrepreneurs are activated. Long-term risk-seeking activities develop different (larger) levels of uncertainty than long-term risk-averting...

Figure 1. Types of entrepreneurship fostered by time and risk-loving orientation
entrepreneurship which in fact may not produce any uncertainty. This could be one explanation as to why individuals who could be classified within this cell of combination of attitudes may not be entrepreneurs at all. Under the specific circumstances uncertainty will not act as a starter to the growth process.

According to the risk-return relationship, short-term risk-averting entrepreneurship will lead to a short-term low-return entrepreneurship which could be characterised as the growth structure since it seems that it cannot promise a strong growth prospect, at least in terms of development prototype. The same could be valid in the opposite situation where long-term risk-averting behaviour prevails.

The human capital proxy and more generally social capital could operate as a mediator of short-term, risk-averting educational investment choices which may not affect the growth process positively. Similar scores will be reflected in capital variables.

Generally speaking, if in the economy short-term, risk-averting values on entrepreneurial decisions are prevailing then capital accumulation and capital investment flows will reflect these values. The capital investment will be designed to engage entrepreneurial resources for a short period of time while it will be characterised by a low rate of returns. Obviously, the structural prototype will have these characteristics as well.

The resulting structural prototypes in the different economies are very well connected with the growth rate of change performance. Thus, growth and structural prototypes depend on cultural values and personal traits and especially on time and risk entrepreneurial attitudes. Long-lasting entrepreneurial behaviours are not subject to easily manageable and short-term policy manipulations.

The policy implications of the previous analysis may extend to a variety of fields. One of the immediate results will refer to policies towards upgrading the growth rate of change performance of peripheral economies through structural change which will be based on the introduction of innovative entrepreneurship. It becomes clear that a general policy towards political stability which could reduce risk could be more effective than a huge programme of zero cost capital.

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This is because the improvement of the entrepreneurial climate, which could be the result of the structural fund development programme (EU structural funds), will lead to a reproduction of the existing industrial process in terms of risk and time characteristics rather than to a required structural change. Thus, it is very probable that the resulting overall rate of change will be weak and correspond to the existing industrial structure. In contrast it becomes evident that the improvement of social capital of the economy through the improvement of entrepreneurial factors by enlarging the investments of human capital (education and continuous education) will change attitudes towards innovation and result in an acceptable longer time of entrepreneurial commitment.

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A Systematic Framework of Equipment Maintenance and Service with Application to Wire Bonder

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Received August 11th, 2009; revised October 2nd, 2009; accepted November 17th, 2009.

ABSTRACT

A systematic framework for the maintenance and service of equipment is developed and proposed. The framework consists of a system of equipment failure analysis, methods, process, and activities, and a procedure in maintenance and service. With axiomatic design mapping, the maintenance procedure is constructed by integrating value engineering, quality function deployment, mechatronics engineering, technique from R&D and supplier, and Taguchi method. The maintenance and service of a wire bonder machine, K&S (Kulicke and Soffa) Maxum Plus, in the first bond failure is employed for illustration.

Keywords: Systematic Framework, Maintenance, Service, Wire Bonder, Failure Modes, Mechatronics, Axiomatic Design, Taguchi Method

1. Introduction

Since the first development of ball bonding technique by the Bell Laboratories, more than five trillion wires have been bonded onto various semiconductor devices routinely every year [1]. Today, with the increasing equipment and workload in a semiconductor business, customers are relying on suppliers to provide efficient and effective maintenance and service. The importance of maintenance function and its management has grown rapidly. As a matter of fact, some research efforts have been undertaken on the maintenance related issues in the semiconductor business through out the years [2,3]. For example, integration of failure analysis in microelectronics manufacturing process was proposed for cost reduction [2]. In the research area, many research efforts have been undertaken on the field of maintenance management. The objectives cover the fields ranging from optimization models, maintenance techniques, scheduling, performance measurement, information systems to policies [4]. In the literature review [4], most of the researches have been established on developing general methods for the development and operation of maintenance system. However, methods for the maintenance and service of equipment in the troubleshooting of system failure and assuring production quality to satisfy customer’s needs are seldom published.

Maintenance engineering and service operation allow customers to have on-going and routine access with experienced engineering experts for minimizing the effort of maintenance management. In addition, it allows customers to focus on their core competencies and areas of individual specialty. Maintenance is an engineering decision and associated actions for the optimization of specified capabilities [5]. A service is to perform an action for customer to keep a product in good operating condition. The benefits of maintenance procedures in manufacturing environment will not only optimize machine reliability to reduce production costs but also improve product quality to increase yield. The service operation enhances the technical oversight of specialized engineering operations at a fraction of the required cost to maintain the performance in-house. Development of a systematic engineering method for efficient and effective maintenance and service of semiconductor equipment should provide large returns in productivity for a semiconductor fabrication business.

In this paper, a novel framework is proposed and applied for the maintenance and service of semiconductor equipment. A systematic framework of equipment maintenance and service is first proposed. Next, a mechatronics structure integrated with axiomatic design mapping of a wire bonder is constructed for documenting the know-
ledge of equipment. Then, the framework is employed for troubleshooting the first bond failure and maintenance service. Finally, the contribution by the present approach on the maintenance and service of equipment is concluded.

2. Systematic Framework of Maintenance and Service

Maintenance activities in engineering service will increase machine utilization and improve productivity. There are several activities such as Failure Mode and Effects Analysis (FMEA), troubleshooting, and process optimization involved in the maintenance and service of equipment. In this section, a systematic framework is developed for providing an efficient and effective maintenance and service.

2.1 Engineering System of Failure Analysis

Engineering maintenance and service usually involve a complex combination of resources. A system engineering method is required to manage engineering resources to fulfill customer’s needs [6]. For providing maintenance service to customers, qualified engineers are to be trained through laboratory and field practice. Engineer training usually includes practicing technical skill, writing reports, and studying ethics. Engineering measuring and testing techniques regarding semiconductor equipment are required and built on the knowledge among a production field. All related information in maintenance practice is to be documented to improve engineer skill and attitude. In failure diagnosis, failure criteria are required a priori to classify operating status. For providing an optimal solution in reducing the failure probability over time, the analysis of the value in industrial environment for the operation of equipments will be tracked and controlled for every aspect of routine and non-routine equipment maintenance.

For the system involved in failure analysis and maintenance, the objective is to optimize maintenance function and servicing cost to satisfy customer’s needs. For system engineering management, the system environment and components are to be identified. The activities of equipment failure analysis and maintenance are deemed to be operated in an industrial environment. The industrial environment may include human and material resources, industrial standards and technologies, political, economic and social factors, and international involvement [6]. For the system components involved in the activities, five components can be identified as Maintenance/Service Engineer, Machine/System Knowledge, Measurement and its Knowledge, Failure Criteria, and Maintenance Documentation. In order to operate maintenance system, all activities are to be relied on maintenance/service engineer. Therefore, the component of Maintenance/Service Engineer will interact with all the other four components. From the above analysis, a system model of equipment failure analysis and maintenance for engineering service is constructed and proposed as depicted in Figure 1.

2.2 Methods, Process, and Activities

A scheme to integrate various methods in maintenance process is constructed for machine diagnostics and process optimization of semiconductor equipment. Several related techniques and methods to be integrated for realizing the system of equipment failure analysis and maintenance in Figure 1 will be briefly introduced.

Value engineering provides a measure of value for the purpose of maintenance and service of semiconductor equipment. Value can be defined as function over cost [6]. The value of maintenance and service for different failure modes needs to be evaluated. The ultimate goal of the maintenance and service support in the fabrication industries is to increase the net value by reducing the cost, and increasing customer’s acceptance during the equipment’s life cycle.

The conversion from customer’s needs to functional requirements in equipment development is an essential issue in a semiconductor business. A systematic method of Quality Function Deployment (QFD) can be applied quantitatively to solve the conversion problem. In realizing QFD, a central element called House of Quality is usually employed. The success of QFD relies on the detailed investigation of the customer’s needs and the evaluation of the markets. The initial tasks in QFD are to acquire market needs by listening to the voice of customer, sorting the needs, and prioritizing the needs numerically. In reliability engineering, the attempt of introducing an integrated usage of QFD and FMEA has been undertaken by several researchers [7].

A machine as a system can be decomposed into many sub-systems for engineering operation and testing. In the
decomposition of semiconductor equipment, it is essential to understand the equipment’s principle and mechanism in operation. The design and implementation of the semiconductor equipment relies on the integration of precision mechanical engineering, electrical control, and system thinking. According to the definition of mechatronics by EEC [8], the technique and the knowledge of semiconductor equipment is classified as a discipline of mechatronics. With the knowledge of mechatronics in semiconductor equipment, failure analysis and maintenance can be undertaken by engineers in service.

Semiconductor equipment is designed and implemented through precision engineering. In the field of precision design, Suh [9] identified two design axioms from abstracting common mapping domains of a body of precision designs, including products, processes, and systems. The foundation of axiomatic design is to construct design mappings in the forward engineering. The design mappings are from Customer Attributes (CAs) to Functional Requirements (FRs), then from FRs to Design Parameters (DPs) and finally from DPs to Process Variables (PVs). Recently, the design method has been integrated with other methods for different applications. For example, a design method to integrate the axiomatic design and robust design was developed for assuring six-sigma quality in product [10]. In addition, some thoughts were proposed on potential integration of axiomatic design with quality tools to enhance product development process [11].

For a semiconductor fabrication process, minimizing the process variations is the fundamental objective in achieving the optimal machine operation. There has long been a desire to increase the yield by utilizing an electrical or mechanical in-process quality control system. Engineers working on designing quality into products and processes should be provided with a tool available for the experimental design in the field tests. Taguchi has developed a robust method for improving the quality of Japanese products with great success [12]. Taguchi’s method is a robust method for improving productivity so that high-quality products can be produced at low cost [13]. The robust method, in essence, is to utilize a Signal-to-Noise (S/N) ratio to estimate and assure the minimum variability in product quality.

Maintenance engineers need to have full knowledge about machine failure in maintenance service. In fabrication industry, a method of FMEA provides a structured approach to analyze the root causes of failure, and assesses the potential failure modes of a process and their causes in risk prevention measures [6,14]. In utilizing FMEA, an integral part is to calculate Risk Priority Number (RPN) for ranking and assessing risk of failure modes [14]. The RPN is used to prioritize items of causes that require additional quality planning or action. The items with the highest RPN and severity ratings usually will be given first consideration. However, the priorities ranking by RPN may not always reflect the true concerns in maintenance management [15].

In the operation of semiconductor equipment, the operational process and equipment setting in production are usually relied on the techniques from R&D and supplier. The operational techniques usually are to be trained through laboratory and field practice.

In the applications of precision engineering to the semiconductor industry, there should also be an efficient and effective maintenance system for providing high performance and quality operations at a reasonable cost. In considering that axiomatic design can be used as the foundation in designing semiconductor equipment, a systematic method through axiomatic design mapping is proposed for engineers to solve the maintenance problems. By integrating the engineering methods mentioned in the previous paragraphs along with the forward and inverse mappings in axiomatic design, a scheme to integrate various methods in maintenance process for machine diagnostics and process optimization of semiconductor equipment is constructed and depicted in Figure 2.

In Figure 2, the maintenance needs are initially raised by the customer. In proceeding maintenance process, the value and worth of maintenance will be analyzed and evaluated. The value analysis requires the mapping between the CAs and FRs. The FRs can be deployed and
defined based on the analysis of quality function. By analyzing and evaluating the maintenance needs and FRs, CAs are determined by using the method of value engineering. In proceeding the analysis of FRs in maintenance, FMEA is undertaken to obtain causes and effects of failure modes. For semiconductor equipment, various components are mutually affected regarding the behaviors of machine and its performance. By utilizing mechatronic engineering, the forward mapping from the FRs to DPs is analyzed to give the reverse mapping of DPs that affect the FRs. With the mapping from the FRs to DPs, the DPs which affect FRs can be verified in troubleshooting during maintenance. With the DPs, a mapping from the DPs to PVs for semiconductor equipment can be constructed. The PVs will affect the variations of DPs in equipment during the life cycle of equipment operation. For the PVs, some PVs related to fabrication processes which are sensitive to disturbances will be involved in quality problems. By assuming a set of PVs which may affect the quality specifications, laboratory experiments can be carried out by supplier or through R&D for identifying the key PVs. The key PVs which are defined as Control Factors (CFs) are employed for assuring production quality. In production, an important aspect of quality in setting CFs is to achieve robustness. Since the issue of robustness cannot be addressed until noise factors are given in an environment, designed experiments by Taguchi method are utilized to find out the optimal setting of CFs for minimizing product variance during equipment operation.

2.3 Procedure

Under the diagram constructed in Figure 2, a procedure for realizing maintenance and service will be developed. In the maintenance procedure starting from Maintenance Needs to Operation, there are five activities associated with the mapping domains, respectively. The five activities including Value Analysis, FMEA, Troubleshooting, Process Variables Validation, and Optimal Setting will proceed with the following steps.

1) Value Analysis
At first, maintenance needs are initiated by the customer. Therefore, from the initiation of maintenance needs, CAs will be reviewed and revised and the value in CAs will be evaluated iteratively. If the maintenance service is valuable for proceeding the troubleshooting and/or process optimization, the FMEA will be undertaken to analyze the root causes of failure modes.

2) FMEA
In proceeding with the FMEA, the failure problem will be defined in operation environment. In addition, information of potential effects of failure and risk factor rating are analyzed and documented. The analysis of failure modes and their causes can be inferred by identifying the failure problem, reviewing FRs, and the corresponding DPs iteratively.

3) Troubleshooting
After FMEA, field tests are undertaken for troubleshooting. The failure due to mechanism or system software in semiconductor equipment will be tested first. The troubleshooting is undertaken by iterating test and check in order to resolve any issues of DPs in the subsystems or components.

4) Process Variables Validation
If the equipment is functionally correct, the equipment will be controlled and tested by setting PVs in fabrication process software. The operation of equipment will be validated iteratively by reviewing and revising PVs to make sure that PVs are correct and no failures occur in the fabrication process software.

5) Optimal Setting
If the equipment operates correctly under the control of fabrication process software, then experimental tests will be applied for process optimization. By analyzing the CFs and noise factors in PVs and testing the CFs in fabrication process software, Taguchi method is applied through reviewing CFs iteratively for obtaining optimal CFs.

The maintenance and service procedure is completed after setting the optimal CFs. The implementation of the maintenance and service procedure will indicate that the failure has been resolved and the machine performance is robust in operation. From the above analysis and referring to Figure 2, a procedure of maintenance and service is proposed and complied as shown in Figure 3. From Figure 3, it is observed that optimal and robust operational quality can be obtained by adjusting CFs as long as there are no issues with PVs. However, if better performance improvement is required, further maintenance service can be undertaken through reviewing PVs, returning PVs to DPs, from DPs to FRs, or even from FRs to CAs for analyzing service value to satisfy customer’s needs.

3. Wire Bonder System

3.1 Mechatronics Structure
The mechatronics functions of subsystems of a wire bonder indicate the functional responsibility by each component in a subsystem. The functionalities of the components of wire bonder equipment can be decomposed into different functional subsystems. For a wire bonder machine K&S (Kulicke and Sofía) Maxхım Plus, the functional subsystems include Console System, Bond Head Assembly, Vision System, Material Handling System, XY-Table Assembly, Equipment Network, and Software. The functional subsystems are composed of different functional components of a mechatronics system. Console System includes sensing components, signal processing and controlling components, and power components. Bond Head Assembly includes driving components, motion executing components, and sensing components. Vision System includes sensing components. Mate-
Material Handling System includes driving components, motion executing components, and sensing components. XY-Table Assembly includes driving components, motion executing components, and sensing components. Equipment Network and Software includes the network communication components, operating system components and also the application software components. The Equipment Network which is constructed by employing Semiconductor Equipment Communication Standard (SECS), General Equipment Model (GEM), and High Speed Message Series (HSMS) follows the Semiconductor Equipment Materials International (SEMI) standards. From the analysis, a three levels structure diagram is depicted as shown in Figure 4. The first level is functional subsystems. The second level is components of the corresponding subsystems. The third level is functional elements corresponding to each component. By utilizing the diagram of Figure 4, the mapping of a wire bonder from FRs to DPs can be analyzed and documented as machine knowledge in Figure 1.

3.2 Knowledge Structure

A wire bonder with five modules of subsystem is required to satisfy functional requirements. The mapping between FRs and DPs which satisfies a decoupled module design is given by (1) with weighting $A_{ij}$ as:

$$
\begin{bmatrix}
FR1 & A_{i1} & 0 & 0 & 0 & [DP1] \\
FR2 & A_{i2} & A_{i2} & 0 & 0 & [DP2] \\
FR3 & A_{i3} & A_{i3} & A_{i3} & 0 & [DP3] \\
FR4 & A_{i4} & A_{i4} & 0 & A_{i4} & 0 & [DP4] \\
FR5 & A_{i5} & A_{i5} & 0 & 0 & A_{i5} & [DP5]
\end{bmatrix}
$$

The FRs in (1) are listed as:

FR1: Provides command control and electronic control of equipment
FR2: Affords bonding motion for each recipe selected
FR3: Recognizes the image of materials by operator and machine
FR4: Provides material transportation capabilities
FR5: Maintains bonding table movement over the working area

The DPs for the subsystems in (1) are listed as:

DP1: Signal, motion, and power control in Console System
DP2: Wire bonding is accomplished by mechanisms and controls of Bond Head Assembly
DP3: Targeting of devices is accomplished by Vision System
DP4: Move the materials for bonding demands as Material Handling System
DP5: XY-Table Assembly moves bonding mechanisms over the working space

3.3 Knowledge Representation

The knowledge representation constructed by axiomatic mapping can be derived from decomposition and zigzag mapping [9]. Only two levels in the representation of equipment knowledge are given in the following list. The lower levels of FRs and DPs will be given in the appendix.

1) Console System
FR1-1: All subsystems to be under control
DP1-1: Monitor and control system
FR1-2: Supply energy resources
DP1-2: Power system
FR1-3: Control the operation of machine
DP1-3: Human/machine interface
FR1-4: Software operations and data storage
DP1-4: Storage system
FR1-5: Air supply and control
DP1-5: Pneumatic system
FR1-6: Feed wire for automatic bonding
DP1-6: Wire feed system

2) Bond Head Assembly

Figure 3. Procedure for maintenance and service
Figure 4. Structure diagram of a wire bonder

The following components are decomposed to be unique and independent and will be used as the basis for formulating DPs which are corresponding to FRs, respectively. The decomposition is undertaken for the Bond Head Assembly.

2.1 Electronic Flame Off (EFO)
FR2-1: Discharge for wire ball formation
DP2-1: EFO assembly

2.2 Wire Clamp
FR2-2: Feed and hold wire
DP2-2: Wire clamp assembly

2.3 Ultrasonic Generator (USG)
FR2-3: Generate and transmit ultrasonic energy
DP2-3: USG system

2.4 Z-axis Servo System
FR2-4: Bond head positioning and force control
DP2-4: Z-axis servo system

2.5 Bond Integrity Test System (BITS)
FR2-5: Detection of bonding outcome
DP2-5: Bond integrity test system

2.6 Flexure Bearing Assembly
FR2-6: Provide rotational movement
DP2-6: Flexure bearing

3) Vision System
The decomposition is undertaken for the Vision System with DP3 corresponding to FR3.

FR3-1: Clear image
FR3-2: Image acquisition with high speed
FR3-3: Focus range and field of view extension

DP3-1: Illumination and image acquisition system
DP3-2: Image processing system

4) Material Handling System
The decomposition is undertaken for the Material Handling System with DP4 corresponding to FR4.

FR4-1: Carry the materials in the bonding cycle
FR4-2: Fix the materials on the bond site
FR4-3: Provide the working temperature
FR4-4: Prevent materials damaged during transportation
FR4-5: Handle magazines during the bonding operation

DP4-1: Transporting mechanism
DP4-2: Clamping assembly
DP4-3: Heater assembly
DP4-4: Detection sensor
DP4-5: Elevator mechanism

5) XY-Table Assembly
The decomposition is undertaken for the XY-Table Assembly with DP5 corresponding to FR5.

FR5-1: I/O density of IC chip become higher
FR5-2: Chip dimension and the bond pad pitch become smaller

DP5-1: High speed and steady XY-servo system
DP5-2: XY-Table mechanism

4. First Bond Failure and Maintenance
By employing the design mappings combined with Mechatronics Engineering and engineer experience in representing the knowledge of a wire bonder, the failure modes regarding the first bond operation and the effects of various components on performance can be analyzed.
The analysis of the first bond failure through DPs and PVs by the present approach is shown in Figure 5. By utilizing both engineering experience and documented equipment knowledge, the results of wire bonder failure modes corresponding to DPs are analyzed and obtained. In addition to these information and knowledge, the implementation results still rely on experience of measurements, tests, record of FRs, and customer feedback.

### 4.1 Value Analysis

Value is the first consideration by customers in needing maintenance as shown in Figure 3. In considering the CAs in needing maintenance service, a maintenance task [6] including task description, elapsed time, estimated cost for achieving specified functional performance will be proposed. With the proposed maintenance task analysis, the maintenance value can be justified and managed by customers. By assuming that the proposed service can satisfy CAs, the maintenance on the first bond failure will be undertaken by following Figure 3 through FMEA, Troubleshooting, Process Variables Validation, and Optimal Setting.

### 4.2 FMEA

In wire bonder industry, the performance of first bond operation can be qualified by employing the tests of ball size, ball shear, intermetallic compound, and etching. For the first bond operation, four common failure modes as Non-stick on Pad, Bond Placement, Deformed Ball, and Metal Peeling are identified as shown in Figure 5.

1) First Bond Failure Modes

1.1 Failure mode I: Non-Stick on Pad

Ball shear stress calculated with the apparent bonded area will provide a conservative underestimation of the quality of the gold-to-aluminum intermetallic bond line. This failure mode means a bond ball lift out of pad.

1.2 Failure mode II: Bond Placement

The accuracy of bond position must be controlled for the bond placement under the bond pad size.

1.3. Failure mode III: Deformed Ball

An ideal bond ball should have the best bond line quality with ball size proper for the bond pad.

1.4. Failure mode IV: Metal Peeling

Bond pad metal peeling is recognized as a serious problem of bonding ability and bond ball reliability in electronic packaging industry.

2) RPN Analysis

By analyzing the RPN value of the first bond failure, a decision making on the priority in maintenance can be justified and managed. The RPN for four failure modes is evaluated. The RPN is calculated as a mathematical product of the numerical ratings of severity, probability of occurrence, and detection likelihood given by

\[
A_{i,j,k} = s_i \times r_{i,j,k} \times m_k \times e_{i,j,k} \times n_k \times f_{i,j,k}
\]

In (2), the indices \(i, j, k\) represent the sub-system, the component of the sub-system, and the failure mode, respectively. The \(A_{i,j,k}\) is the RPN for each DPs of the failure mode \(k\). The \(s_i\) is a severity rating for failure mode \(k\) and the \(r_{i,j,k}\) is a severity rating for each DPs of the failure mode \(k\). The \(m_k\) is a probability rating for failure mode \(k\) and the \(e_{i,j,k}\) is a probability rating for each DPs of the failure mode \(k\). The \(n_k\) is a detection rating for failure mode \(k\) and the \(f_{i,j,k}\) is a detection rating for each DPs of the failure mode \(k\). The RPN is calculated by assigning potential failure modes ranking from 1 to 10 with respect to the severity of the failure mode effect, its probability of occurrence, and the likelihood of its being detected [14, 15]. The assignment of ratings in the present study is according to the classification by SAE J1739 [15]. In applications, these ranking factors are highly dependent on the attributes of the system in operation. For providing a direct comparison of failure effects, the RPN value is normalized to give
The results of RPN ratio for the four kinds of failure modes of the first bond process are to be computed by utilizing (2) and (3) with data from Table 1. The results of RPN ratio with respect to DPs for the four failure modes are calculated and obtained as shown in Figure 6. From Figure 6, the optimal decision and associated actions can be inferred. In Figure 6, DPs with higher RPN ratio for each failure mode are assumed to be more important and given higher maintenance priority than those having a lower RPN ratio. From Figure 6, it is observed that the highest priority for failure mode I, II, and IV is DP2-6. The DP2-6 is a flexure bearing. For failure mode III, the highest priority is DP2-1. The DP2-1 is an EFO assembly. The priority distribution of RPN ratio for the components of wire bonder provides enough information for maintenance engineers to realize the effects of failure modes.

4.3 Troubleshooting

If there is no failure in the Software of Figure 5, the causes for the failure of DPs in the mechanism of the wire bonder are obtained by utilizing the knowledge representation and engineering experience in Figure 5 to give the following list.

1) Console System: failure related to mode I, II, and III
   DP1-1: Monitor and control system
   DP1-2: Power system
   DP1-5: Pneumatic system
   DP1-6: Wire feed system
2) Bond Head Assembly: failure related to mode I, II, III, and IV
   DP2-1: EFO assembly
   DP2-2: Wire clamp assembly
   DP2-3: USG system
   DP2-4: Z-axis servo system
   DP2-5: Bond integrity test system
   DP2-6: Flexure bearing
3) Vision System: failure related to mode II
   DP3-1: Illumination and image acquisition system
4) Material Handling System: failure related to mode I, II, and III
   DP4-2: Clamping assembly
   DP4-3: Heater assembly
5) XY-Table Assembly: failure related to mode II and III
   DP5-2: XY-Table mechanism

From the analysis of DPs in the knowledge representation, causes analysis, and utilizing engineering experience for the first bond failure, the detail troubleshooting result of DPs is obtained as shown in Figure 7. The lower levels of DPs in Figure 7 are referred to Appendix. In Figure 7, the DPs are employed as DP1 for Console System, DP2 for Bond Head Assembly, DP3 for Vision System, DP4 for Material Handling System, and DP5 for XY-Table Assembly.

4.4 Process Variables Validation

From Figure 7, the related PVs will be analyzed through the mapping from DPs to PVs [9]. The PVs related to the bonding process in the maintenance and service of equipment operation can be analyzed, inferred, tested, and verified. For the first bond process, the environment
Figure 7. First bond failure troubleshooting

is met by the production standard. Bonding material and bonding temperature are fixed. A gold wire of 20μm is used. The temperature of bond-site area is 150°C. Suitable capillary is chosen on K&S Maxμm Plus wire bonder. From the results obtained for the process study, the feedback of quality analysis responds the relationships between PVs and DPs. The PVs related to the process of the first bond failure are validated to give

PV1-1: Signal to electronic devices
PV1-2: Different rating of supply voltages
PV1-3: Different input commands
PV1-4: Different program storage selections
PV1-5: System flow rate adjustments
PV1-6: Wire feed flow rate adjustments
PV2-1: Adjustment of EFO firing time and control current
PV2-2: Adjust wire pullout
PV2-3: Setting ultrasonic power utilization
PV2-3-1: Setting USG applied amplitude and frequency
PV2-3-2: Capillary tube and transducer installation adjustment
PV2-3-3: Setting USG in bonding process
PV2-3-3-1: Setting pre-bleed USG
PV2-3-3-2: Setting bonding USG
PV2-4: Variables in Z-axis motion on bonding time and force
PV2-4-1: Bonding force
PV2-4-2: Z-axis position
PV2-4-3: Bonding time
PV2-4-4: Capillary searching speed
PV2-5: Signal of bonding processes
PV3-1: Adjust optical limit and select image setting
PV3-2: Set parameters of image processing
PV3-3: Select different cameras and magnifications
PV4-1: Material transportation variables
PV4-2: Clamping compensation adjustments
PV4-3: Variables of bonding temperature
PV4-4: Set up sensor sensitivity
PV4-5: Adjust elevator parameters
PV5-1: Adjust XY-axes motion and speed

PV5-2: Adjust XY-motion accuracy

4.5 Optimal Setting

Minimization of the variation of the bonding process is to achieve high yield in production. The specifications of bond ball can be set according to customer’s requirements. Optimization of CFs for assuring bond ball quality is undertaken by employing Taguchi method [12,13]. In the Taguchi’s experimental tests, the quality target is called signal and the variation in the target is called noise.

1) Quality Characteristics

For the first bond process, the quality requirements of ball size and ball shear are specified. The quality target of ball size, as tri-axial appearances, is given as Nominal-the-Best. The quality target of ball shear force is given as The-Larger-the-Better. The shear force is obtained by utilizing shear strength, as shear force per unit area, multiplied by the estimated area. The quality specifications for the first bond in the experiment are given as

1.1. Quality Targets:
a. Ball size: Nominal-the-Best
   Ball X & Ball Y (Plane of bond pad) — 40μm +/-2μm
   Ball Z (Plane orthogonal to bond pad) — 10μm
   +/-2μm
b. Ball shear: The-Larger-the-Better
   Ball shear force — Above 12 grams

1.2. Portability of Quality:

For the requirement of portability of quality, experimental tests need large sample size, different machine bonding, and high productive yield.

2) Control Factors Analysis

The function of a wire bonder is assumed correct. The CFs influencing the quality of bond ball forming are selected. For the first bond, the experimental CFs use Constant Velocity in Capillary Searching Speed (PV2-4-4), Bonding USG (PV2-3-3-2), Bonding Time (PV2-4-3), Bonding Force (PV2-4-1), and Pre-Bleed USG (PV2-3-3-1) to verify failure modes I and III.

3) Experimental Tests and Confirmation
The experimental tests are undertaken in laboratory by the combination of five CFs and different levels as shown in Table 2. For portability tests, three devices are separately bonded on two machines. For one factor with two levels and four factors with three levels in combination, the experimental results are based on L18 orthogonal arrays and listed in Table 3.

By following the procedure of Taguchi method [13], the tables and graphs of factor response are obtained and employed to show $S/N$ ratio for different combinations of parameters. The $S/N$ ratio for the Nominal-the-Best is calculated by (4) with the mean and standard deviation of data $y_i$ as

$$S/N = -10 \log \left( \frac{\sigma^2}{\bar{y}^2} \right)$$

The $S/N$ ratio for The-Larger-the-Better is calculated by (5) as

$$S/N = -10 \log \left( \frac{1}{n} \sum_{i=1}^{n} y_i \right)$$

From Figure 8, it is observed that the variations of bonding time for the quality targets are small. Thus, the bonding time is considered as an adjustable factor and selected as C1. From the $S/N$ ratio obtained in Figure 8, the final optimal combinations are inferred by four sets of parameters in sequence as [A1 B2 C1 D2 E2], [A1 B3 C1 D2 E3], [A1 B3 C1 D2 E3].

Table 2. Control factors and levels for first bond process.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Variables Description</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A: Capillary Searching Speed (mil/ms)</td>
<td>0.1</td>
<td>0.14</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>B: Bonding USG (mA)</td>
<td>80</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>C: Bond Time (ms)</td>
<td>8</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>D: Bond Force (grams)</td>
<td>15</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>5</td>
<td>E: Pre-Bleed USG (%)</td>
<td>25</td>
<td>45</td>
<td>65</td>
</tr>
</tbody>
</table>

Figure 8. Overall factors response

Table 4. Comparisons of $S/N$ ratio for four sets of optimal combination

<table>
<thead>
<tr>
<th>Optimal Set</th>
<th>$S/N$ Ratio</th>
<th>Ball X</th>
<th>Ball Y</th>
<th>Ball Z</th>
<th>Ball Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction</td>
<td>44.53</td>
<td>44.47</td>
<td>32.41</td>
<td>23.85</td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>42.74</td>
<td>45.12</td>
<td>38.33</td>
<td>30.48</td>
<td></td>
</tr>
<tr>
<td>Prediction</td>
<td>45.11</td>
<td>41.29</td>
<td>28.65</td>
<td>25.01</td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>41.4</td>
<td>43.15</td>
<td>32.33</td>
<td>29.84</td>
<td></td>
</tr>
<tr>
<td>Prediction</td>
<td>46.92</td>
<td>42.74</td>
<td>36.67</td>
<td>22.42</td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>46.25</td>
<td>43.02</td>
<td>32.02</td>
<td>23.41</td>
<td></td>
</tr>
<tr>
<td>Prediction</td>
<td>47.5</td>
<td>39.56</td>
<td>32.91</td>
<td>23.6</td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>46.77</td>
<td>43.47</td>
<td>31.53</td>
<td>30.1</td>
<td></td>
</tr>
</tbody>
</table>

though there are four sets of optimal parameters in solution, a set of optimal parameters will be selected by confirmation experiments. The confirmation test is undertaken by the fabrication of ten devices under four sets of optimal combinations respectively. Four sets of confirmation for the experimental and predicted $S/N$ are obtained as given in Table 4. In Table 4, the experimental result is calculated from the mean $S/N$ ratio of testing results and the prediction of $S/N$ ratio is obtained by utilizing a linear additive predictive model. The confirmation test reveals that the quality targets are satisfied by all the four sets of optimal combination. By comparing the
closeness of \( S/N \) ratio of each set of prediction and experimental result in Table 4, it is realized that the interactions of CFs are insensitive for Ball X and Ball Y, but the interactions for Ball Z and Ball Shear are sensitive.

With the interactions in laboratory tests, the optimal result obtained cannot be directly applied for customer service. In order to achieve optimal bonding performance and robustness in field operation, further experimental designs and tests are required [13]. For the present results obtained in laboratory, the results of ball size are acceptable by the quality target. The experimental \( S/N \) ratio of Ball Shear for Set 1 is higher than the other three sets of experimental results. With the higher \( S/N \) ratio in Set 1, the wire bonding process will be more robust. From the experimental confirmation tests, the final optimal parameters for K\&S Max\textsuperscript{um} Plus are \{A1 B2 C1 D2 E2\}, i.e. Capillary Searching Speed: 0.1 mil/ms, Bonding USG: 90 mAmp, Bonding Time: 8 ms, Bonding Force: 25 grams, and Pre-bleed USG: 45 %.

5. Conclusions

A systematic framework which consists of a system of equipment failure analysis, methods, process, and activities, and a procedure is proposed for the maintenance and service of semiconductor equipment. The maintenance procedure in sequence starting from Maintenance Needs, Value Analysis, FMEA, Troubleshooting, Manufacturing Process Validation, and Optimal Setting to Operation is developed. By employing axiomatic design mapping integrated with Value Engineering, Quality Function Deployment, Mechatronics Engineering, Techniques from R\&D and Supplier, and Taguchi Method, the framework is highly effective in translating Maintenance Needs into Design Parameters for troubleshooting, and into Control Factors for process optimization. In the troubleshooting and process optimization of a wire bonder, the framework is applied to assure robust production quality in the first bond process by K\&S Max\textsuperscript{um} Plus. The systematic framework provides an effective and efficient scheme to provide maintenance and service for the acceptance or worth by customers.

Appendix

The lower levels of FRs and DPs are listed as follows.

1) Console System
FR1-1-1: Mechanism motion control
FR1-1-2: Signal transmission
FR1-1-3: Image processing
FR1-1-4: Communication relationship
DP1-1-1: Electronic mechanism control
DP1-1-2: Sensor interfaces
DP1-1-3: Image processing system
DP1-1-4: Circuit connection and cabling
FR1-2-1: Provide power for all components
FR1-2-2: Circuit and mechanism protection

2) Bond Head Assembly
FR2-1-1: Required wire bonding quality by EFO
FR2-1-1-1: Fine Pitch bonding
FR2-1-1-2: High yield and bond ability
DP2-1-1: Three-phase controller of EFO.
DP2-1-1-1: Control of discharge energy of the EFO
DP2-1-1-2: Control the wear and lifetime of electrode
FR2-2-1: Proven reliability in operation
FR2-2-1-1: Eliminate motion wear
FR2-2-1-2: High operational times
FR2-2-2: Clamp performance
FR2-2-2-1: Active damping of clamping mechanical resonance
FR2-2-2-2: Shorter opening and closing time
DP2-2-1: Wire contact in handling and mounting
DP2-2-1-1: Compliant motion mechanism
DP2-2-1-2: Fixed arm and bimorph arm
DP2-2-2: Wire clamp driver with voltage profiling for open-loop control
DP2-2-2-1: Bimorph clamp actuator
DP2-2-2-2: Piezoelectric actuation
FR2-3-1: Efficient and effective ultrasonic energy
FR2-3-1-1: Ball roundness
FR2-3-1-2: Fine pitch wire bonding capabilities
FR2-3-1-3: High speed wire bonding
FR2-3-1-4: Minimize the loss of ultrasonic energy
FR2-3-2: Good placement accuracy
FR2-3-2-1: Higher bonding accuracy
FR2-3-2-2: Good stability and reproducibility of capillary tip motion
FR2-3-3: Good bonding capability
FR2-3-3-1: USG applied before capillary contact substrate
FR2-3-3-2: USG applied during contact and bonding operation
DP2-3-1: Generation, transmission and focusing mechanism of ultrasonic energy
DP2-3-1-1: Accurate ultrasonic amplitude and frequency
DP2-3-1-2: High frequency vibration of PZT
DP2-3-1-3: Increase system stiffness by using titanium
DP2-3-1-4: Holder and horn mechanism
DP2-3-2: Vibration of transducer tip
DP2-3-2-1: Transducer material and structure
DP2-3-2-2: Capillary clamping system of the transducer
DP2-3-3: Ultrasonic energy by USG in bonding process
DP2-3-3-1: Capillary tube and ultrasonic profile
DP2-3-3-2: Bonding ultrasonic control circuitry
FR2-4-1: Precise motion and force control on bond head
FR2-4-1-1: Capable of high acceleration
FR2-4-1-2: High motion repeatability
FR2-4-1-3: Bonding accuracy
FR2-4-2: Monitor Z-axis position for force control
FR2-4-2-1: Monitor bonding tool position precisely
FR2-4-2-2: Real-time signals response
FR2-4-3: Speed control of bond head
FR2-4-3-1: Higher acceleration
FR2-4-3-2: High performance of control system
FR2-4-4: Capillary and wire motion control
FR2-4-4-1: Detecting and switching the approaching to substrate
FR2-4-4-2: Searching speed requirement
DP2-4-1: Voice coil actuating control system
DP2-4-1-1: Minimize the mass of the motor and balance the centre of gravity of the rotational inertia.
DP2-4-1-2: Electromagnetic and mechanical subsystems
DP2-4-1-3: Accurate servo mechanism
DP2-4-2: Encoder assembly
DP2-4-2-1: High resolution optical grid
DP2-4-2-2: Electronic encoder system
DP2-4-3: Speed control system
DP2-4-3-1: Low inertia mechanism
DP2-4-3-2: High bandwidth in control loop
DP2-4-4: Capillary and wire motion control system
DP2-4-4-1: Detection and switching control mechanism
DP2-4-4-2: Searching speed control circuitry
FR2-5-1: Capable of detection
FR2-5-1-1: Enhance detection signal
FR2-5-1-2: Avoid false detection
FR2-5-2: Test for the outcome of the bonding process
FR2-5-2-1: Detect non-stick on pad
FR2-5-2-2: Detect non-stick on lead
FR2-5-2-3: Detect the tail left on the capillary after wire-cycle bonding
FR2-5-2-4: Detect ball formation by electronic firing
DP2-5-1: Effective detector
DP2-5-1-1: High-impedance devices
DP2-5-1-2: Noise eliminator
DP2-5-2: Electrically detectable interface system
DP2-5-2-1: Current from bond pad to machine chassis ground
DP2-5-2-2: Current from lead to machine chassis ground
DP2-5-2-3: Current from wire tail to machine chassis ground
DP2-5-2-4: Current from wire tail to wand
FR2-6-1: Support precision machine components with rotational motion
FR2-6-1-1: Robust bearing
FR2-6-1-2: Infinite lifetime/service time
FR2-6-2: Provide motion accuracy of bond head
FR2-6-2-1: Minimize the restoring force
FR2-6-2-2: Increase bonding speed and line pitches
DP2-6-1: Robust linkage with flexure pivot
DP2-6-1-1: Stainless steel cross-flexure pivot bearings
DP2-6-1-2: Zero wear and friction operation
DP2-6-2: Bond head inertia and stiffness in assembly
DP2-6-2-1: Flexure bearing pivots in loading angle
DP2-6-2-2: High stiffness in assembly
3) Vision system
FR3-1-1: Sufficient illumination
FR3-1-2: Clear image features
FR3-2-1: High accuracy and robustness
FR3-2-2: Faster image processing
FR3-3-1: Show bond height difference and capture wider image of bonds
FR3-3-2: Image features requirements
DP3-1-1: Illumination assembly and work light
DP3-1-2: Image acquisition system
DP3-2-1: Pattern matching by image processing tools
DP3-2-2: High-speed processor
DP3-3-1: Mechanism for different magnifications
DP3-3-2: Installation and calibration
4) Material Handling System
FR4-1-1: Pull the materials from input magazine into work holder
FR4-1-2: Support the materials with suitable rail width
FR4-1-3: Index the materials into bond site and index motion
FR4-1-4: Eject the materials into output magazine
FR4-2-1: Mechanism secures the carrier during bonding operation
FR4-2-2: Hold the fine-pitch and specific materials bonding more stable
FR4-3-1: Raise temperature before entering the bond site
FR4-3-2: Maintain the bonding temperature
FR4-3-3: Prevent damage to devices after bonding by rapid heating and cooling
FR4-4: Prevent materials damaged during transportation
FR4-4-1: Prevent devices damaged during transportation from input magazine or into output magazine
FR4-4-2: Prevent devices damaged during injection
FR4-4-3: Prevent devices damaged during ejection
FR4-5-1: Inject/eject the magazine
FR4-5-2: Jog/reverse magazine
DP4-1-1: Injector assembly
DP4-1-2: Front and real rails assembly
DP4-1-3: Indexer assembly
DP4-1-4: Ejector assembly
DP4-2-1: Clamp mechanism
DP4-2-2: Hold down mechanism
DP4-3-1: Pre-heat plate
DP4-3-2: Bond-site heat plate
DP4-3-3: Post-heat plates
DP4-4-1: Wall sensors on both sides of input and output
DP4-4-2: Inject Y-axis sensor detection
DP4-4-3: Jam detection sensor during ejection
DP4-5-1: Gripper motor injects and ejects magazines
DP4-5-2: Z-axis motor drives the jog/reverse motion
5) XY-Table Mechanism
FR5-1-2: Less structural vibration
FR5-2-1: High motion precision
FR5-2-2: High precision in fabrication
DP5-1-1: High acceleration
DP5-1-2: High damping in material and servo loop
DP5-2-1: Decrease joint clearance
DP5-2-2: Decrease the wear of motion joint

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A Study of Quantum Strategies for Newcomb’s Paradox

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Received August 24th, 2009; revised October 11th, 2009; accepted November 23rd, 2009.

ABSTRACT

Newcomb’s problem is a game between two players, one of who has an ability to predict the future: let Bob have an ability to predict Alice’s will. Now, Bob prepares two boxes, Box1 and Box2, and Alice can select either Box2 or both boxes. Box1 contains $1. Box2 contains $1,000 only if Alice selects only Box2; otherwise Box2 is empty ($0). Which is better for Alice? Since Alice cannot decide which one is better in general, this problem is called Newcomb’s paradox. In this paper, we propose quantum strategies for this paradox by Bob having quantum ability. Many other results including quantum strategies put emphasis on finding out equilibrium points. On the other hand, our results put emphasis on whether a player can predict another player’s will. Then, we show some positive solutions for this problem.

Keywords: Game Theory, Newcomb’s Paradox, Quantum Strategy, Meyer’s Strategy

1. Introduction

Game theory is one of the most famous decision making methods and has been used in many situations both theoretically and practically. There had existed the basic concept with respect to these games since early times but in corporation with Morgenstern, von Neumann [3] firstly constructed the theory systematically. However, the main principle of this theory was based on classical physics although he was familiar with quantum mechanics.

In 1998, for a coin flipping game, Meyer [4] proposed a quantum strategy for the first time and showed that the quantum strategy has an advantage over classical ones. This game is called PQ Penny Flip.

PQ Penny Flip: The starship Enterprise is facing some immanent—and apparently inescapable—calamity when Q appears on the bridge and offers to help, provided Captain Picard can beat him at penny flipping. Picard is to place a penny head up in a box, whereupon they will take turns (Q, then Picard, then Q) flipping the penny (or not), without being able to see it. Q wins if the penny is head up when they open the box.

This game is a two-player zero-sum game and the probability that each player wins is at most 1/2 with classical strategies. Meyer showed a quantum strategy with which Q can always win by using a superposition of quantum states effectively. In this game, Picard is constrained to play classically. The quantum strategy is then executed in the following way. Let and represent the head and tail of the penny, respectively. First, Picard prepares and Q applies a Walsh-Hadamard operation \( H \) defined in the next section to the state:

\[
|0\rangle + \frac{1}{\sqrt{2}} |1\rangle.
\]

Next, Picard decides classically whether he flips it or not. However, the state does not change even if Picard flipped it. Finally, Q applies \( H \) to the state and always obtains \( |0\rangle \). This means that Q always wins.

Moreover, he also showed the importance of a relationship between quantum game theory and quantum algorithms.

Later, other types of quantum strategies have been also proposed. In their strategies, all the players can use quantum operations. For example, Eisert et al. [5] proposed a quantum strategy with entanglement for a fa-
mous two-player game called the **Prisoner’s Dilemma** (also see Du et al. [6,7], Eisert and Wilkens [8], and Iqbal and Toor [9]). In their strategy, entanglement plays an important role. For another famous two-player game called the **Battle of the Sexes**, Marinatto et al. [10] also proposed a quantum strategy with entanglement. For these games, they showed quantum Nash equilibriums different from classical ones. Furthermore, there are many results being related to games such as the Monty Hall problem by D’Ariano et al. [11], Flitney and Abbott [12], and Li et al. [13], Parrondo’s game by Flitney et al. [14], games in economics by Piotrowski and Sladkowski [15–17], Newcomb’s paradox by Piotrowski and Sladkowski [18], and so on.

In this paper, we study Newcomb’s problem. Newcomb’s problem is a thought experiment between two players, Alice and Bob. Alice is a common human being. On the other hand, Bob may be a wizard having an ability to predict the future, or not. Bob can predict Alice’s will if he is a wizard. Then, the problem is as follows:

**Newcomb’s problem:** Bob prepares two boxes, **Box** \(1\) and **Box** \(2\), and Alice can select either **Box** \(2\) or both boxes. **Box** \(1\) contains \(1\). **Box** \(2\) contains \(1\) or \(0\) only if Alice selects only **Box** \(2\); otherwise **Box** \(2\) is empty(0). Which is better for Alice?

No one knows the answer except Bob. Namely, there exists no best classical strategy. Therefore, this problem is called **Newcomb’s paradox**. We show some quantum strategies for Newcomb’s paradox by using entanglement.

It is thought that entanglement is essential as the main power of quantum information and many results mentioned above also have used entanglement effectively. First, we show some basic quantum strategies with entanglement. In the other related studies mentioned above, each player operates only each assigned qubit although the states are entangled. On the other hand, our proposed strategies operate not only one qubit but also states between two qubits. Consequently, we show that our quantum strategies with entanglement are more powerful than classical ones.

Finally, we show some quantum strategies for Newcomb’s paradox. Piotrowski and Sladkowski showed a quantum solution for Newcomb’s paradox by using Meyer’s strategy [18]. Newcomb’s paradox is whether a player can predict another player’s will. We also study this problem by applying our strategies. Then, we obtain positive results. That is, in some case, a player can predict another player’s will.

The remainder of this paper has the following organization. In Section 2, first, we define notations and basic operations used in this paper. Moreover, as the tools of our quantum strategies, we show two fundamental lemmas with relation to entanglement. In Section 3, we denote two types of two-player zero-sum games. We then show that in these games, each player cannot win with certainty with classical strategies but one side player can win with certainty with quantum ones. In Section 4, we study Newcomb’s paradox. We modify this problem and show some quantum strategies to it by using the results in Section 3. Finally, in Section 5, we provide some concluding remarks.

## 2. Preliminaries

In this section, first, we define some notations used in this paper. Let \(\oplus\) be a bitwise exclusive-or operator, i.e., \(1100\oplus1010 = 0110\). Let \(\overline{a}\) be the negation of a bit \(a\) for \(a \in \{0,1\}\), i.e., \(\overline{a} = a \oplus 1\). Moreover, let \(b\cdot c = \sum_{i=1}^{n} b_i c_i\) be the inner product of \(b\) and \(c\), where \(b = (b_1, b_2, \ldots, b_n)\) and \(c = (c_1, c_2, \ldots, c_n)\) for \(b_i, c_i \in \{0,1\}^n\) \((i = 1, 2, \ldots, n)\).

Next, we define some basic operations. Let \(|0\rangle = (1, 0)\), \(|1\rangle = (0, 1)\), where \(|\cdot\rangle\) is Dirac notation and \(A^T\) is the transposed matrix of a matrix \(A\). Let \(I\) be the \(2 \times 2\) identity matrix. This operation means no operation. A Walsh-Hadamard operation \(H\) is

\[
H = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}
\]

\( (H |0\rangle = (1/\sqrt{2})(|0\rangle+|1\rangle)\) and \(H |1\rangle = (1/\sqrt{2})(|0\rangle-|1\rangle)\).

Note that \(H = H^{-1}\). This operation is used when we make a superposition of states. As an operation used when they flip a coin classically, players use an operation \(X\),

\[
X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}
\]

\(|X |0\rangle = |1\rangle\) and \(|X |1\rangle = |0\rangle\). We also define a phase-shift operation \(S(\theta)\) by

\[
S(\theta) = \begin{pmatrix} 1 & 0 \\ 0 & e^{i\theta} \end{pmatrix}
\]

\(|S(\theta) |0\rangle = e^{i\theta} |1\rangle\) and \(|S(\theta) |1\rangle = e^{-i\theta} |0\rangle\).
(CNOT |c,t⟩ = |c,t ⊕ c⟩), where the first bit c is the controlled bit and the second bit t is the target bit. We denote the operation by CNOT_{(i,j)} when the i-th bit is the controlled bit and the j-th bit is the target bit.

Finally, we show two basic results operating entangled states. These results can be used as tools of making a specific state in order that one side player always wins games by using our quantum strategies mentioned in the following sections.

**Lemma 2.1** Let

|ψ^{(i)}⟩ = \frac{1}{\sqrt{2}} (b_1, b_2, ..., b_k) + (-1)^{c} |b_1, b_2, ..., b_k⟩

be a k -qubit entangled state, where b_i ∈ {0,1} (i = 1,2,... ,k) and c ∈ {0,1} . Then,

|ψ^{(i)}⟩ \rightarrow \frac{1}{\sqrt{2^{|c|}}} \sum_{c_{j} \in c_{j}} (-1)^{c_{j}} |c_{1},c_{2},...,c_{k}⟩

when we apply the Walsh-Hadamard operation H to all the qubits of |ψ^{(i)}⟩ .

**Proof.** When we apply H to all the qubits of |ψ^{(i)}⟩ ,

|ψ^{(i)}⟩ \rightarrow \frac{1}{\sqrt{2^{|c|}}} \sum_{c_{j} \in c_{j}} (-1)^{c_{j}} |c_{1},c_{2},...,c_{k}⟩

where \( i = (1,1,...,1) \). Then, the statement of this lemma is then satisfied.

This lemma means that a player can obtain a state |c_{1},...,c_{k}⟩ satisfying \( \bigoplus_{j=1}^{k} c_{j} = 0 \) if he makes the state |ψ^{(0)}⟩ and that he can obtain a state |c_{1},...,c_{k}⟩ satisfying \( \bigoplus_{j=1}^{k} c_{j} = 1 \) if he makes the state |ψ^{(1)}⟩ .

Next, we show a result used as a player’s quantum strategy when another player flips coins classically.

**Lemma 2.2** Let |ψ^{(i)}⟩ be the k -qubit entangled state of Lemma 2.1, and let

|ψ^{(i)}⟩ \rightarrow |ψ^{(-i)}⟩ = \frac{1}{\sqrt{2^{|c|}}} \sum_{c_{j} \in c_{j}} (-1)^{c_{j}} |c_{1},c_{2},...,c_{k}⟩.

Now, let the operation X be applied to some qubits of |ψ^{(-i)}⟩ , i.e.,

|ψ^{(-i)}⟩ \rightarrow |ψ^{(-i)}⟩ = \frac{1}{\sqrt{2^{|c|}}} \sum_{c_{j} \in c_{j}} (-1)^{c_{j}} |c_{1} \oplus x_{1},c_{2} \oplus x_{2},...,c_{k} \oplus x_{k}⟩,

where \( x_{i} \in \{0,1\} (i = 1,2,...,k) \). Note that \( x_{i} = 1 \) if X has been executed. Then,

|ψ^{(-i)}⟩ \rightarrow \frac{1}{\sqrt{2}} (-1)^{x_{i}} (b_1, b_2, ..., b_k) + (-1)^{y}(-1)^{x_{i}} |b_1, b_2, ..., b_k⟩

**Proof.** When we apply H to all the qubits of |ψ^{(-i)}⟩ ,

|ψ^{(-i)}⟩ \rightarrow \frac{1}{\sqrt{2^{|c|}}} \sum_{c_{j} \in c_{j}} \sum_{c_{j} \in c_{j}} \sum_{c_{j} \in c_{j}} (-1)^{c_{j}} |d_{1},d_{2},...,d_{k}⟩

where the last expression is obtained by noting that except for the states corresponding to \( b \oplus d = 0 \) and \( b \oplus d = 1 \), the states vanish. The statement of this lemma is then satisfied.

### 3. Quantum Strategies Using Entangled States

#### 3.1 Strategic Games

We denote a strategic game \( \Gamma \) as \( \Gamma = (N,\{S_{i}\}_{i \in N},\{u_{i}\}_{i \in N}) \), where \( N \) is the set of players, \( S_{i} \) is the set of strategies of player \( i \), and \( u_{i} \) is the payoff function of player \( i \) , i.e., \( u_{i} : S_{1} \times S_{2} \times \cdots \times S_{N} \rightarrow R \) (the set of real numbers).

The game \( \Gamma \) can be given also by a matrix shown in Figure 1. For more details, we shall refer the reader to the books by, e.g., references [22,23]. For two players, \( N = \{\text{Alice, Bob}\} \), the set of Alice’s strategies is \( S_{a} = \{s_{a_{1}},s_{a_{2}}\} \), and the set of Bob’s strategies is \( S_{b} = \{s_{b_{1}},s_{b_{2}}\} \). Then, each value of Alice’s payoff function is \( u_{i}(s_{a_{1}},s_{b_{1}}) = a_{i} \), and each value of Bob’s payoff function is \( u_{i}(s_{a_{1}},s_{b_{1}}) = b_{j} \), where \( j, k \in \{1,2\} \). If \( b_{j} = -a_{i} \) for any \( j, k \in \{1,2\} \), \( b_{j} \) can be omitted. In certain circumstances, we represent a value of payoff function not as a real number but as some players’ win or loss, and so on. In addition, quantum strategies are permitted any unitary matrices, i.e., we can make a super-

|Bob| Alice \n|---|---|---|
|---|---|---|
|\( s_{a_{1}} \)| \( a_{i_{1}},b_{1} \)| \( a_{i_{2}},b_{12} \)| \( a_{i_{3}},b_{13} \)| \( a_{i_{4}},b_{14} \)|

**Figure 1. Two players’ payoff matrix**

<table>
<thead>
<tr>
<th>Q</th>
<th>Unchanged</th>
<th>Changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Q wins</td>
<td>Q loses</td>
</tr>
<tr>
<td>X</td>
<td>Q wins</td>
<td>Q loses</td>
</tr>
</tbody>
</table>

**Figure 2. PQ penny Flip**
position of some fundamental strategies by quantum strategies.

Now, let us formalize PQ Penny Flip. The set of players is $N = \{\text{Picard}, \text{Q}\}$, the set of Picard’s strategies is $S_p = \{I, X\}$, the set of Q’s strategies is $S_q = \{\text{any unitary matrices}\}$. Operation $I$ means no coin flip, and operation $X$ means a coin flip. The payoff matrix is shown in Figure 2. “Unchanged”/“Changed” means that the state of the coin is finally unchanged/changed. Meyer showed a quantum strategy that $Q$ always wins [4].

Next, we show a simple solution for the Battle of the Sexes using an entangled state. This idea leads to the results of the following subsections. The payoff matrix is shown in Figure 3. Alice prefers movie to soccer, and Bob prefers soccer to movie. However, both prefer having a date.

The strategy is as follows. Alice and Bob share the following entangled state:

$$\frac{1}{\sqrt{2}}(|0,0\rangle + |1,1\rangle),$$

where Alice has a first qubit and Bob has a second qubit. In deciding either soccer or movie, both measure the state. Alice/Bob selects soccer when the outcome of the bit is 0, otherwise she/he selects movie. Note that if Alice’s outcome is 0, Bob’s outcome is also 0, and vice versa. Namely, the probability of selecting (Soccer, Soccer)/(Movie, Movie) is $1/2$, and the probability of selecting (Soccer, Movie)/(Movie, Soccer) is 0. Therefore, they can have a date with certainty. Moreover, for example, if the payoff of (Soccer, Soccer) is $(4,6)$ instead of $(3,5)$, the probability of selecting (Soccer, Soccer) becomes greater than that of (Movie, Movie) by preparing

$$c_1|0,0\rangle + c_2|1,1\rangle$$

as the entangled state, where $c_1, c_2$ is complex numbers satisfying $|c_1|^2 + |c_2|^2 = 1$ and $|c_1| > |c_2|$.  

3.2 $k$-Coin Even-Odd Games

First, we denote a zero-sum game using $k$ coins between two players, $N = \{\text{Alice, Bob}\}$. Throughout this paper, suppose that Alice is constrained to play classically, i.e., $S_p = \{I, X\}$. Then, we show that neither Alice nor Bob can win the game with certainty.

With only classical strategies but Bob can win it with certainty with our quantum strategy. Here, let $H$ and $T$ represent the head and tail of a coin, respectively.

$k$-Coin Even-Odd Check: First, Alice prepares $k$ coins and puts them into a box in the state of all the coins being heads, i.e., $(H, H, \ldots, H)$. Suppose that any player cannot see the inside of the box. Next, Bob flips some coins(or not), Alice flips some coins(or not), and Bob flips some coins(or not). Finally, they open the box. Alice wins if the number of $H$ is odd; otherwise Bob wins if the number of $H$ is even.

Because we can regard this problem as whether Bob can predict Alice’s strategy, the payoff matrix can be also shown as Figure 4. It is obvious that if they use only classical strategies, neither Alice nor Bob can win the game with certainty. However, if Bob uses a quantum strategy, he can win the game with certainty. Now, we show a quantum strategy for this game with which Bob wins with certainty.

Theorem 3.1 For $k$-Coin Even-Odd Check, there exists a quantum strategy with which Bob wins with certainty.

Proof. We denote $H$ and $T$ by $|0\rangle$ and $|1\rangle$, respectively. This means that Alice prepares $|0,0,\ldots,0\rangle$. First, Bob executes the following operation.

$$|0,0,\ldots,0\rangle \rightarrow \frac{1}{\sqrt{2}}(|0,0,\ldots,0\rangle + |1,1,\ldots,1\rangle) \rightarrow \frac{1}{\sqrt{2}}(|0,0,\ldots,0\rangle + |1,1,\ldots,1\rangle)$$

Next, Alice flips the coins using the operations $X$ and $I$, because she can only execute classical strategies. Then, the state becomes

$$\frac{1}{\sqrt{2}}(|b_1,b_2,\ldots,b_k\rangle + |\bar{b}_1,\bar{b}_2,\ldots,\bar{b}_k\rangle),$$

where $b_i \in \{0,1\}$ $(i = 1,2,\ldots,k)$.

Finally, by using Lemma 2.1, Bob obtains

$$\frac{1}{\sqrt{2^k-1}} \sum_{\{c_i\}=0} (-1)^{\sum c_i} |c_1,c_2,\ldots,c_k\rangle.$$

Thus, Bob can obtain the bits $c_1,c_2,\ldots,c_k$ satisfying $\sum_{i=1}^k c_i \equiv 0 \mod 2$. This means that the number of $H$ is even and he can win the game with certainty.

We can prove the same theorem by using the Meyer’s quantum strategy [4] for $k$ coins.
Therefore, we next denote a generalized even-odd game such that Bob cannot win with certainty by using only Meyer’s strategy but can win with certainty with our strategy.

**k-Coin Even-Odd Check(G):** First, Alice prepares \( k \) coins and puts them into a box in the state of \((H,D_2,\ldots, D_k)\), where \( D_i \in \{H,T\} \) \((i = 2, 3, \ldots, k)\). Suppose that any player cannot see the inside of the box and that Bob does not know \( D_i \). Next, Bob flips some coins(or not), Alice flips some coins(or not), and Bob flips some coins(or not). Finally, they open the box. Alice wins if the number of \( H \) is odd; otherwise, Bob wins if the number of \( H \) is even.

The payoff matrix of this problem can be shown as same as Figure 4. Also in this case, it is obvious that if they use classical strategies, neither Alice nor Bob can win the game with certainty. Moreover, because Meyer’s strategy uses the property of:

\[
\frac{1}{\sqrt{2}}(|0\pm|1\rangle) \rightarrow \frac{1}{\sqrt{2}}(|0\pm|1\rangle).
\]

Bob must know the initial state of all the coins in order to win the game. However, if we use our quantum strategy, Bob can win the game with certainty. Now, we show a quantum strategy for this game with which Bob wins with certainty.

**Theorem 3.2** For **k-Coin Even-Odd Check(G)**, there exists a quantum strategy with which Bob wins with certainty.

**Proof.** Also in this case, we denote \( H \) and \( T \) by \(|0\rangle\) and \(|1\rangle\), respectively. Therefore, Alice prepares \(|0, d_2, \ldots, d_k\rangle\), where \( d_i \in \{0,1\} \) \((i = 2, 3, \ldots, k)\). First, Bob executes the following operation:

\[
|0, d_2, \ldots, d_k\rangle \rightarrow \frac{1}{\sqrt{2}}(|0\oplus|1\rangle|d_2, \ldots, d_k\rangle)
\]

Next, Alice flips the coins using the operations \( X \) and \( I \). Then, the state becomes

\[
\frac{1}{\sqrt{2}}(|b_1, b_2, \ldots, b_k\rangle + |\overline{b_1}, \overline{b_2}, \ldots, \overline{b_k}\rangle).
\]

Finally, by using Lemma 2.1, Bob obtains

\[
\frac{1}{\sqrt{2^{k-1}}} \sum_{c_i=0}^{k-1} (-1)^{c_i} |c_1, c_2, \ldots, c_k\rangle.
\]

Thus, Bob can obtain the bits \( c_1, c_2, \ldots, c_k \) satisfying \( \oplus_{i=1}^k c_i = 0 \). This means that the number of \( H \) is even and he can win the game with certainty.

### 3.3 k-Coin Flipping Games

Next, we denote zero-sum games between two players modifying the games in the previous subsection and show that neither Alice nor Bob can win the games with certainty with classical strategies but Bob can win them with certainty with our quantum strategy.

**k-Coin Flip:** First, Alice prepares \( k \) coins and puts them into a box in the state of all the coins being heads, i.e., \((H, H, \ldots, H)\). Suppose that any player cannot see the inside of the box. Next, Bob flips some coins(or not), Alice flips some coins(or not), and Bob flips some coins(or not). Finally, they open the box. Alice wins if the value of \( m \) secret from Bob, and Bob flips some coins(or not). Finally, they open the box. Then, Bob wins if all the coins are in the following state: the state of the coins is \((H, H, \ldots, H)\) if \( m \) is even, or the state of the coins is \((T, H, \ldots, H)\) if \( m \) is odd. Otherwise, Alice wins.

We show the payoff matrix in Figure 5. We can regard also this problem as whether Bob can predict Alice’s strategy. It is obvious that if they use classical strategies, neither Alice nor Bob can win the game with certainty. Moreover, by the same reason in the previous subsection, Bob cannot also win the game with certainty even if Meyer’s strategy is used. However, if Bob uses our quantum strategy, he can win the game with certainty. Now, we show a quantum strategy for this game with which Bob wins with certainty.

**Theorem 3.3** For **k-Coin Flip**, there exists a quantum strategy with which Bob wins with certainty.

**Proof.** Alice prepares \(|0, 0, \ldots, 0\rangle\). First, Bob executes the following operation.

\[
|0, 0, \ldots, 0\rangle \rightarrow \frac{1}{\sqrt{2}}(|0\rangle|0, 0, \ldots, 0\rangle
\]

Next, Alice flips the coins using the operations \( X \) and \( I \). Then, the state becomes

\[
\frac{1}{\sqrt{2}}(|b_1, b_2, \ldots, b_k\rangle + |\overline{b_1}, \overline{b_2}, \ldots, \overline{b_k}\rangle).
\]

Finally, by using Lemma 2.1, Bob obtains

\[
\frac{1}{\sqrt{2^{k-1}}} \sum_{c_i=0}^{k-1} (-1)^{c_i} |c_1, c_2, \ldots, c_k\rangle.
\]

![Figure 5. k-Coin Flip](image-url)
Next, Alice flips $m$ coins using the operation $X$. Then, the state becomes

$$\frac{1}{\sqrt{2}} \sum_{\sum_{i=1}^{k} x_i = m} | c_1 \oplus x_1, c_2 \oplus x_2, \ldots, c_k \oplus x_k \rangle,$$

where $x_i \in \{0,1\}$ ($i = 1, 2, \ldots, k$) and $\sum_{i=1}^{k} x_i = m$.

By using Lemma 2.2, Bob obtains

$$\frac{1}{\sqrt{2}} \left( |0,0,\ldots,0\rangle + (-1)^{\sum_{i=1}^{k} x_i} |1,1,\ldots,1\rangle \right).$$

Moreover, he executes the following operation.

$$H^{\otimes k-1} \sum_{\sum_{i=1}^{k} x_i = m} (-1)^{x_i} | c_1 \oplus x_1, c_2 \oplus x_2, \ldots, c_k \oplus x_k \rangle \rightarrow \sum_{\sum_{i=1}^{k} x_i = m} (-1)^{x_i} | 0,0,\ldots,0\rangle.$$

Then, $\bigoplus_{i=1}^{k} x_i = 0$ if $m$ is even; otherwise $\bigoplus_{i=1}^{k} x_i = 1$ if $m$ is odd. Therefore, Bob can win the game with certainty.

Next, we denote a generalized $k$-coin flipping game.

**$k$-Coin Flip(G):** First, Alice prepares $k$ coins and puts them into a box in the state of (H,D$_2$ , . . . , D$_k$ ), where $D_i \in \{H,T\}$ ($i = 2, 3, \ldots, k$). Suppose that any player cannot see the inside of the box and that Bob does not know $D_i$. Next, Bob flips some coins (or not). Alice flips $m$ coins ($m \in \{0,1,\ldots,k\}$ ) under keeping the value of $m$ secret from Bob, and Bob flips some coins (or not). Finally, they open the box. Then, Bob wins if all the coins are in the following state: the state of the coins is (H,D$_2$ , . . . , D$_k$ ) if $m$ is even, or the state of the coins is (T,D$_2$ , . . . , D$_k$ ) if $m$ is odd. Otherwise Alice wins.

We show the payoff matrix in Figure 6. Also in this case, it is obvious that if they use classical strategies, neither Alice nor Bob can win the game with certainty and that Bob cannot win the game with certainty even if Meyer’s strategy is used. However, if Bob can use our quantum strategy, he wins the game with certainty. If Bob wishes to know only whether $m$ is even or odd, we can easily construct the following protocol.

**Figure 6.** $k$-Coin Flip(G)

<table>
<thead>
<tr>
<th>Alice</th>
<th>Bob</th>
</tr>
</thead>
<tbody>
<tr>
<td>even</td>
<td>Predict even</td>
</tr>
<tr>
<td></td>
<td>Predict odd</td>
</tr>
<tr>
<td>odd</td>
<td>other states</td>
</tr>
</tbody>
</table>

where $d_i, x_i \in \{0,1\}$ ($i = 1, 2, \ldots, k$).

Now, we show a quantum strategy for this game with which Bob wins with certainty.

**Theorem 3.4** For $k$-Coin Flip(G), there exists a quantum strategy with which Bob wins with certainty.

**Proof.** Alice prepares $|0,d_2,\ldots,d_k\rangle$, where $d_i \in \{0,1\}$ ($i = 2, 3, \ldots, k$). First, Bob executes the following operation.

$$|0,d_2,\ldots,d_k\rangle \rightarrow \frac{1}{\sqrt{2}} \left( |0,0,\ldots,0\rangle + |1,1,\ldots,1\rangle \right) |d_2,\ldots,d_k\rangle \rightarrow \sum_{\sum_{i=1}^{k} x_i = m} (-1)^{x_i} | c_1, c_2, \ldots, c_k \rangle,$$

where $d = (0,d_2,\ldots,d_k)$ and $c = (c_1, c_2, \ldots, c_k)$.

Next, Alice flips $m$ coins using the operation $X$. Then, the state becomes

$$\frac{1}{\sqrt{2^{k-1}}} \sum_{\sum_{i=1}^{k} x_i = m} (-1)^{x_i} | c_1 \oplus x_1, c_2 \oplus x_2, \ldots, c_k \oplus x_k \rangle \rightarrow \sum_{\sum_{i=1}^{k} x_i = m} (-1)^{x_i} | 0,0,\ldots,0\rangle.$$

Then, $\bigoplus_{i=1}^{k} x_i = 0$ if $m$ is even; otherwise $\bigoplus_{i=1}^{k} x_i = 1$ if $m$ is odd. Therefore, Bob can win the game with certainty.

Finally, we denote a game combining the Even-Odd game and the Flipping game.
**Extended \( k \)-Coin Flip:** First, Alice prepares \( k \) coins and puts them into a box in the state of all the coins being heads, i.e., \((H, H, \ldots, H)\). Suppose that any player cannot see the inside of the box. Next, Bob flips some coins (or not), Alice flips \( m \) coins (\( m \in N_0 \cup N_1 \)) under the keeping of the value of \( m \) secret from Bob, and Bob flips some coins (or not), where for some positive even number \( C \), \( N_0 = \{ m \mid 0 \leq m \leq k \text{ and } m = Cn \text{ for any integer } n \} \) and \( N_1 = \{ m \mid 0 \leq m \leq k \text{ and } m = C(2n+1)/2 \text{ for any integer } n \} \).

Finally, they open the box. Then, Bob wins if all the coins are in the following state: the number of \( H \) is even if \( m \) is an element in \( N_0 \), or the number of \( H \) is odd if \( m \) is an element in \( N_1 \). Otherwise, Alice wins.

We show the payoff matrix in **Figure 7**, and construct a quantum strategy such that Bob wins with certainty.

**Theorem 3.5** For Extended \( k \)-Coin Flip, there exists a quantum strategy with which Bob wins with certainty.

**Proof.** Alice prepares \(|0,0,...,0\rangle\). First, Bob executes the following operation:

\[
\begin{align*}
N_{\bar{m}}/1 &
\rightarrow \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)|0,0,...,0\rangle \\
S_{(\pi/C)^{-1}} &
\rightarrow \frac{1}{\sqrt{2}}(|0,0,...,0\rangle + |1,1,...,1\rangle) \\
S_{(\pi/C)^{-1}} &
\rightarrow \frac{1}{\sqrt{2}}(|0,0,...,0\rangle + e^{i\pi/C}|1,1,...,1\rangle)
\end{align*}
\]

Next, Alice flips \( m \) coins using the operation \( X \). Then, the state becomes

\[
\frac{1}{\sqrt{2}}(|b_1, b_2, \ldots, b_k\rangle + e^{i\pi/C} |\bar{b}_1, \bar{b}_2, \ldots, \bar{b}_k\rangle),
\]

where \( b_i \in \{0,1\} \) (\( i = 1,2,\ldots,k \)) and \( \sum_{i=1}^k b_i = m \).

Bob applies \( S(\pi/C)^{-1} \) to the state.

\[
\frac{1}{\sqrt{2}}(|b_1, b_2, \ldots, b_k\rangle + e^{i\pi/C} |\bar{b}_1, \bar{b}_2, \ldots, \bar{b}_k\rangle)
\]

\[
\rightarrow \frac{1}{\sqrt{2}}(e^{-i\pi m/C} |b_1, b_2, \ldots, b_k\rangle + e^{i\pi/C} |\bar{b}_1, \bar{b}_2, \ldots, \bar{b}_k\rangle)
\]

\[
= \frac{1}{\sqrt{2}} e^{-i\pi m/C} (|b_1, b_2, \ldots, b_k\rangle + e^{i\pi/C} |\bar{b}_1, \bar{b}_2, \ldots, \bar{b}_k\rangle).
\]

Moreover, by using Lemma 2.1, Bob obtains

\[
\frac{1}{\sqrt{2}^{3-1}} e^{-i\pi m/C} \sum_{0 \leq i \leq n} (-1)^{k-i} |c_1, c_2, \ldots, c_k\rangle
\]

if \( e^{i\pi m/C} = 1 \); otherwise he obtains

\[
\frac{1}{\sqrt{2}^{3-1}} e^{-i\pi m/C} \sum_{0 \leq i \leq n} (-1)^{k-i} |c_1, c_2, \ldots, c_k\rangle
\]

if \( e^{i\pi m/C} = -1 \).

Thus, \( m \) is an element in \( N_0 \) and \( \bigoplus_{i=1}^k c_i = 0 \) if \( e^{i\pi m/C} = 1 \); otherwise \( m \) is an element in \( N_1 \) and \( \bigoplus_{i=1}^k c_i = 1 \) if \( e^{i\pi m/C} = -1 \). Therefore, Bob can win the game with certainty.

When \( C(2n+1)/2 \) is odd, Bob can always win without operating to \( k \) coins. On the other hand, our strategy succeeds even if \( C(2n+1)/2 \) is even.

**4. Applications to Newcomb’s Paradox**

In this section, we study Newcomb’s paradox (Free Will problem) and show some quantum strategies for this problem. A quantum solution of this problem is shown by using Meyer’s quantum strategy by Piotrowski and Sladkowski [18]. We study this problem by using our results in previous section. A problem is as follows:

**Newcomb’s problem:** Let Bob have the ability to predict Alice’s will. Now, Bob prepares two boxes, \( \text{Box}_1 \) and \( \text{Box}_2 \), and Alice can select either \( \text{Box}_1 \) or both boxes. \( \text{Box}_1 \) contains $1. \ (\text{Box}_2 \) contains $1,000 only if Alice selects \( \text{Box}_2 \); otherwise \( \text{Box}_2 \) is empty ($0). Which is better for Alice?

The payoff matrix is shown in **Figure 8**. The focus of this problem is whether Bob can really predict Alice’s will, or whether Bob can control Alice’s will. Obviously, Alice’s strategy is selecting both boxes if Bob cannot predict Alice’s will. Now, we modify this problem as simplified problems. In addition, we observe only strategies on \( \text{Box}_2 \).

**Newcomb1:** First, Alice decides whether she selects either \( \text{Box}_2 \) or not, but Bob cannot know her selection. \( \text{Box}_2 \) contains $1,000 only if Alice selects \( \text{Box}_2 \); otherwise \( \text{Box}_2 \) is empty ($0). Can Bob let Alice select her first will even if Alice changes her will after the first selection?

**Theorem 4.1** For Newcomb1, there exists a quantum strategy that can be positively solved.

**Proof.** Alice selects a state \(|0\rangle\) if she selects \( \text{Box}_2 \); otherwise she selects a state \(|1\rangle\). Note that Bob does not know the state. To this state, Bob applies \( H \), Alice applies \( X \) if she changes her will, and Bob applies \( H \).
nally, the state is $|0\rangle$ if her first selection is Box$_{2}$; otherwise it is $±|1\rangle$. Then, Bob can let Alice select her first will.

This strategy uses Meyer’s strategy. Moreover, we can also show other proofs by using Theorem 3.3 or Theorem 3.4. For Newcomb1, Bob does not permit Alice’s change. Next, by using $k$-Coin Flip(G), we modify this problem to problems such that Bob permits Alice’s change.

**Newcomb2:** Alice prepares $k$ coins and puts them into a box in the state of $(H, D_{2}$,..., $D_{k}$), where $D_{i} \in \{H,T\}$ ($i = 1,2,...,k$). Next, Bob flips some coins(or not), Alice flips $m$ coins($m \in \{0,1,...,k\}$) under keeping the value of $m$ secret from Bob, and Bob flips some coins(or not), where let Alice do not change her will if $m$ is even; otherwise let she change her will. Can Bob know whether $m$ is even or odd?

**Theorem 4.2** For Newcomb2, there exist a quantum strategy that can be positively solved.

**Proof.** This result is immediately obtained by Theorem 3.4.

We can regard this problem as Newcomb’s problem when the value of $m$ is her will, i.e., she selects Box$_{2}$ when $m$ is even; otherwise she selects both boxes. Thus, Bob can predict Alice’s will. We can also modify Newcomb’s problem by using $k$-Coin Flip and Extended $k$-Coin Flip.

Next, we denote that we can also modify Alice’s will in Newcomb2 to $k$-player’s will.

**$k$-Newcomb2:** First, $k$ players, $A_{1}, A_{2},...,A_{k}$, decide whether they selects Box$_{2}$ or not. They prepare $k$ coins and puts them into a box in the state of $(H,D_{2}$,..., $D_{k})$, where $D_{i} \in \{H,T\}$ ($i = 1,2,...,k$), and let player $A_{i}$ ($i \in \{1,2,...,k\}$) deal with the $i$-th coin. Now, Bob flips some coins(or not). Next, each $A_{i}$ ($i \in \{1,2,...,k\}$) flips his/her coin(or not), where let the number of $k$-player’s flips be $m$ ($m \in \{0,1,...,k\}$), and let they do not change their will if $m$ is even; otherwise let they change their will. Finally, Bob flips some coins(or not). Can Bob know whether $m$ is even or odd?

The quantum strategy for Bob is same as Newcomb2.

Finally, we study the Chicken game. The payoff matrix is shown in Figure 9. In the Chicken game, the Nash equilibrium points are (Swerve, Drive straight) and (Drive straight, Swerve). By classical strategies, the probability that each player selects either Swerve or Drive straight is $1/2$. This means that if either (Swerve, Swerve) or (Drive straight, Drive straight) may be selected. On the other hand, by our quantum strategies, either (Swerve, Drive straight) and (Drive straight, Swerve) can be selected with certainty because Bob can predict Alice’s will.

5. Conclusions

In this paper, we proposed quantum strategies with entanglement for $k$-coin flipping games. These games are multi-qubit variations of the quantum strategy by Meyer [4]. One player is constrained to play classically but the other player can use a quantum strategy. We then showed that by using a technique in quantum communication complexity theory, our quantum strategies have an advantage over classical ones. For a player using the quantum strategy, the entanglement is used in order to obtain the information of the enemy and the player can always win the games. Moreover, by rewriting Newcomb’s paradox including multi-player’s will, we also showed that we can use our results as its quantum strategies and that a player can have an ability to predict another player’s will.

Can Bob always win our games even if both players use quantum strategies? This answer is “No”. Meyer also showed that Q cannot always win if Picard can also use a quantum strategy [4]. In the same reason, Bob cannot always win our games if Alice can also use a quantum strategy. Therefore, it is an interesting question whether Bob can always win the games in the case when both players are constrained to only execute some restricted quantum operations.

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A Study of Quantum Strategies for Newcomb’s Paradox


The Research of Knowledge Workers’ Competencies Based on EEG Experiment of Mental Operations

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Received September 12th, 2009; revised October 28th, 2009; accepted December 10th, 2009.

ABSTRACT

The paper analyzes the limitation of the method to study the competencies. The differences between competencies of knowledge workers exist in the “therbligs” used in information process. Based on 191 questionnaires, advance the 9 common mental operations: metacognition, distinguishing, memory, transforming, imagining, character extracting, character integrating, reasoning and concretization. And the metacognition plays a role on planning, supervising and adjusting to the other mind operations. Then the paper designs a mental arithmetic experiment to compare the difference in the brain electric power spectrum and the brain electronic topographic diagram between the subjects of the different performance. And the paper further discusses the feasibility of the method to explore the competencies.

Keywords: Mental Therbligs, EEG, Knowledge Workers, Competencies

1. Introduction

In today’s competitive business world, sustainable competitive advantage is the fundamental factor for organizations to survive. Many organizations have found that the ability of their workforce is the key to gain competitive advantage. For organizations to perform effectively, they need system to assess and develop employee performance against conceptually sound and measurable criteria, because it is necessary for an organization to know whether its people possess the abilities critical for success to adapt to changing demands [1]. An important milestone for clarifying the requirements for successful performance is the competency approach. The set of competencies usually serves as a platform for various HR practice such as performance evaluation, compensation, selection, and training [2].

The study of competency could be traced back to the Taylor’s “motion-time” study. According to the Management Competencies Movement, Taylor became the first scholar who explored the competency systematically. McClelland published the article Testing for Competency rather than Intelligence which indicates the beginning of the modern competency movement.

Today, due to the nature of work shifting into the mental labor, the research on the competency should not depend on the motion-time analysis any more, but turn to job analysis, and should analyze it rationally [3-5].

The competency attracts a lot of interested among the scholars of management, psychology and human resource. And the research could be divided into 3 fields: differential psychology, education and behavior, and organizational psychology [6].

There are two common approaches to competencies: the US approach and the UK approach. Boyatzis, who exemplifies the US approach, define competency broadly as “an underlying characteristics of a person”. It could be a “motive, trait, skill, aspect of one’s self-image or social role, or a body of knowledge which he or she uses”. The UK Government Employment Department defined competencies more broadly. This approach identified the outcome expected from a job when it is performed adequately. Day’s definition of competence “the ability to put skills and knowledge into action” is an apt description of the UK approach.

Folch, Lyon and Trost [10] put forward the focus group session which required the excellent performance employee to retrospect, discuss the duty and requirement of the work, and infer the trend in the future.

Sandberg [11] used the phenomenography to study the competency of engineers in Volvo. Through the interview, he concluded that what kind of competency will be developed is accord with the worker’s own concept of work itself.

Chen [12] uses the text analysis and phone interview to develop the questionnaire of Chinese HR managers’ competency.

Luo [13] used the Delphi to explore the military commander students’ competency.

Comparing the different methods, Zhong [6] concluded, the picture story exercise, focus group session and systematic multiple level observation of groups are the most effective method to study the competency of manager.

In spite of the flourishing popularity of competency research, there exists the limitation as follows:

1) Until now, there is no unified definition of competency [14]. According to Bradley, our ways of thinking and describing competence are “primitive and clumsy”; for all the definitions and articles, “few are certain in their own minds what it means”. As the concept matured, literatures focus specific view of competencies on “knowledge, skills, abilities, or other characteristics (KSAOs) that differentiate high from average performance”.

2) But the researches neglect the basic difference in brain which would directly lead to the difference in performance of knowledge work. Try to explore the competency in neurological view will reveal the basic difference exist in individuals.

The common method to study competency is under skepticism [14]. The validity of “competencies” as measurable constructs appears to be at the core of this controversy [15]. Specifically, the process of deriving competencies requires a rather large inferential leap which is too subjective [2]. For BET, which require the employee to tell the most successful and unsuccessful events, may exist the flash effect. And the employee may just tell the most profound part in their memory which may not be the key factors lead to the performance. And some scholars resort to questionnaire or interview which is also subjective.

Beside the traditional method to investigate the competency, there should be some new methods which should be more objective. And using the neurological method will meet the need.

Our research focus on two hypotheses:

1) The nature of the knowledge work is to use mind operation (MO) to process the information. So we could apply the mind operation to represent the work itself.

2) The difference in competency could be reflected in the speed and efficiency of mind operations which would be reflected in brainwaves.

2. The Confirmatory Research on MO

2.1 The Hypothesis for the Concept Model of the MO

Before classic scientific management, the process of manual movements was a “black box” similar to knowledge tasking. Since Taylor and Gilbreth brought forward the concepts of “basic movement” and “therbligs”, manual processes began the “white box” which can be described and measured. This became the foundation of scientific management. If we describe the process of knowledge task by activities, the inner process of it can turn the “black box” into a “white box”. In cognitive science, the activity is the mental operations.

Knowledge work is a complex, unstructured and knowledge-intensive process that depends on the human cognitive capacity. Knowledge work can be considered as a process that requires knowledge from both internal and external source to generate information-based products.

The knowledge workers process the information as follows: input, process and output. Newell and Simon put forward the classic model as shown in Figure 1.

The processor comprise 3 elements: 1) Elementary information processes, represent, change and compare the symbols; 2) Short memory, keep the basic structure of the symbols; 3) Interpreter, synergize the information and determine the consequence of the information process.

In 1959, Wofac Corporation took the lead to put forward the method of Variable Factor Program (VFP), which studies the brainwork. In 1967, it brought forward Wofac Mento-Fator System (WMFS) based on Pre-determined Motion-Time Study (PMTS). WMFS had determined the task element system which included fourteen elements: sight movement, sight watching, looking, nerve transmitting, distinguishing, estimating, identifying, deciding, remembering, recalling, calculating, confirming, transforming and attention transferring.

Guilford brought forth his “three-dimension” theory of intelligence in 1959. This theory considered that intelligence was a three-dimensional space structure comprised of operations (thinking methods, including five components: cognition, memory, divergent thinking, converge thinking, evaluating) × contents (objects which thinking
operates on: figure, symbol, semantic meaning, action) × results (outcomes when certain operation acts on certain content: cell, kind, relation, system, transform, meanings).

In the middle of the 1970’s, the cognitive revolution began to impact on the research field of intelligence. The most representative research was Sternberg’s Triarchic, “Theory of Human Intelligence” and the PASS theory put forward by Das. Their consensus in intelligence research was a transferring focus from traits analysis to interior process. They depicted the mind mechanism of intelligence operation by way of the cognitive process. They used the process analysis method of information-process, and described the interior process of intellectual activities more quantitatively.

A component was the basic cell of intelligence operation analysis in Sternberg’s Triarchic Theory of Human Intelligence. Sternberg’s thought was that a “component is a type of basic information processing. It operates on the basis of interior representation of objects or symbols. Such a process can transform a sensation input into a concept representation; it also can transform a concept representation into a movement output” [16]. Sternberg divided components into metacomponents, performance components and knowledge-acquisition components. Metacomponent was the highest-level control process. It played a role in constituting plans, choosing strategy, supervising execute, appraising results and adjusting feedback. The performance component was the component that a subject used when he implemented task operations with various strategies. Its function was implementing the dictates of metacognition and carrying out various idiographic cognitive process operations. Some performance components would only be used in a multitude of special tasks. Universal performance components, such as coding, combination and comparing of stimulating, inference etc., gained more attention [16]. Those could be viewed as basic mind operations, or mind operations at the “therblig” level.

In light of the analysis from the view of cognitive psychology, we can regard the process of knowledge task as the process of information symbol transformation [17]. In the view of modern cognitive ergonomics, knowledge task is the reasonable sequence of MO [18].

Using the perspective of the Scientific Management’s process, the analysis of knowledge task process can be thought of being comprised of “a series of” mind operations which are similar to the “basic motions” or “Therbligs”. From the perspective of cognitive science, knowledge task is an operational (transforming) process of the mind on information symbols. The mind’s operation is an algorithm of knowledge tasking (transformative rule). Based on these definitions, the mind’s operation can be viewed as “operational modes of information processing”, while knowledge task process is the set of these information-processing modes (mind operations). We can then present simple manipulative definitions of mind operation concepts on the “therblig” level as follows:

1) Metacognition. Simply speaking, metacognition is cognition and adjustment on cognitive activity processes. It plays a role in constituting plans, choosing strategies, supervising execute, appraising results and adjusting feedback. It is the highest-level control or fountainhead of the following MOs.

2) Distinguishing. The ability to discern and confirm expressive forms of information, every kind of perception, discrimination and recognition. Its meaning is similar to the “cognize” defined by Guilford.

3) Memory. Maintains existing knowledge, searches and memorizes new information.

4) Transforming. Changes the forms of information. For example, transform letter information into table information.

5) Imagining. Changes and transforms images into new one. For example, we read the ancient poetry sentence “Flocks and herds appear as grass bends to wind”; it would appear a beautiful picture in our brain. This is the result of imagination. When we imagine, we all depend on the images already stored in our brain.

6) Character extracting. Breaking down the whole object (cognitive object) into parts and extract the characters of cognitive objects. It has three levels: 1) Action thinking level, such as tearing down the clock’s parts one by one within brain; 2) Imagery thinking level, such as breaking down the image of a tree into roots, branches and leaves; 2) Abstract thinking level, such as disassembling the chemistry equation.

7) Character integrating. Combining the parts of the cognitive objects, i.e., characters, attributes, within the brain. “Character integrating” and “character extracting” are both dialectic mind operations. They also have three levels: 1) Motion thinking level, such as assembling the clock’s parts one by one within the brain; 2) Imagery thinking level, such as synthesizing the image of roots, branches and leaves into a tree within the brain; 3) Abstract thinking level, such as combining and establishing simultaneous equations.

8) Reasoning. Concluding from known or assumptive facts, or inferring a new judgment from one or more known judgments.

9) Concretization. Applying general conclusions to idiographic things; it is a type of deduction.

2.2 The Empirical Study of MO

2.2.1 The Collection and Summary of the Data

We used the questionnaire to collect the data to verify the common mind operations that the knowledge workers will use.

The sources of subjects in this study were students in the following programs: Master of Software Engineering (MSE) in University of Electronic Science and Technol-
The Research of Knowledge Workers’ Competencies Based on EEG Experiment of Mental Operations

The Research of Knowledge Workers’ Competencies Based on EEG Experiment of Mental Operations

The Research of Knowledge Workers’ Competencies Based on EEG Experiment of Mental Operations

The Research of Knowledge Workers’ Competencies Based on EEG Experiment of Mental Operations

2.3 Results and Discussions

The structure of mind operation concepts set is shown in Figure 2 below.

The program chose fit indices as follows: Chi-square ($\chi^2$), NNFI and CFI (critical value is 0.9), RMSEA (critical value is 0.08) [19]. $\chi^2$ goodness-of-fit test is the most often used measure standard about a models degree of total fit. According to the critical values of each index, the data in Table 1 showed that the structural equation model described in Figure 1 fit the observed data; the fit indices were comparatively perfect. In this paper, RMSEA equaled 0.06 and less than 0.08 (RMSEA = 0.06 < 0.08). The absolute index RMSEA weighed the fit degree between the theoretical model and sample data [19]. This indicated that observed data’s ability to interpret knowledge task process with a 9-factors model showed in Figure 2. The nine factors were comprised of metacognition and other eight factors controlled by metacognition.

3. The EEG Study of MO

During the knowledge work, the workers usually use the MOs to process the information. So the difference in the speed and efficiency of the MOs would eventually lead to the difference in performance. We designed the mental arithmetic problem as the experimental materials. Mental arithmetic is a typical knowledge task which needs most basic cognitive functions to be achieved, such as attention, computing, memory et al.

3.1 The Design of the Experiment

Using the 17 inches computer screen to display the problems. The problem appears in the center of the screen. The four choices appear 2 centimeters above bottom. The distance from the eye to the screen is about 40 centimeters. Keep the eye horizontal with the center of the screen and the sight vertical with the screen. 15 college males are as the subjects. All short hair considered the requirement of electroencephalogram. Good eyesight, right handed and without brain damage. Using the EGI system 200 made from American Electrical Geodesics Incorporated to record the data. Through 128 channels to collect sample and the frequency is 500Hz; the NetAmps 200 and 129 lead electrode hat collected the brain electric signal. The precision of reaction time is 0.001sec. The subjects are asked to finish the 10 mental arithmetic problems as 14 digits to add.

3.2 The Result and Analysis

3.2.1 Divided the Subject According to the Reaction Time

Reaction time is a popular index used in experimental psychology. It could measure the activation and restrain of the pallium, and further used to analyze the mental activities, such as sense, attention, learning, thinking etc..

To delete the data that is abnormal and beyond the 3 times standard deviation, and analyze the data by SPSS 15.0, here is the result:

The average reaction time of the quick group is 21292.438 ms; the average reaction time of the slow group is 27776.494 ms. There exist significant difference in reaction time. ($t = 3.407, \ P = 0.009 < 0.05$)

3.2.2 Computed EEG Topography (CET)

Computed EEG Topography (CET) also named as EEG Cartography, Brain Electrical Activity Mapping, EEG Isopotential Mapping. Put the data into matlab2006, and use the toolbox of EEGLAB. Here is the result:

Table 1. Fit indices of MO concept set

<table>
<thead>
<tr>
<th>$\chi^2 / df$</th>
<th>NNFI</th>
<th>IFI</th>
<th>CFI</th>
<th>RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.669</td>
<td>0.916</td>
<td>0.924</td>
<td>0.924</td>
<td>0.0593</td>
</tr>
</tbody>
</table>

by mind operational concept structure showed in Figure 2. The nine factors were comprised of metacognition and other eight factors controlled by metacognition.

Figure 2. Structure of mind operation concepts set

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The brain could be divided into four areas: frontal lobe, parietal lobe, occipital lobe and temporal lobe. And each one is in charge of the specific function: parietal lobe is relevant with the visual processing. Frontal lobe is relevant with the action, direction, computation and discerning. Temporal lobe is relevant with the sound, verbal comprehension and memory. Frontal lobe is relevant with the thinking, concept, the execution of plan and conscientious emotion.

Compare the two group’s CET, we can tell there exist difference in activation of the different brain areas. During the mental arithmetic, most areas were involved. A lot research indicates that during the task with number, the parietal lobe will be activated. The meta analysis of activation images point out that the HIPS (horizontal segment of intraparietal sulus) is the area which represent the number [20]. Our research supports the finding. The difference between the quick and slow group is that the frontal lobe of quick group is activated in higher degree. The frontal lobe connects with the working memory. The different performance in mental arithmetic is probably due to the involvement of the meta-cognition of the working memory.

3.2.3 Brain Electric Power Spectrum Analysis

The electroencephalogram (EEG) during information processing is influenced by specific changes in brain electrical activity. Brain electric power spectrum analysis is one quantitative analysis developed recently. It could reflect the frequency characteristic of brain electrical signals, and also could reflect the density of brain electrical signals. The basis of brain electric power spectrum analysis is power spectrum density (PSD).

We use the EEGLAB and Matlab2006 to further explore the data of electroencephalogram. Compare the common activated area of the two groups, and choose the electrode 37 to be analyzed, the result is shown in Figure 5.

We can tell there exist difference in α (8〜12.8 Hz). The frequency band of quick group is lower than the slow group. A lot of researches indicate the power of α is relevant with the IQ [21,22]. Jausovec [23,24] also indicated that the differences in EEG current density related to intelligence.

4. Conclusions

The essence of knowledge work is the information process. And the process could be represented by 9 common mind operations. The competency difference between the employees could partly be explained as the difference in speed and efficiency of the mind operation. So explore the competency of the knowledge workers in neurological method will help to give the full picture of the competency. And the neurological method also could be more objective to study the competency. And the conclusion will be more convincible. The neurological method has a bright future in the field of economics and management.

REFERENCES


Evolution and Forecasting of Business-Centric Technoeconomics: A Time-Series Pursuit via Digital Ecology

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Received August 18th, 2009; revised October 3rd, 2009; accepted November 19th, 2009.

ABSTRACT

Time-evolution and hence, forecasting the growth profiles of business-centric technoeconomics are ascertained. As an example, the vast telecommunication (telco)-specific business is considered as a complex enterprise depicting a cyber-space of digital ecology (DE) with a backbone of network that supports a host of information sources and destinations facilitating a variety of triple (voice, data and video) services. To specify the temporal trend of evolution of telco economics in a series format, the approach pursued here (and differs from traditional series analyses) takes into account only a selective (and justifiable) set of autoregressive integrated moving average (ARIMA) parameters consistent with the test data. However, this simplified approach yields sufficiently accurate time-series (depicting the business growth) extendable to forecasting regimes. The efficacy of the proposed method is determined via goodness-fit evaluations both in time- and frequency-domains. The data adopted in the computations conform to typical telco service industry.

Keywords: Digital Ecology, Business-Centric Economics, Evolution and Forecasting, ARIMA Modeling, Telecommunication Services

1. Introduction

In modern business world, the plethora of telecommunication (telco) networks and the associated information technology (IT) is comprised of a technological infrastructure supporting streams of voice, data and video (entertainment) data flow plus an economic base that earns revenues as well as incurs capital and operational expenses (CAPEX and OPEX). In this technoeconomic context, the entirety of telco service industry constitutes a complex digital ecology (DE) populated by a set of “digital species” denoting various (tele)-communication entities (information, technology, service options etc.) along with the entirety of computing systems (soft- and hardware), constituents of entertainment media and items of economics. DE is a neo-tmeric perception [1], which can be attributed to the complex system of telecommunications [2].

Within the broad scope of DE, addressed exclusively in this paper are heuristics of business-centric digital ecosystems (such as telco service industry) in ascertaining the temporal trend and seasonal/non-seasonal movements of the underlying technoeconomic parameters (expressed in terms of a time-series representation of the associated data). The approach pursued thereof differs from traditional analyses by considering only a selective set of global moving-average (such as autoregressive integrated moving average or ARIMA) parameters compatible for the test data. The reasons for selective parameter-set usage are justifiably explained.

In spite of the simplified approach (via selective parameter usage), the method indicated yields sufficiently accurate time-series depiction of business growth/evolution compatible for forecasting efforts. The efficacy of the proposed technique is determined via goodness-fit evaluations both in time- and frequency-domains. The data adopted in the computations conform to typical telecommunication (telco) service industry.

2. Technoeconomic Growth Profile

In the context of modern telco service business, modeling the associated growth scenario (viewed in terms of service expansion, revenue growth, customer population etc.) will lead to predicting the survival of the business in the cyberspace of service provisioning implicated by interacting aspects of quality-of-service (QoS) expectations, variety in services (of voice, data and video), competitive deregulated market, government regulations, customer churning, revenue/return-on-investment (RoI) etc..
Given a set of data on technoeconomic evolution, which is invariably nonlinear [3], it is governed by various endogenous and/or exogenous variables; and, a regression analysis of it can be normally performed in order to get a trend curve, which is projected to forecast an estimate of possible values of the dependent variable at any specified value of the dependent variable extrapolated beyond the range over which the regression is performed. This is called trend projection (forward) procedure. Further, forecasting is exercised via exponential smoothing of the trend projection, wherein greater weights to recent observations are prescribed in the time-series.

Considering time-series representation of short-term growth of technoeconomics, often cyclical and/or seasonal variations (specified as what are known as seasonal indices) are seen in the trend projection. In the time-series analysis of long-term business planning issues and decision suite, such seasonal movements and variations should be explicitly included in realistic trend projections toward forecasting (because, the growth of underlying economic features is supposedly centered on such movements and trend details on such movements imply a moving average (MA) of seasonal variations). The associated seasonal indices are decided by annihilation and augmentation of details (technoeconomic information) applied on the growth function dynamics (mostly in random manner); and as such, the growth aspect of the system would exhibit a jagged variation (largely in the initial phase) caused by the (random) interactions of endogenous and/or exogenous entities [3].

The seasonal index indicated above can be defined, for example, in terms of raw data of pertinent economic information across specified periods, (such as quarters of a year). Normally the pattern of time-series is assumed to be stable over the “season” of interest and the seasonal variations presumably follow the baseline trend. Hence, the series of successive moving averages roughly denote the trend as well as cyclic/seasonal elements. Typically, the time-series of economic variation conceived in terms of original/raw observations periodically (say, quarterly) are expressed as MA figures and data-shift components (namely, cyclical, seasonal and irregular (random) entities) [4].

Forecasting time-series typically follows the classical methodology known as X-12 procedure proposed by the US Bureau of Census [5]. It implements the strategy of segregating descriptive components into trend and cyclic movements and leads to evaluating the constants and seasonal indices of time-series data. The underlying procedure eliminates large (as well as small) outliers of the data. It also smoothenes out speckles of non-informative fluctuations. That is, in estimating the parameters via X-12 procedure, relevant seasonal adjustment implies a signal-extraction technique of seasonal movements manifesting as a noise-like feature. Therefore non-informative artifacts have to be suppressed in order to reveal the signal part of interest more explicitly. A practical method that includes such signal extraction procedure is due to Box and Jenkins [6,7], which can be implemented basically by the following steps: 1) Exercising an identification procedure so as to determine whether the time-series can be specified by a combination of MA and autocorrelation terms; 2) using this combination performing an estimation of parameters of a tentative model; and 3) applying a diagnostic test to examine the adequacy of matching between fitted models vis-à-vis raw data.

In general, the technoeconomic growth trend plus the seasonal and non-seasonal variations can be modeled either in an analytical format [3] or in terms of MA series (like ARIMA). In both cases, the task ahead is to formulate a fairly reasonable forecasting strategy. Such economic forecasting refers to the “best estimate” of futuristic projection of an economic entity’s disposition, (its growth or decline) as a function of time. Thus, the purpose of forecasting (an economic entity) should be an insight of certain foreseeable realism rolled ahead with the global uncertainty of associated economics tagging along; (and, for sure it is not just a projection of a set of numbers crunched (into a regression curve) as a futuristic roadmap).

All the aforesaid factors inherently involve the inclusion of buried details in the seasonal and non-seasonal indices across the data set presented as a time-series for eventual forecasting.

3. Statement of the Problem

Commensurate with the modeling objective to realize a systematic and a simplified ARIMA representation of a test technoeconomic data set in describing the time-evolution of the underlying digital economy of real-world telco business, this paper describes a relevant computational effort (by duly including the seasonal and non-seasonal features). In its computational simplicity, the approach indicated uses only a limited number of coefficients (of the time-series). The logistics behind the selection and use of such limited coefficients thereof are identified. Further, the efficacy of the procedure in hand is verified via goodness-fit tests in time- and frequency-domains. Lastly, using the time-series developed, the feasibility of forecasting (in the ex ante regime) of the growth of a test business economics is demonstrated.

4. Method of Approach

In general, the time-series analyses conform to, for example, the so-called airline model due to Box-Jenkins [6] and its variations [7] or, more generally, the seasonal ARIMA models described in [8] by Hillmer and Tiao. The airline model denotes the seasonal ARIMA process.
pertain to the time-series $y_t$ as given by the following lag-polynomial expression:

$$(1-L)(1-L^s)y_t=(1-\theta L)(1-\Theta L^s)\varepsilon_t \quad (1)$$

where $L$ is the time lag (that is, the backshift) operator performing $Ly_t = y_{t-1}$ and $L^s y_t = y_{t-s}$. Here, $\theta$ and $\Theta$ are parameters that characterize respectively the non-seasonal and seasonal moving average (MA) components. The process further, the exponent $s$ (on $L$) depicts the number of observations per year, and $\varepsilon_t$ is a sequence of independent identically distributed (i.i.d.) set of random variables with $E[\varepsilon_t] = 0$, and $E[\varepsilon_t^2] = \sigma^2$.

The airline model is a member of the broader class of seasonal ARIMA models, which generalize the airline model formulation. Conventionally, in the relevant ARIMA pursuits, models are characterized by a set of parameters, namely, \{autoregressive order, number of unit roots, moving average order\} depicted identically as \{(p, d, q); (P, D, Q)s\} and are specified by the following lag polynomial expression:

$$\phi(L)\gamma(L') \left(1-L\right)^d \left(1-L^s\right)y_t = \theta(L)\Theta(L')\varepsilon_t \quad (2)$$

where $L$, $s$, and $\varepsilon_t$ are as in (1), the lag polynomials $\phi(L)$ and $\gamma(L')$ depict non-seasonal and seasonal auto-correlation (AR) filters, with orders $p$ and $P$ respectively. Further, the polynomials $\theta(L)$ and $\Theta(L')$ represent the non-seasonal and seasonal moving-average (MA) components, and are of order $q$ and $Q$ respectively. These polynomials generalize the parameters $\theta$ and $\Theta$ of the airline model in (1). Lastly, $d$ and $D$ denote the orders of non-seasonal and seasonal differencing of the original series $y_t$, respectively.

The airline model of Equation (1) can be obtained from the general formulation in (2) by setting $p=0$, $P=0$, $d=1$, $D=1$, $q=1$ and $Q=1$, that is, it is the seasonal ARIMA model \{(1,1,1); (0, 1, 1)s\}.

There are several alternatives to the airline model addressed in [7] (due to Findley et al.). They include more generalized airline models plus a restricted version known as the 1-12-13, which is used in the present work. It is specified in a convenient form in [9] as follows:

$$(1-L)(1-L^2)y_t = (1-\theta_1 L - \theta_2 L^2 - \theta_{13} L^{13})\varepsilon_t \quad (3)$$

where $\theta_1$, $\theta_2$, and $\theta_{13}$ are the parameters of the model. Note that the airline model defined in Equation (1) corresponds to a restricted version of Equation (3), where $\theta_1 = \theta$, $\theta_2 = \Theta$, and $\theta_{13} = \theta$.

The ARIMA approach currently envisaged (following the Box-Jenkins model) decomposes the series into seasonal and non-seasonal parts and obtains the estimated time-series (which can be extended to forecast regime as well). The goodness-fit of such simplified models is then evaluated by applying some well-known criteria due to Akaike [10,11], and also validated in the frequency-domain [9]. Consideration is also given to the fact that these estimated models can be extended to the forecast regime as well.

5. Proposed Time-Series Analysis

The seasonal ARIMA model of Equation (2) is used to represent seasonal time series in the widely used forecasting software X12 [5] and TSW [12]. For a given data series, these programs can either estimate the coefficients of a given \{(p, d, q); (P, D, Q)s\} model chosen by the analyst, or be requested to choose the “best” seasonal ARIMA model from the set of all possible models. In the latter case the generalized model chosen is the one that shows a better adjustment to the series, when evaluated by a statistical metric such as Akaike Information Criterion (AIC) [10,11].

In typical use, this optimal choice of model is performed for an ensemble of time-series yielding several “best” models, one for each series of the data set. However, a cursory examination of the models chosen and represented by vectors \{(p, d, q); (P, D, Q)s\}, often indicates that the models that appear most frequently in yielding the “best” estimate constitute only a limited subset, as compared to the whole set of possible models. It follows that the analysis can be simplified by giving due consideration only to this restricted subset of “best” models. This selective adoption of models would significantly reduce computational burden that is otherwise imposed.

Hence, it is proposed in this work that it would suffice to identify and use only the models in this limited sense of subsets so as to get a good fit for the estimation. The models in this restricted set are further separated into two subsets of models: One comprises of non-seasonal models; and another of seasonal models. The choice of the subset in the analysis will be made for each time-series on the basis of a test for the presence/absence of the seasonal features.

In addition to the models selected by X12 and TSW, the 1-12-13 model is also included in the present work inasmuch as it is effective in signal extraction efforts as it is evident in the models of economic series pertinent to several case studies tested by Findley et al. [7].

The selective option (of subsets) suggested above should, however, yield consistently an acceptable estimate of time-series that fits to the actual data set, regardless of the vagaries in the business structures to which the data belongs to. Hence, the underlying efficacy of the selective procedure should first be ascertained and confirmed, both time-and frequency-domain analyses. Relevant goodness of the estimation (of the time-series) is decided by the Akaike method [10,11]; and, the goodness-fit in frequency-domain is ascertained by computing the mean Euclidean distance between the actual frequency spectrum of the time-series (obtained via fast Fourier transform).
(FFT)) and the ARIMA-based estimates of the frequency spectrum.

5.1 Model Estimation

Model estimation steps are as follows (Figure 1):

Step 1: (a) The chosen telco economic test series are first transformed by taking logarithms so as to highlight the intrinsic properties of the time-series data. Relevant filtering or data-smoothing partially minimizes the computational burden due to outliers [13]; (b) also, in cases of extreme values typically observed with large amplitude fluctuations in the series [14], the logarithmic transformation smoothens out and stabilizes the variance; and, (c) the calculated mean of the transformed series (obtained as above) is then subtracted leading to “demeaning” of the log-transformed series.

Step 2: (a) The airline model (ARIMA (0, 1, 1) (0, 1, 1)), is fitted to each test time-series in the ensemble data set. When seasonality is present ($\Theta \neq 1$), the models being fitted to the series are chosen from the subset of seasonal models. Alternatively, if seasonality is absent ($\Theta = 1$), then the models are chosen from the subset of non-seasonal models. That is, when $\Theta = 1$ in Equation (1), the seasonal MA term in the right hand side cancels out the seasonal unit-root term in the left hand side, and the ARIMA process becomes a non-seasonal MA(1) process for the differenced series, namely, $(1-L)y_t = (1-\Theta L)\varepsilon_t$; and, (b) this method of identifying the presence of a seasonal unit root is simpler than those traditionally available in the literature (due to Hylleberg et al. [15] and Frances [16] respectively).

Step 3: (a) Next the ensemble of time-series test-data is subjected to ARIMA modeling using the X12 [13] and TSW [19] programs so as to decide on the “best” model for each series; and, (b) from the collection of such optimally-decided ARIMA models, only a limited (five) subset (indicated as Models II, III, IV, VI, and VII in Figure 1) is chosen for subsequent use. The choice of five in the present study conforms to a set of two models having a seasonal unit root, and another set of three models that do not have a seasonal unit root. Additionally, the 1-12-13 model is also used (and designated as Model V in Figure 1).

Step 4: In this step, the ARIMA coefficients of the test-series for the models selected above are estimated. Relevant computation is done using the WinRats-7 time-series analysis software [17,18]. Models (in Step 3) with D=0 signify series that do not have a seasonal unit root, while models with D $\neq 0$ are for series that do have a seasonal unit root.

Step 5: In the time-domain, the goodness-fit of the estimation is evaluated by comparing the raw time-series (log-formatted and demeaned) with the time-series constructed with parameters obtained. The models fitted thereof should have a good adherence to actual time-domain data for any forecasting applications. The evaluation of the fit used here is based on the AIC of the Akaike method [10,11].

The frequency-domain goodness-fit of the model is evaluated by comparing the spectrum of the raw time-series to the frequency-spectrum of the corresponding ARIMA representation [19]. The spectrum of the raw data corresponds to the FFT transform of the given (raw) series, and the ARIMA-estimated spectrum is synthesized from the coefficients obtained. The fitted model should have a significant closeness to the raw data spectrum. Relevant evaluation is based on the calculation of an index equal to the sum over all frequencies of the absolute Euclidean distance between the FFT of the raw signal ARIMA-estimated spectrum.

5.2 Time-Domain Analysis

The test models are evaluated for their efficacy in time-domain in terms of the AIC. The lowest value of AIC indicates the “best estimate”. Specifically adopted in WinRats-7 software [17,18] is the formula for AIC given by: $AIC = [\ln (RSS) / T] + 2n / T$, where T is the number of

Figure 1. Flow-chart for the proposed estimation of ARIMA coefficients. (*Model V: corresponds to the 1-12-13 model of [7] where the set [{p, d, q}; (P, D, Q)] is not used)
of observations along the time scale, \( n \) is the number of parameters estimated, and \( \text{RSS} \) is the residual sum-squared value, which refers to the sum of squared differences between the series, \( y_t \), and its projected value, \( \hat{y}_t \). That is, \( \text{RSS} = \sum_{t=0}^{T} (y_t - \hat{y}_t)^2 \).

The calculations above are done for each of the test raw series, with an appropriate model (out of the seven indicated earlier). This is denoted by indexing the statistics as \( \text{AIC}_{i,m} \), where the subscripts \( i \) and \( m \) correspond to the raw series (\( i=1, 2, ..., I \)) and the model (\( m=1, 2, ..., M=7 \)) respectively. The index of average performance of (each model) in the time-domain can be calculated as the average \( \text{AIC} \) over all series fitted with that model. That is, \( \text{AIC}_{(iM)} = \frac{1}{I} \sum_{i=1}^{I} \text{AIC}_{i,m} \).

The test models of each category (with and without the seasonal unit root), is then compared in the time-domain on the basis of their average \( \text{AIC} \). The goodness-fit in the time-domain can also be evaluated by comparing the plots of actual raw series (in log-demeaned format) and the corresponding series predicted by the ARIMA model, and also by evaluating the forecasting performance (each model) in the time-domain can be calculated as the average \( \text{AIC} \) over all series fitted with that model. That is, \( \text{RSS}(y_t) = \sum_{t=0}^{T} (y_t - \hat{y}_t)^2 \).

5.3 Frequency-Domain Analysis

For a given test series, the discrete spectrum is evaluated at (discrete) frequencies (given by \( \omega = (2\pi/T)k \), where \( k = 1, 2, ..., T \)) via Discrete Fourier Transform (DFT), namely, \( F_i = \text{FFT}[\{(2\pi/T)k\}] \). The ARIMA-estimated power spectrum density \( S_k \) is the square of the norm of the aforementioned discrete frequency response, given by: \( S_k = |F_k|^2 \).

In order to compare the test models (Models I, etc.) of the present study, a statistical measure depicting the difference between them is indicated as the mean absolute deviation (MAD), which is calculated as follows:

\[
\text{MAD} = \sum_{k=1}^{T} |S_k - G_k| 
\]  

(4)

where \( G_k \) is the power spectrum density (PSD) of the data computed via Fast Fourier Transform (FFT) and \( S_k \), respectively. (Both \( G_k \) and \( S_k \) are expressed in dB). Further, the values of \( k \) corresponding to the seasonal frequencies are not included in the summation of Equation (9). Lastly, by indexing MAD as \( \text{MAD}_{i,m} \), with the subscripts \( i = (1, 2, 3, ..., I) \) and \( m = (1, 2, 3, ..., M) \) each of the test series and the models is respectively designated. The average performance of each model in the frequency domain can be calculated by considering the average of all MAD values over the series fitted. That is, \( \text{MAD}_{i,m} = \frac{1}{I} \sum_{i=1}^{I} \text{MAD}_{i,m} \), where \( I = 8 \) is the total number of series that are fitted with model \( m \). Thus, the models of each category, (with and without seasonal unit root), can be compared in the frequency-domain on the basis of average MAD.

5.4 Combined Time- and Frequency-domain Analyses

The indicators of the performance via AIC and MAD in time- and frequency-domains (defined by Equations (4) and (10) respectively) can be linearly rescaled (normalized) between 0 and 1 and are denoted \( \text{AIC}_{(iM)} \) and \( \text{MAD}_{i,m} \). For either of these indices, the best performance corresponds to a value tending to zero, because it indicates the minimum absolute deviation in the time- and frequency-domains; and, a value of the indices tending to unity would correspond to the worst performance because it implies the largest deviation of the models selected over the series in the data set. Lastly, the two indices as above can be combined by their arithmetic average to produce an index of overall performance of each model. That is, \( \text{IDX}_{i,m} = (\text{AIC}_{(iM)} + \text{MAD}_{i,m})/2 \).

5.5 Merits of the Proposed Approach

The novelty of the proposed efforts can be observed by comparing the underlying considerations with those of existing methods. For example, the efforts in Hyndman et al. [20] do not include an upfront assertion as regards to knowing whether the data contains seasonal variations or not; and if the outcome on the computed time-series fail to give results to an expected level of accuracy, then the computation is redone (with the inclusion of seasonal attributes). Further, their computations refer only to a time-domain exercise with eventual goodness-fit done only in the time-domain. However, the goodness-fit of the series is verified in the present study, both in time- as well as in frequency-domain; hence it is more comprehensive in ascertaining the goodness-fit.

The present approach significantly pursues and extends the efforts due to Findley et al. [7] on the economic series pertinent to non-telco macroeconomic data. However, the differences in the levels of such estimations (in terms of accuracy) are not easily discernible because the seasonal component present is usually small in amplitude. Further evaluated in [9] is the efficacy of the generalized models in the frequency-domain with the introduction of a canonical seasonal adjustment filter, but without the adoption of a goodness-of-fit index done in the present approach.

According to [21], the simplified pre-selected use of a limited number of models was employed in pre-2000 versions of X12, but not in its current version [5]. The
convenience of simplifying the models chosen by the automatic choice feature of the current version of X12 is indicated in [22], but has not been implemented.

6. Proposed Methodology: Implementation

In view of the above considerations and in concurrence with the views of Findley et al. [7], the present research is directed in applying the proposed method to the time evolutionary profiles of service growth data of modern telco enterprises. Essentially, the research effort pursued uses the available data specified in an ex post regime and the ex ante details of the technoeconomic growth are obtained. Determination of ex ante profile leads to forecasting feasibilities.

6.1 Description of the Telco Test Data

Few sets of seasonal data on telco services are readily available in the literature. From the published work, eight test time-series data (whose names and mnemonics are given in Table 1) are chosen as follows:

Table 1. Description of telco series (# T1 to # T8) test data

<table>
<thead>
<tr>
<th>Series</th>
<th>Mnemonic</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td># T1</td>
<td>INWARD</td>
<td>Number of inward calls from telephone exchange in Wisconsin</td>
</tr>
<tr>
<td># T2</td>
<td>OUTWARD</td>
<td>Number of outward calls into telephone exchange in Wisconsin</td>
</tr>
<tr>
<td># T3</td>
<td>NATIONAL</td>
<td>Number of national outward calls from university campus</td>
</tr>
<tr>
<td># T4</td>
<td>MOBILE</td>
<td>Number of mobile outward calls from university campus</td>
</tr>
<tr>
<td># T5</td>
<td>INTERNAT</td>
<td>Number of international outward calls from university campus</td>
</tr>
<tr>
<td># T6</td>
<td>N2806</td>
<td>Telecom series number 2806 of M3 IIF forecasting competition</td>
</tr>
<tr>
<td># T7</td>
<td>N2817</td>
<td>Telecom series number 2806 of M3 IIF forecasting competition</td>
</tr>
<tr>
<td># T8</td>
<td>N2822</td>
<td>Telecom series number 2806 of M3 IIF forecasting competition</td>
</tr>
</tbody>
</table>

The two first Series (#T1 and #T2) report the number of incoming and outgoing telephone calls in an exchange of the Wisconsin Telephone Company, as reported by Thompson and Tiao [23]. This data has often been used to test telecommunications load forecasting models as, for example, by Madden et al. [24]. The test series considered display marked seasonal features, as well as clear technoeconomic time-trends.

The next three series (#T3 to #T5) refer to the number of outgoing calls of three types (national, mobile, and international) gathered at a university campus over a period of six years, and are available in [25].

The remaining three Series (#T6 to #T8) are from the dataset relevant to telco services and produced by the Institute of Forecasters for the M3 competition [26,27]. No explicit details on the underlying telco services are indicated in the data sources. They are simply identified by the codes N2806, N2817 and N2822 for those series [26]. A cursory examination of Figure 2, that displays the demeaned log transformed series, obtained as described earlier, indicates that telco Series # T2 to # T5 seem to exhibit a seasonal behavior, with the possible exception of 3, which displays irregular peaks and valleys. Series # T1, # T2 and # T4 have a clear time-trend, while the other seasonal series do not. The series # T6 to # T8, (extracted from the M3 IIF competition database), do not however, show any obvious seasonality et al. Series # T7 and # T8 have negative time trend, while Series # T6 has a peculiar behavior, namely, it is stable for the first 2 years, and then displays a “hump” in the last four years.

6.2 Selection of Models (I, II, ..., VII)

In the seasonal ARIMA framework used here, the temporal trend is captured by the non-seasonal ARIMA parameters, while the seasonal ARIMA parameters capture the recurring time pattern. Consistent with this observation, both X12 and TSW programs choose as the “best” models for series 1 to 4 of the non-telco dataset those without a seasonal unit root with the vectors (1,1,1), (0,1,1) and (1,1,2) most frequently appearing in the non-seasonal part of these models. As such, these vectors are chosen as the non-seasonal specification of the Models II, III and IV and the seasonal part of those models is chosen as (0,0,0).

In all the chosen models, the seasonal part is seen to be the same as that of the airline model. Therefore, Models VI and VII, which have a seasonal unit root, also bear the same seasonal specification. For the non-seasonal part of these models, the vectors that appear most frequently are (1, 1, 2) and (2, 1, 1), and are therefore chosen as the non-seasonal specification of the Models VI and VII respectively.

6.3 Estimation of Seasonal ARIMA Coefficients

Consistent with Figure 1, first the procedures of
log-transforming in demeaned format of the test data ensembles are performed. Then, the ARIMA coefficient estimation procedure of Model I (the airline model) is applied to the series and tested for the presence/absence of a seasonal unit root. Next, the ARIMA coefficients of the pertinent models are estimated with the software WinRats-7\(^{17,18}\).

The pseudocode of the procedure as above is presented Table 2. (The Box-Jenkins command is used with the option that allows for maximum-likelihood estimation because it enables more precise estimation than the alternative least-squares option).

### 6.4 Raw Data versus Estimated Models in Time-Domain

This section discusses the fitted and the original series in the time-domain making use of Series \#T1 of the telco dataset as shown in Figure 3. A qualitative observation shows that for the test series, not only the airline model, but also its generalized versions appear to offer a good adherence to the raw data (inasmuch as no large deviations are observed across the broad stretches of their graphs). A small difference between the graphs of the different models is however, observed for the other series of the dataset but within limits of acceptability of the goodness fit in the time-domain.

For quantitative model comparison, an indicator such as the quadratic-error adjusted for the different number of degrees of freedom encountered in different models, is needed. Hence, AIC mentioned earlier is used.

Another important dimension of goodness-of-fit in the time-domain refers to the forecasting performance. For this evaluation, the models of the series (of the telco database) are re-estimated excluding the end-section of nine months, respectively. With this exclusion, the data is considered as \textit{ex post} data. And the forecasting is done in the period of last nine months taken as the \textit{ex ante} regime. The forecast result is compared against the excluded data points. Relevant examples of such comparison are shown in Figure 4. They show a good forecasting performance of the estimated models.

### 6.5 Comparison of RAW Data and Estimated Models in the Frequency-Domain

Figure 5 shows the one-sided frequency-spectrum of the (demeaned and log-formatted) test series of telco data ensembles. These are obtained by calculating the discrete Fourier transform. The computation is performed through the FFT subroutine of MatLab\(^{TM}\). Examination of Figure 5 confirms the presence of seasonality, seen as peaks. The spectra of telco correspond to Series \# (T1-T5). With the seasonal unit root ascertained, each series is conformed to an appropriate model designated earlier (as Models I to VII). The ARIMA-estimated spectrum is constructed for each series, and compared against the FFT-estimated spectrum. Examples of such comparisons are shown in Figure 6 for series \#T1 of the telco dataset. The spectrum estimated by the airline model as well as the one estimated by the best extended airline model, are displayed.

In the estimated spectrum, the peaks occur at the frequencies that correspond to discrete locales (cycles per year) of the seasonal roots in the ARIMA models (I through VII), at the monthly, bi-monthly, quarterly, 4-month, half-year and yearly frequency. Only six peaks, rather than 12, appear in Figure 6 because they display the half-spectrum of the full spectrum symmetry.

As in the quarterly seasonal model above, there is also a peak at the zero frequency corresponding to the non-seasonal unit root. To a large extent, the models studies lead to estimated spectra that closely approximate the actual data spectra reproducing most of the peaks as in Figure 5. However, the symmetric nature of the unit roots in the seasonal ARIMA model imposes peaks at all integer seasonal frequencies, while the actual data do not display them for some frequencies. Also, in some cases, a peak exists in the actual spectrum for some frequencies, but does not have the intensity prescribed by the seasonal ARIMA model.

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*Figure 3. Actual and fitted values for demeaned and log-transformed data set of telco Series \# T1 (E\(_v\): Economic variable of interest normalized). (Note: The actual time-series data is shown as A and the computed model time-series data are indicated as B and C, which appear almost overlapping for the models pursued)*

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*Figure 4. Actual and fitted values for demeaned and log-transformed data set of telco Series \# T1 (E\(_v\): Economic variable of interest normalized). (Note: The actual time-series data is shown as A and the computed model time-series data are indicated as B and C, which appear almost overlapping for the models pursued)*

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*Figure 5. Actual and fitted values for demeaned and log-transformed data set of telco Series \# T1 (E\(_v\): Economic variable of interest normalized). (Note: The actual time-series data is shown as A and the computed model time-series data are indicated as B and C, which appear almost overlapping for the models pursued)*
Figure 4. Time-series estimation in the forecast (ex ante) regime denoted as FR (3-steps ahead of last 9 months forecast based on demeaned log-transformed telco Series #T1 data). The forecast regime FR is shown with grey background expanded for clarity. (a) depicts Model 2: (1, 1, 1) (0, 0, 0) and (b) denotes Model 4: (1, 1, 2) (0, 0, 1). (E_v: Economic variable of interest normalized).

Figure 5. One-sided frequency spectrum: Demeaned and log-formatted telco series. (The encircled regimes denote some samples of explicit seasonal peaks)

6.6 Overall Performance with AIC and MAD

The relative values of AIC and MAD indices are presented in Figure 7 for telco datasets. In general, they show that the lowest value of the AIC (that indicates the best fit in the time-domain) is not necessarily compatible to the lowest value for the MAD index (depicting the best fit in the frequency-domain). Hence, an aggregation index can be specified by taking the mean of AIC and MAD indices as the overall goodness fit indicator in time- and frequency-domains.

Figure 7 shows, for example, that model VII namely, ARIMA (2, 1, 1) (0, 1, 1) is the best overall model for the Series # T1 and # T5 of the telco data set. In Figure 14, it can be observed that some series do not have values of AIC or MAD indices displayed for some models. This indicates that the estimation procedure does not converge for those cases. For example, it can be seen in Figure 14 Findley’s 1-12-13 model referred to Model 5 has not converged for any of the series in the telco dataset (that have a unit root).

7. Concluding Remarks

Telecommunications is viewed as a part of digital ecology with its underlying technoeconomics is analyzed via evolution considerations in terms of time-series. Hence, consistent with relevant procedure described in this paper, the following can be stated as closing remarks:

A simplified ARIMA-based time-series modeling of technoeconomic evolution in telecommunications (that display seasonal features) is feasible via the approach.
summarized as follows:

- A decision hypothesis is first projected to declare whether the data set is seasonal or not via the Box-Jenkins airline model. This avoids the complexity of pursuing computation with seasonal variation implications when seasonal attributes are absent. The use of the airline model for this purpose to the best of the authors’ knowledge is novel.
- The ARIMA-type models that characterize the seasonal and non-seasonal aspects of the time-series model are selected. The assertion above on the existence of seasonal and non-seasonal components leads to choosing the models to be estimated for the time-series from within two possible sets of models.
- In order to test the efficacy of the proposed methodology and to choose the “best” model, a comparison of estimated models versus real data is done in time- and frequency-domains. The criteria correspond to Akaike Information Criterion (AIC) and mean absolute deviation (MAD) metrics, respectively. They provide a dual assertion on the goodness-fit of the models for the time-series being evaluated. An aggregation index is specified by taking the mean of AIC and MAD indices to indicate the overall goodness-of-fit.

The usefulness of the proposed approach is ascertained in the present study by applying it to a diverse ensemble of time-series data of typical telco technoeconomics. The fitted models are compared with raw data in the time- and frequency-domains and their performance is assessed both in heuristic and quantitative terms summarized below:

- Examples of the heuristic assessment in both domains correspond to the inspection of graphs comparing the time-evolutions of the fitted and original series, and figures comparing the actual and fitted frequency spectra of some of the test series. The models as chosen in this study provide a good fit for the data in both domains.
- Quantitatively assessment of AIC, MAD and their average confirms the selected model-based results offer good adherence to the raw data.
- The estimated models also lead to a good forecasting performance assessment for the test data.

In short, claimed here is that the proposed approach is computationally simple, enables an assured convergence of the series (regardless of the data set being intense or sparse) and the goodness fit of the estimation conforms to an acceptable extent both in time- and frequency domains. The efficacy of the proposal is demonstrated with real-world data sets concerning telco economics. Thus, the evolutionary aspect of a digital ecosystem is comprehended via time-series approach.

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Building Inter-Organizational Social Capital Instruments to Evaluate Collaborative Networks

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Received October 20th, 2009; revised November 29th, 2009; accepted December 30th, 2009.

ABSTRACT

This paper presents the development process of an inter-organizational social capital survey to evaluate collaborative networks. The survey instrument construction was based on three main sources. The first one, was a deep literature research that covered social capital and collaborative network issues. The second, a meta-analysis from well-known journals basically taken from the Business Source Premier Database. Finally, the third, was an exploratory research done in a Brazilian enterprise collaborative network. In this exploratory phase, we used semi-structured interviews, direct observation and document analysis. As a result of this work, we present two instruments for inter-organizational social capital evaluation: a qualitative instrument, built in the first stage of the study and a quantitative instrument (survey) built from the results of the exploratory phase.

Keywords: Interorganizational Social Capital, Collaborative Networks, Qualitative Instrument, Survey Instrument, Brazil

1. Introduction

In the south of Brazil, micro and small businesses represent 94.9% of formal businesses, occupying about 63% of jobs [1]. In most cases, these small companies, because of their size, face many difficulties because they do not have competitive skills and resources. In this sense, it is important to create mechanisms to enhance their development and consequently the development of the region.

Considered as one of the emerging forms of management, collaboration between competitors can happen in different ways. The focus of this work is in cooperation through collaborative networks. The initiative for studies on these new forms of management is more significant in the European Community, where there are several projects, among them the ECOLEAD (European Collaborative Networked Organizations Leadership Initiative), projects such as the German and Swiss Virtuelle Fabrik, in Portugal there are the TeleCare (Tele-Supervision System for Elderly Care), the PRODNET-II (Production Planning and Management in the Extended Enterprise) and COVE (Cooperation Infrastructure for Virtual Enterprises and Electronic Business). In France there is the project ATHENA (Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and Applications) and in England the project EC-NET (Concurrent Enterprising Network of Excellence).

There are also important research and projects in this area outside Europe. Some examples are the American NIIIP (National Industrial Information Infrastructure Protocols), the Japanese Industrial Cluster (Japan) and the project Virtual Industry Cluster (Mexico). In Brazil, three major projects in the area may be cited: the VIRTEC, the Millennium Factory Institute (IFM) and the VIRFEBRAS, object of study of this paper.

At the University of Caxias do Sul (Serra Gaucha region, south of Brazil), two research groups may be related to the theme of social capital within a collaborative network: the “Enterprise Collaborative Networks Group” and the “Organizational Social Theory Group”, in which research includes social capital, social responsibility and local development. Both groups are registered in the National Council for Scientific and Technological Development (CNPq), in Brazil.

This work aims to build an instrument (survey) to evaluate inter-organizational social capital within a collaborative network. To achieve this main purpose, we did a preliminary (exploratory) research in an enterprise collaborative network in VIRFEBRAS network. In this exploratory phase, we used semi-structured interviews, direct observation and document analysis. We analyzed the social capital elements that influence the dynamics of the network and identified the local aspects related to the network competitiveness. So, it was possible to raise
variables to build the survey instrument.

2. Social Capital

Social capital can be understood as a set of informal norms and values, common to the members of a specific group which allow the cooperation among them.

Since the concept of Social Capital emerged, it is being used to explain a lot of social phenomena; most of the researches have focused on the role of Social Capital in the human capital development [2,3], in the economic performance [4], in the development of regions [5] and in the development of countries [6].

In the study that relates capital to the creation of intellectual capital, Nahapiet and Ghoshal [7] propose three macro-dimensions of social capital: the structural, the relational and cognitive. For these authors social capital is the “sum of the actual and potential resources embedded within, available through and derived from the network of relationship possessed by an individual or social unit” [7].

Although they have made the analytical separation of the capital in three dimensions, the authors believe that there is a relationship between the great traits in each of them. The principal elements of each dimension are presented in Figure 1.

The structural dimension of Social Capital is related to: the presence or not of relationships between the actors, the configuration or morphology of the network describing the standards of connections through variables such as density, connectivity network configuration, stability and ties. The relational dimension describes the kind of personal relationship developed through a history of interactions. This concept focuses on aspects that influence behaviors as: trust and distrust, norms, obligations and expectations and identity. Finally, the cognitive dimension of social capital refers to the resources that emanate shared visions, interpretations and systems of meaning, mainly codes and narratives shared, values, and other cultural elements. Some authors affirm that this dimension is not being explored in the literature [7].

3. VIRFEBRAS: A Collaborative Network

The establishment of cooperation between competitors can bring more benefits than confrontation if goals, interests and limits were defined in the early collaboration process. The goals may be different, some examples are: the development of products in search of suppliers, new markets, new technologies, the empowerment of people, etc. The interests may differ even between companies within the network [8].

This work has focused on emerging forms of cooperation, such forms are called collaborative networks that consists in entities (people and organizations) autonomous, geographically distributed and heterogeneous with respect to its environment of operation, their culture, their goals and their capital [9].

The VIRFEBRAS is a group of small and medium enterprises of the sector of industrial tools that work in combination with common goals while maintaining their own identities. Nowadays, seven companies are part of this network: Metallurgical Coprima LTDA, JR Oliveira, CJN Industry LTDA of Matrices, Matrices Sadel LTDA, Sildre, Inova Matrices and Roltex Polishing and Texturing Ltda. The idea of this association appeared in 1998 with the support of the Department of Mechanical Engineering (DEMC), of the University of Caxias do Sul (UCS).

In the exploratory phase we developed a qualitative instrument that was applied in nine companies—six members of VIRFEBRAS and three ex-members. The interviews had the following questions (see Figure 2).

In the content analysis, three main aspects can be highlighted. The first is a kind of lack of leadership, which was identified as a problem for all companies, participants and ex-participants. The social capital theory states that the horizontal relationships should be receive more attention, but, on the other hand, some networks can suffer from not having a more proactive member that feels responsibly for solving problems and promoting essential changes. Most networks in the Cooperation Network Program have the universities covering this lack.

The second aspect is a problem of network identity. In the specific case of VIRFEBRAS, an aspect related to this lack is that they do not have a physical place belonging to the network: the members had meetings in a different place each time (member’s head office). One way to face this problem could be creating a community of practice, which allows to share and learn from each other by physical contact or virtual, with a goal or need to solve problems, share experiences, techniques or methodologies, to consider the provision of best practice [10].

The third and last point concerns the information exchanges. It is common for a network to find difficulties in sharing equally technical, human and conceptual skills (Katz [11] classifies business skills in these three categories). In most cases, one kind of skill is more shared than the others, like it happens in VIRFEBRAS, where most part of the information exchanged is technical.
After content analysis, we used the software NVivo 8 to generate items of inter-organizational social capital. One of the tools we adopted was a matrix to verify the simultaneous occurrence of elements cited (see Figure 3).

Thus, the pairs of concepts that appear most in the interviews in VIRFEBRAS are: 1) “technical skills” and “technical information exchange”, cited in six of the nine respondents; 2) “technical skills” and “time dedicated to the network, both cited in five of the nine interviews; and 3) “technical skills” and “leadership”, cited in five of the nine interviews.

Therefore, the inter-organizational social capital survey was built in three sources. The first derived from literature review, specially the World Bank framework [12] and the Onyx and Bullen [13] instrument. The second source was a meta-analysis performed by Vallejos et al. [14], which emphasizes that the issue of social capital in the CN context is lack explored (although the word “trust” appears most of the time, it is related as an isolated concept and not as an element of social capital). And the third, was the qualitative research conducted in VIRFEBRAS.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Tell a story about a business process carried out by your company within the Network.</td>
<td></td>
</tr>
<tr>
<td>2 - What issues do you believe facilitate network collaboration?</td>
<td></td>
</tr>
<tr>
<td>3 - What issues do you believe undermine network collaboration?</td>
<td></td>
</tr>
<tr>
<td>4 - How do you think the cooperation in a network should be?</td>
<td></td>
</tr>
<tr>
<td>5 - Do you believe that NETWORK should be redesigned? What elements do you believe are essential to this restructuring?</td>
<td></td>
</tr>
<tr>
<td>6 - A client offers your company a very favorable contract, involving significant profits for a long time, but you do not have capacity to meet the demands of this customer alone. Point out the name of three companies you would choose to work with you and comment the reasons for these choices.</td>
<td></td>
</tr>
<tr>
<td>7 - Has your company already asked for a help in the NETWORK?</td>
<td></td>
</tr>
<tr>
<td>8 - Are there rules for conducting of the business processes within the NETWORK?</td>
<td></td>
</tr>
<tr>
<td>9 - Point out some characteristics you think you have in common with other members of the NETWORK</td>
<td></td>
</tr>
<tr>
<td>10 - Why have the ex-participants of VIRFEBRAS leave the association? (in the case of interviewing ex-participants: Why did your company decide to leave the Network?)</td>
<td></td>
</tr>
<tr>
<td>11 - In your opinion, what made the ex-participants leave the NETWORK?</td>
<td></td>
</tr>
<tr>
<td>12 - Do you share experiences (about market, staff, customers, suppliers) with other members?</td>
<td></td>
</tr>
<tr>
<td>13 - Speak about one important experience you had in the NETWORK.</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2. Qualitative instrument to evaluate inter-organizational social capital**

**Figure 3. Matrix of elements in the exploratory phase**

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### Items of Social Capital Dimensions and Competitiveness in Inter-Organizational Environment

#### Cognitive Dimension
- Most members know and agree with the objective of the NETWORK.
- The objective of the NETWORK is also clear to those not participating in the network.
- I participate in the NETWORK because I agree with the purpose for which it was created.
- The members of the NETWORK always share information with others.
- Most people in the NETWORK are reliable.
- When I need help, I can count on other members of the NETWORK.
- Within the NETWORK you need to be aware that no one takes advantage of the situation.
- The government would not take an attitude that harms my business.
- In the formal activities of the NETWORK, I feel part of a group.
- I feel a member of the NETWORK.
- The similarities between participants facilitate the dynamics of the NETWORK.
- The differences within the group do not affect the NETWORK.
- The members of the NETWORK always seek to work together through ideas, resources and information.
- Within the NETWORK, the members think and act in accordance with the interests of all.
- Even if my opinion is contrary to most other members of the NETWORK, I feel comfortable to discuss it.
- The more the different ideas within the NETWORK, the better it becomes.
- If I need some information for a decision, I know where to find on the NETWORK.
- Within the NETWORK there are several opportunities to exchange information.
- The NETWORK is connected to other entities, as other networks of businesses, unions, government agencies, among others.
- The NETWORK has a hierarchical structure (president, directors and other members).
- I have contact with members of the NETWORK at least once a week.
- I also have contact with members of the NETWORK outside the formal activities of the same.
- I consider the members of the NETWORK my friends.

#### Relational Dimension
- Within the NETWORK there are different types of skills such as technical, managerial and social competencies;
- When a problem occurs within the network, the members work together to solve it;
- If there is a problem in the company of one of the members, others work with him to solve the problem;
- The leadership of the Network respects the views of all;
- The activities of the network are aligned with the main objective;
- Most members of the network have capacity to be leaders;
- If there is a conflict between members of the network, I offer myself to mediate;
- I feel motivated to participate in the network;
- The members of the network are encouraged to propose ideas for change;
- The members are responsible for bringing new business opportunities for the network.

#### Structural Dimension
- If I need some information for a decision, I know where to find on the NETWORK.
- Within the NETWORK there are several opportunities to exchange information.
- The NETWORK is connected to other entities, as other networks of businesses, unions, government agencies, among others.
- The NETWORK has a hierarchical structure (president, directors and other members).
- I have contact with members of the NETWORK at least once a week.
- I also have contact with members of the NETWORK outside the formal activities of the same.
- I consider the members of the NETWORK my friends.
- Within the network there are different types of skills such as technical, managerial and social competencies;
- When a problem occurs within the network, the members work together to solve it;
- If there is a problem in the company of one of the members, others work with him to solve the problem;
- The leadership of the Network respects the views of all;
- The activities of the network are aligned with the main objective;
- Most members of the network have capacity to be leaders;
- If there is a conflict between members of the network, I offer myself to mediate;
- I feel motivated to participate in the network;
- The members of the network are encouraged to propose ideas for change;
- The members are responsible for bringing new business opportunities for the network.

#### Competitiveness
- If I need some information for a decision, I know where to find on the NETWORK.
- Within the NETWORK there are several opportunities to exchange information.
- The NETWORK is connected to other entities, as other networks of businesses, unions, government agencies, among others.
- The NETWORK has a hierarchical structure (president, directors and other members).
- I have contact with members of the NETWORK at least once a week.
- I also have contact with members of the NETWORK outside the formal activities of the same.
- I consider the members of the NETWORK my friends.

4. Results

In this section we present the survey items, according to the social capital dimensions. The exploratory phase also allows to indicate competitive variables (see Figure 4). It is important to notice that some peculiarities of local context must be observed before surveying the network.

The first key point is, besides social capital is strongly dependent on local context, it is possible suppose that his survey can be tested in many others collaborative networks. In fact, we are looking for foreigner researches, which are interested in test the instrument and make a cross-cultural research.

5. Final Considerations

Social Capital is a component of the Social Theory that is being considered as a key-element for the human and economic development of the communities. Some reasons that contribute for the interest in Social Capital are: the value of the social relations in social and economic discussions, the transformations of the society and the role of the State, the importance of network relations to improve economic performances and the need of concepts to understand the complexity of human being. The Social Capital can be understood as a set of informal norms and values, common to the members of a specific group, that allow the cooperation among them. Many authors point the difficulty to measure this concept; most of the time it is possible to measure the absence of Social Capital instead of its presence.

Considering Collaborative Networks (CN) it is important to analyze the impact of their development and, consequently, evaluate aspects of their creation, operation, and dissolution. In other words, the exploitation and, even though, the generation of social capital are closely related on the programming of the groups qualification (induction) and in which way the agents manage the network. Therefore it is important to build instruments to evaluate inter-organizational social capital.
6. Acknowledgments

This work is being supported by the University of Caxias do Sul (Universidade de Caxias do Sul-UCS), the Faculdade FTec Brasil, and the National Counsel for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico-CNPq).

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Research on Development of Modern Service Industry in Wuhan City Circle

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Received August 25\textsuperscript{th}, 2009; revised October 16\textsuperscript{th}, 2009; accepted November 20\textsuperscript{th}, 2009.

ABSTRACT

The modern service industry is an important force of promoting economic growth and social sustainable development. By analyzing the importance of modern service industry to the construction of “Two-oriented Society” and the advantages and disadvantages of the development of modern service industry in Wuhan City Circle, the paper presents many strategies of the development of modern service industry in Wuhan City Circle: changing concept of development, improving policies and the organizational guarantee system, accelerating industrial restructuring, clearing development ideas, strengthening market supervision, strengthening the introduction of human resources, carrying out international exchanges and cooperation.

Keywords: Wuhan City Circle, Modern Service Industry, Two-Oriented Society

1. Introduction

Since the 60’s in the 20th century, the global economy has shown the major trends that the industrial economy turns to the service-based economy, the proportion of service industry in GDP is increasing continuously. With the advent of the information age, in the industrial added value, the proportion of pure manufacturing sector is becoming less and less, but the proportion of modern service industry supported by information technology is more and more. According to UN statistics, from 1970 to 2002, the services industry had accounted for 25% to 60\textsuperscript{th} of entire world’s stock of direct investment from foreign. While the manufacturing industry fell from 42% to 34\textsuperscript{th}. At present, the services industry in the Europe and the United States, particularly the knowledge-intensive modern service industry, accounts for more than half of all the services industry [1].

1.1 The Modern Service Industry and Its Characteristics

The modern service industry is relative to the “traditional services”, is produced in a highly developed stage of the industry. The development of modern service industry is based on electronic information and modern management concepts. Its information and knowledge is relatively intensive, and its essence is the modernization of modern service industry [2]. The modern service industry has four basic characteristics: 1) Intellectual. The modern service industry provides consumers with the production, dissemination and use of the knowledge and makes the knowledge achieve value-added in process of service; 2) Hi-tech. Advanced information technology and modern management concept is the basic conditions of formation and development of modern service industry; 3) High added value and clustering. Modern service industry can not only make the process of service produce the value-added of knowledge, but also can produce the scale effect of services and agglomeration effect of integration of various services, so causes services a significant value-added; 4) Emerging nature. The modern service industry rises from the modern, or evolves from the past in terms of time.

1.2 The Significance of Modern Service Industry to Construction of the “Two-Oriented Society”

The characteristics of “Two-oriented Society” are resource-saving and environment-friendly as a pattern of social development. It builds on the basis of reflection to the traditional model of economic development, is a new economic and social development model that is conducive to resource saving and environment-friendly, is a concrete manifestation of sustainable development. It requires that all aspects of economic and social devel-
opment comply with the laws of ecology and develop in the direction of resource conservation and recycling to maintain a good ecological environment [3].

The modern service industry is a great significance to the construction and development of “Two-oriented Society” because of its characteristics. Firstly, the modern service industry helps to breakthrough the resource constrained bottleneck of the construction of “Two-oriented Society”. The modern service industry is generally high-knowledge and high-tech industries, such as the financial industry, consulting industry, information industry, logistics, education and training. These industries have the features of low energy consumption and high added value that are conducive to resource conservation. Secondly, the modern service industry is conducive to reducing environmental pressure of the construction of the “Two-oriented Society”. Other industries of modern service industry, such as commerce, tourism, convention and exhibition industry, catering and hotel industries, have so little pollution and are conducive to achieving sustainable development.

2. The Advantages of the Development of Modern Service Industry in Wuhan City Circle

Wuhan City Circle is made up of Wuhan and Huangshi, Ezhou, Xiaogan, Huanggang, Xianning, Xiantao, Tianmen, Qianjiang within 100 kilometers from Wuhan. It is the regional economic consortium the center of which is Wuhan. It is the most intensive of industries and factors of production and the most dynamic region in Hubei Province. Wuhan City Circle was approved as a “Two-oriented Society” pilot area by the State Council and the National Development and Reform Commission in the December 14, 2007. Wuhan City Circle places emphasis on the modern service industry in the regional economic development planning building a “Two-oriented Society” as the advantages of the modern service industry in resource conservation and environmental protection. In fact, Wuhan City Circle does have many advantages to develop modern service industry.

2.1 Policy Advantage

Policy advantage is the biggest advantage of Wuhan City Circle. Wuhan City Circle was approved as a national-level “Two-oriented Society” pilot area and did not get the amount of direct investment from the central, the key is to obtain a pilot policy advantages, can carry out important reforms to achieve a sustainable economic and social development in the scope of policy. Furthermore, Wuhan City Circle embarks on the path of regional development by this opportunity. Wuhan City Circle will achieve economies of scale of the region development by connecting relatively independent units in circle into a complementary economic union.

2.2 Talent Advantage

Hubei Province has always attached much importance to science and education, talent advantages are clear. The talents of Hubei Province gather in Wuhan City Circle. There is rich in human resources, strong in science and technology, intensive in high-level talent. The comprehensive strength of science and education in Wuhan ranks the third in domestic major cities. Other cities in the circle also have a certain talent resource base. The scientific and technological human resources of Wuhan and other cities in the circle formates gradient distribution and integration trends to laid the resource base for sharing of human resources in Wuhan City Circle.

2.3 Cultural Resources Advantage

The cultural resources of the cities in Wuhan City Circle are rich. There are many historical and cultural attractions in Wuhan, such as Yellow Crane Tower, Panlong city, Wuchang Red Building, East Lake, Guiyuan Temple. Huangshi is the birthplace of Chinese bronze culture and has ancient copper mine sites in Tonglushan, ancient battlefields in Xisaishan, buddhist cultural sites in the East Mountain, etc.. Ezhou has the ancient capital of Wu King as the representative of the history landscape, Sun Quan and Su Shi as the representative of the cultural landscape, the Guling Temple as the representative of buddhist landscape. Huanggang has Huangmei drama, Li-Shizhen Chinese herbal medicine as the representative of non-material cultural heritage, as well as numerous cemeteries of revolutionary martyrs and the martyrs memorial. Xiaogan has a strong cultural tradition of filial piety, the story that Dongyong sold himself to bury his father is widespread. Xianning has a profound cultural background and has Chibi ancient battlefield, Tea-Horse ancient Road, etc.. The folk art in Xiantao has a long history. There are paper-cuts, shadow puppets, shell carving and other characteristics of art, besides a nationally known gymnastics town. Tianmen has Lu Yu, the ancestors of the tea ceremony and Pi Rixiu of the poet as the representative of cultural celebrities, and flower-drum drama, shadow puppets as the representative of folk art. Tianmen has also a high level of education, is nationally renowned as “the hometown of champion”. Qianjiang is one of the important birthplaces of Chu Culture, there is Zhanghua-tai in the palace of Chu-ling King in Eastern Zhou, Cao Yu and other excellence talents. These cultural resources are conducive to the development of cultural tourism and other modern service industry.

2.4 Natural Resources Advantage

Wuhan City Circle is rich natural resources. Wuhan has abundant water resources. Yangtze River and Hanjiang
River flow together in Wuhan. East Lake, the largest city lake in our country, is also in Wuhan. Huangshi has rich mineral resources, is known as “the cornucopia of Jiangnan”. Ezhou has the “two lakes” (Liangzi, Red Lotus Lake) and the “Two Mountains” (Lotus Hill, Western Hills), may develop leisure tourism. Huanggang has rich agricultural and sideline native products, may be built into important regional chain distribution logistics areas. Xiaogan is rich in forest resources. Tangchi Hot Springs in yingcheng of Xiaogan city is a Well-known holiday resort. Xianning has pleasant climate and beautiful scene, is known as “yao-chi in the world”. Xiantao has a flat terrain and many rivers, is rich in rivers and lakes features. Tianmen is rich in aquatic resources, salt, anhydrous Glauber's salt and oil reserves are also substantial. Qianjiang has grain, cotton, oil on ground and oil, gas and salt under ground, is the second hometown of meta-sequoia known as “living fossil”.

3. The Disadvantages of the Development of Modern Service Industry in Wuhan City Circle

Wuhan City Circle has the advantage of developing modern service industry, but there is also its disadvantage.

3.1 Low Quality Level and Small Scale of Modern Service Industry

Modern services industry is small-scale, non-standardized, low-grade, and some have even been classified as urban environmental improvement targets. The traditional wholesale and retail trade and catering services industry accounts for a too much proportion, new services, such as information consultation, computer applications, is lack of market growth. Compared with the advanced regions and the demands of economic development, there is a wide gap. Now the service industry of most developed countries has reached 3 70%. The service industry accounts for 70% of GDP, the employees of the service industry accounts for 70% of the employed population, 70% of economic growth comes from services industry. The proportion of modern service industry of Beijing and Shanghai in China accounts for more than 70% of GDP, as well as the proportion of modern service industry of Wuhan City Circle accounts only for about 50% of GDP.

3.2 Unbalanced Development of Modern Service Industry

In nine cities of Wuhan City Circle, the development level of modern service industry in Wuhan is the highest and its leading position is very clear. In 2008 year, Wuhan City Circle achieves added value in services 303.894 billion yuan, in which Wuhan city achieve 198.773 billion yuan, accounts for 65.4% of city circle. From growth rate, growth rate of Wuhan is 13.5%, lower than 0.7% of the average growth rate of city circle. In 9 cities 18.3% of Xianning is the highest and 10.6% of Ezhou is the lowest. From the industrial perspective, the proportion of service of only Wuhan city of nine cities is just over 50%, other eight cities are lower than 40%, of which there are four cities that the proportion of primary industry is higher than 20% [4].

3.3 Lack of Unified Planning of the Development of Modern Service Industry

Each city of city circle is aware of the importance of modern service industry to the development of society and economy, from their own interests, and has made its own development plan according to local resources conditions and levels of economic development. But the local optimum may not be able to achieve an overall optimum. Although the Wuhan City Circle is approved, there have been some good phenomena, such as the joint meeting of the mayor in 9 cities, but the form more than content, a lot of planning has still not been uniform.

3.4 Irregular Management of Modern Service Industry

On the hard environment side, the conditions of some earlier market can not meet the need of development and need be improved. On the soft environment side, some markets still remain chaotic management in public security, health, taxes. Illegal business around the market has seriously affected the confidence of Investors. Market owners and the relevant functional departments should reach a consensus, and further standardize and enhance the market's management level.

4. The Development Strategy of Modern Service Industry in Wuhan City Circle

4.1 Changing Concept of Development

All the cities of Wuhan City Circle should change as soon as possible the concept of development. Firstly, all the cities should establish the concept of unified planning and coordinated development, consider city circle as a whole, take full account of the resource situation and existing development advantages of each city, carry out reasonably industrial distribution, promote common development of economy and common prosperity of society in the city circle. If every city develops alone and constructs unplanned and repetitive, it will cause the waste of resources. Secondly, all the cities should establish a win-win concept of resource-saving and environment-friendly and economic development, and break-through backwardness development concept that things will be managed after construction. All the cities should have long-term development vision and adhere to sustainable development.
4.2 Improving the Policies and the Organizational Guarantee System

The preferential policies of accelerating the development of modern service industry should be studied and formulated. The bottlenecks of structure, mechanism and talents should be breakthroughed. Government should make efforts to create the policy environment that is conducive to the rapid development of modern service industry by strengthening the macro guidance. Government should establish and improve a multi-level joint meeting, such as a joint meeting of mayors, discuss together industrial development, public facilities construction, taxation, finance, Investment, environmental protection, social management and public services, and achieve an efficient coordination of governments. Government should format Construction Management Committee of Wuhan City Circle that has certain administrative levels and powers, give and strengthen its coordination right, supervise right and implement right to overall program and a variety of special planning, and solve comprehensively the problems in the construction of Wuhan City Circle.

4.3 Speeding Up Industrial Restructuring

The government should scientifically make the development plan of modern service industry that is line with the actual development of Wuhan City Circle, highlight the focus of development and advance at different levels the development of modern service industry. Government should play a leading role of plan, use a means of combination of legal, administrative and market, guide resource elements to focus the emphasis areas of and regional of the modern service industry, create a distinctive industrial agglomeration area, promote the division and cooperation of modern service industry, implement differential development, optimize the layout of modern service industry of Wuhan City Circle.

4.4 Clearing Development Ideas

The basic idea of the development of modern service industry in Wuhan City Circle is echelon development, highlighting focal point and a difference emphasis in different cities. There is no doubt that the first echelon of echelon development is Wuhan. The second echelon is Huangshi and Ezhou. In addition to Wuhan, these two cities are the fastest cities. The third echelon is Xiantao and Qianjiang. The industry structure of these two cities is same and the development trend of industrialization is getting better. The fourth echelon is Xianning, Xiaogan, Huanggang and Tianmen. The economic strength of these four cities is weak, the level of urbanization and industrialization is not high, and the pressure of the farmers increasing income is heavy. Highlighting focal point is highlighting the core of the location and function of the Wuhan City Circle, making full use of advantages of the elements together, consolidating and developing the big traffic and big circulation to further enhance its competitiveness and radiation. A difference emphasis in different cities is that the other eight cities of Wuhan City Circle determine their own development priorities according to the actual situation. The industrial base of Huangshi, Ezhou is relatively strong, while they develop vigorously the manufacturing industry, they should also focus on the separation of the manufacturing industry and services industry, develop producer services as a breakthrough point, take new path of industrialization.

The industrial development trend of Xiantao, Qianjiang is getting better, but the levels of per capita consumption is low, so they should speed up the process of industrialization, take simultaneously various measures to increase people’s income and stimulate consumption, develop and expand various types of consumer services. Xianning, Xiaogan, Huanggang, Tianmen expand mainly their respective economic strengths, accept the radiation of Wuhan, do a good job of industries docking, and promote jointly the economic development of Wuhan City Circle.

4.5 Strengthening Market Supervision

Laws and regulations should be developed and improved, and market behavior of services industry should be standardized. Industry standards, scope of services, price fees, property management, incentives and disincentives, professional ethics, and dispute arbitration should be clearly and reasonably set. Regulation, investigation, statistics, information release system of services should be established and improved. Government should adhere to enforce strictly law, intensify efforts to rectify market order, crack down on acts of manufacturing and selling counterfeit and shoddy goods, clean-up comprehensively operation without a license, and create a fair competition environment for the development of modern service industry. The Government should also step up publicity efforts and make all sectors of society understand comprehensively the function, development planning and policy-oriented of the modern service industry.

4.6 Intensifying the Introduction of Talent

The Government should vigorously develop high-quality, professional service personnel, make efforts to improve the knowledge and intelligent level of the employees the modern service industry. Colleges and universities should be close to the market, found some modern service professionals, such as information services, software outsourcing, logistics, property management, finance, insurance, tourism, and foster the high-level application-oriented talents for the development of modern service industry. The Government should actively introduce high-quality services talent from domestic and abroad to venture in Wuhan City Circle and make the modern ser-
The government should continually expand the field of foreign investment, further expand the degree of openness of the telecommunications, finance, commodities, social intermediary services, tourism, etc. By delegate merchants, intermediary merchants and other international means of attracting investment, the government should attract particularly international renowned multinational headquarters, the modern service enterprises brands, develop vigorously the headquarter economy and speed up to enhance the core service functions of the city to drive the overall demand and development of modern service industry. The government should strengthen project cooperation with the government of developed countries and regions in finance, information services and other key areas to promote fully the restructuring and optimization of the modern service industry in Wuhan City Circle.

5. Conclusions

In a word, the strengths and weaknesses of the development of modern service industry in Wuhan City Circle exist at the same time, but the strengths are more than weaknesses. As long as all levels of government departments and enterprises seize the rare opportunities of development, make full use of preferential policies granted by the government, respect the basic laws of market development, change timely the concepts of development, select scientifically the development of strategy, the modern service industry in Wuhan City Circle will surely be a good development, the construction of “Two-oriented Society” also will be a success.

REFERENCES


Influence of Lateral Transshipment Policy on Supply Chain Performance: A Stochastic Demand Case

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Received September 14th, 2009; revised October 25th, 2009; accepted December 2nd, 2009.

ABSTRACT

Considering the supply chain consists of one supplier and two retailers, we construct the system’s dynamic models which face stochastic demand in the case of non-lateral transshipment (NLT), unidirectional lateral transshipment (ULT) and bidirectional lateral transshipment (BLT). Numerical example simulation experiments of these models were run on Venple. We adopt customer demand satisfaction rate and total inventory as performance indicators of supply chain. Through the comparative of the simulation results with the NLT policy, we analyze the influence of ULT policy and BLT policy on system performance. It shows that, if retailers face the same random distribution demand, lateral transshipment policy can effectively improve the performance of supply chain system; if the retailers face different random distribution demand, lateral transshipment policy cannot effectively improve the performance of supply chain systems, even reduce system’s customer demand satisfaction rate, and increase system inventory variation.

Keywords: Supply Chain, Inventory System, Lateral Transshipment, Performance

1. Introduction

Lateral transshipment, an important inventory replenishment policy, has gained a common concern of the academics and business managers in recent years. There are numerous researches about this issue. Lateral transshipment is defined as the redistribution of stock from retailers with stock on hand to retailers that cannot meet customer demands or to retailers that expect significant losses due to high risk [1]. The early pioneering work of Krishnan and Rao [2] examine a periodic review policy in a single-echelon, single-periodic setting [2]. Robinson [3] extends the research to a multi-period case, and establishes the system’s lateral transshipment model [3]. The emergency lateral transshipment model of repairable product was analyzed by Lee [4] for the two-echelon inventory system case [4]. Axsaeter [5] studies the emergency lateral transshipment problem of the multi-level repairable product inventory system, and gets some interesting conclusions different from Lee’s [5]. Archibald et al. [6] develop a lateral transshipment model among the multi-retailer based on Markov decision-making methods [6]. Grahovac and Chakravarty [7] limit the research object to low demanded expensive product and analyze the lateral transshipments model in a multi-echelon supply chain system [7]. Kukreja et al. [8] consider a single-echelon continuous review inventory system which contains n depots, and takes the expensive consumable product as object, study the one-to-one lateral transshipment model [8]. Rudi et al. [9] work on optimal order policy of the vendors in the existence of lateral transshipment circumstances [9]. Minner and Silver [10] provide a new decision rule of system’s lateral transshipment, and prove it can figure out the size of transshipment as well as some important problems [10]. Xu et al. [11] analyze emergency lateral transshipment policy between the two-echelon continuous review inventory system that use \((Q,R)\) policy [11]. Banerjee et al. [12] study lateral transshipment of two-echelon supply chain systems which include multiple retailers and single supplier based on DOE [12]. Xu and Luo [13] use Expect Cost Method to analyze lateral transshipment policy in cross-docking system [13]. Xu and Xiong [14] analyze the best time for one-off transshipments in a cross-docking system with stochastic demand [14]. Wang et al. [15] conduct a quantitative analysis to the value of lateral transshipment policy of regional inventory distribution systems, which consist of a distribution center and...
multiple retail points [15]. Huo and Li [16] develop batch ordering policy in a single-echelon, multi-location transshipment inventory system [16]. Li et al. [17] study inventory management model of the cluster supply chain system with the existence of emergency lateral transshipment [17].

Most of the papers above dealing with transshipment assume that lateral transshipment already exists in system. However, lateral transshipment will make the problem complicate and tend to be very difficult to analyze analytically, especially BLT [18]. Hence, will lateral transshipment really need? This paper handles this problem from the performance measurement point. We consider one supply chain system consists of one supplier and two retailers, allowing a retailer transship from the other one for inventory replenishment besides order from supplier. System’s models were developed by system dynamics assume that all the members use the order-up-to policy, and numerical experiment was run on Venple platform.

The paper is organized as follows: in Section 2, the models with lateral transshipment were developed, as well as without lateral transshipment. The accuracy of the model is tested against simulation in Section 3; Section 4 deals with the influence of ULT and BLT. The conclusion of this paper was presented in Section 5.

2. Model Description

We consider two retailers facing independent stochastic customer demand and one supplier (Figure 1). Without lateral transshipment, retailers order from suppliers to replenish inventory in case of stock out. In order to respond to customer demand quickly, they can use lateral transshipment policy besides order from the supplier, which means they replenish inventory from the other one if there exist surplus stock on hand.

2.1 Model Assumption

Development of the model needs the following assumptions.

- Customer1 and Customer2 face independent stochastic demand;
- Both retailers adopt order-up-to policy, the ordering period is constant;
- Lateral transshipments take no time;
- Transshipments take place when there are surplus stocks. That is, if retailer 1 needs transshipment from retailer 2, retailer 2 only transships the redundant stock.

2.2 System Model

As a modeling and simulation technology, system dynamics has a wide range of applications since its birth, especially in dealing with long-term, chronic, dynamic management problems [19]. Forrester [20] applies system dynamics in industrial business management, addressing issues such as fluctuations in production and employees, instability of market shares and market growth [20]. Logistics and Supply Chain Management is an important area of System Dynamics. Sterman [21] designs the well-known beer game by System Dynamics, and carries out detailed analysis on feedback loops, nonlinear, time-delay and management behavior in the system [21]. Diseny et al. [22] analyze VMI in transport operation by system dynamics [22]. Marquez [23] establishes a model for measuring financial and operational performance in the supply chain based on System Dynamics [23], and so on.

Generally speaking, a complete system dynamics model usually consists of three parts: model variables, causal loop diagrams and mathematical description. We analyze the three part of model in turn as follows.

2.2.1 Model Variables

The structure of a system dynamics model contains stock, smoothed stock, flow rate, auxiliary variables and constants. Stock variables are used to describe the cumulative effect of the system. Smoothed stock variables are the expected values of specific variables obtained by exponential smoothing techniques. Flow rate describes the rate of the cumulative effect of the system. Auxiliary variables are the middle variables which express the decision-making process. Constants change little or relatively do not change during the study period. The fundamental notations of the model are following:

![Figure 1. 2-echelon supply chain. Filled arrows represent the flow of regular replenishments while dashed arrows represent the lateral transshipment flow](image-url)
Nomenclature

Indices

\( i, i = 1, 2 \) index for retailers

\( j, j = 1, 2 \) index for retailers

Stock Variables

\( SI \) inventory of supplier

\( IRi \) inventory of retailer \( i \)

Smoothed Stock Variables

\( AOQRi \) average order quantity of retailer \( i \)

\( ASRRi \) average sales rate of retailer \( i \)

Flow Rate Variables

\( SRTRi \) shipment rate to retailer \( i \)

\( ORRi \) order rate of retailer \( i \)

\( ORSi \) order rate of supplier

\( SRRi \) sales rate of retailer \( i \)

\( LTij \) lateral transshipment from retailer \( i \) to retailer \( j \)

Auxiliary Variables and Constants

\( DICTS \) desired inventory cover time of supplier

\( DIS \) desired inventory supplier

\( IGS \) inventory gap of supplier

\( IARS \) inventory gap of supplier

\( IATSi \) inventory adjustment rate of supplier

\( ODTS \) order delay time of supplier

\( ASRSTRI \) average sales rate smooth time of retailer \( i \)

\( ODTRI \) order delay time of retailer \( i \)

\( ASRSTRI \) average order quantity smooth time of retailer \( i \)

\( IGRI \) inventory gap of retailer \( i \)

\( DICTRI \) desired inventory cover time of retailer \( i \)

\( IARRI \) inventory adjustment rate of retailer \( i \)

\( IATRI \) inventory adjustment time of retailer \( i \)

\( CSRRI \) customer demand satisfaction rate of retailer \( i \)

\( TI \) total inventory

2.2.2 Causal Loop Diagrams
Causal loop diagram is a tool that expresses the structure of the system, playing an extremely important role in system dynamics. There are two reasons for that. First, during model development, they serve as preliminary sketches of causal hypotheses and secondly, they can simplify the representation of a model.

The first step of our analysis is to capture the relationship among the system operations in a system dynamics manner and to construct the appropriate causal loop diagram. Figure 2 describes the causal loop of the supply chain without lateral transshipment.

The system structure in Figure 2 contains supplier and retailers. For the supplier, \( SI \) is decided by \( ORSi \) and \( SRTRi \). \( ORSi \) is determined commonly by \( OQS \) and \( ODTS \). Delivery rate \( SRTRi \) is determined by \( OQRi \) and \( SI \). Supplier adjust inventory level by setting \( DIS \), together with \( SI \) determine \( IGS \). \( IGS \) and \( IATSi \) determine \( IARS \), in turn, \( IARS \) has a direct impact on \( OQS \) and an indirect impact on \( ORSi \). For retailers, \( IRi \) is determined by \( ORRI \) and \( SRRi \). \( ORRI \) is the delay of \( SRTRi \), delay time is \( ODTRI \). \( SRRi \) is decided by \( IRi \) and \( CDRI \). \( ASRRi \) is obtained from

Figure 2. Causal loop diagram of the supply chain without lateral transshipment
\( ASRi \), \( IGri \), \( IARRi \), and \( AOQSTri \) determine \( AOQri \). There are two performance variables, customer demand satisfaction rate \( CSRRi \) and total inventory \( TI \). \( CSRRi \) is decided by inventory \( IRi \) and customer demands \( CDRI \), \( TI \) is a accumulation sum of supplier inventory \( SI \) and \( IRi \).

Figure 3 describes the causal loop diagram of supply chain with ULT. \( LT21 \) means the transshipment from retailer 2 to retailer 1. It is a flow rate variable and means that when retailer 1 out of stock, retailer 2 will replenish retailer 1 by transshipment on condition that it has surplus stock. \( LT21 \) is decided by \( CDRI \) and \( IRi \), and influence \( OQRi \).

Figure 4 describes the causal loop diagram of the supply chain with bidirectional lateral transshipment. It is a flow rate variable and means that when retailer 1 out of stock, retailer 2 will replenish retailer 1 by transshipment on condition that it has surplus stock. \( LT21 \) is decided by \( CDRI \) and \( IRi \), and influence \( OQRi \).

2.2.3 Mathematical Description

The next step of system dynamics methodology includes the development of the mathematical model, usually presented as a stock-flow diagram that captures the model structure and the interrelationships among the variables. Combining mathematical description and causal loop diagram of variables, we use visual simulation software (Venple) to reflect the behavior of the system and provide a basis for decision-making. We analyze the mathematical description of the main variables in the system under the three cases of NLT, ULT and BLT so as to lay a good foundation for model simulation.

**NLT case**

\[
SI(t) = SI(t-1) + \Delta t \times (ORS - SRTRi - SRTRj)
\]  
\[
IRi(t) = IRi(t-1) + \Delta t \times (ORRi - SRRi)
\]

(1) is the inventory dynamics equation of supplier, (2) is the inventory dynamics equation of retailer \( i \).

\[
AOQri = SMOOTH(OQRi, AOQSTri)
\]

(3) is the average order quantity equation of retailer \( i \), (4) is the average sales rate equation of retailer \( i \).

\[
ORRi = DELAY1(SRTRi, ODTRi)
\]

(5) and (6) are the order rate equations of suppliers and retailers, which are the delay function of the corresponding order quantities in a given period of time. (7) is the equation of supplier shipment rate to retailers. It means when \( SI \leq 0 \), \( SRTRi \) is 0; when \( SI > 0 \) and the total order quantity \( \sum OQRi \leq SI \), supplier can fully meet the orders of retailers, shipment rate is the order quantity of retailers \( OQRi \); when \( SI > 0 \) and \( \sum OQRi > SI \), supplier partly meet the orders of retailers. According to the proportion of orders, shipment rate is \( SI \times \left( OQRi / \sum OQRi \right) \). (8) is the sales rate equation of retailer \( i \). When \( IRi > CDRI \), meaning that customers’ demand will be met completely, \( SRRi = CDRI \); When \( 0 \leq IRi \leq CDRI \), meaning that the customer demand will
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be met partly, \( SRR_i = IR_i \); when \( IR_i < 0 \), meaning that the customer demand will never be met, \( SRR_i = 0 \).

\[
\begin{align*}
D_{IS} & = \sum_{j=1}^{2} O_{QRI} \times D_{ICT}S \quad (9) \\
O_{RS} & = \text{DELAY}(OQS, ODTS) \quad (10) \\
I_{GS} & = D_{IS} - S_I \quad (11) \\
I_{ARS} & = I_{GS} / I_{ATS} \quad (12) \\
OQS & = \begin{cases} 
0 & \text{if } I_{GS} \leq 0 \text{ or } I_{ARS} + \sum_{i} O_{QRI} \leq 0 \\
I_{ARS} + \sum_{i} O_{QRI} & \text{if } I_{GS} > 0 \text{ and } I_{ARS} + \sum_{i} O_{QRI} > 0
\end{cases} \quad (13) \\
D_{IR_i} & = A_{SRRI} \times D_{ICT}R_i \quad (14) \\
I_{GR_i} & = D_{IR_i} - I_{R_i} \quad (15) \\
O_{QRI} & = \begin{cases} 
0 & \text{if } I_{GR_i} \leq 0 \text{ or } I_{ARR_i} + A_{SRRI} \leq 0 \\
I_{ARR_i} + A_{SRRI} & \text{if } I_{GR_i} > 0 \text{ and } I_{ARR_i} + A_{SRRI} > 0
\end{cases} \quad (16)
\end{align*}
\]

\( DICTS, ODTS, IATS, ASRSTR_i, DICTR_i, IATR_i, ODTR_i \) and \( AQSTR_i \) are constants.

\( (9) \sim (13) \) are the auxiliary variables equations of supplier. \( (9) \) is the desired inventory equation of supplier. \( (10) \) is the order rate equation of supplier. \( (11) \) is the inventory gap equation of supplier. \( (12) \) is the inventory adjustment rate equation of supplier. \( (13) \) is the ordquan
ty equation of supplier. When \( I_{GS} \leq 0 \) or \( I_{ARS} + \sum_{i} O_{QRI} \leq 0 \), \( OQS = 0 \); When \( I_{GS} > 0 \) and \( I_{ARS} + \sum_{i} O_{QRI} > 0 \), \( OQS = I_{ARR_i} + A_{SRRI} \).

\[
T = I = S_I + \sum_{i} I_{R_i} \quad (17)
\]

\( (17) \) is the total inventory equation of the supply chain system. \( (18) \) is the customer demand satisfaction rate equation of the supply chain system. When \( I_{R_i} \leq 0 \), \( CSSR_i = 0 \); When \( 0 < I_{R_i} < C_{DR_i} \), \( CSSR_i = I_{R_i}/C_{DR_i} \); When \( I_{R_i} \geq C_{DR_i} \), \( CSSR_i = 1 \). \( C_{DR_i} \) is a random variable, and it obeys a certain random distribution.

**ULT case.**

\[
LT_{21} = \begin{cases} 
0 & \text{if } I_{R_i} \geq C_{DR_i} \text{ or } I_{R_2} \leq C_{DR_2} \\
C_{DR_1} - I_{R_1} & \text{if } I_{R_1} < C_{DR_1} \text{ and } I_{R_2} > C_{DR_2} \text{ and } (I_{R_2} - C_{DR_2}) \geq (C_{DR_1} - I_{R_1}) \\
I_{R_2} - C_{DR_2} & \text{if } I_{R_1} < C_{DR_1} \text{ and } I_{R_2} > C_{DR_2} \text{ and } (I_{R_2} - C_{DR_2}) < (C_{DR_1} - I_{R_1}) \\
I_{R_1}(t) = I_{R_1}(t - 1) + dt \times (O_{QRI} - S_{RR_1} + LT_{21}) & \text{if } I_{R_1} \geq C_{DR_1} \\
I_{R_2}(t) = I_{R_2}(t - 1) + dt \times (O_{QRI} - S_{RR_2} - LT_{21}) & \text{if } I_{R_1} < C_{DR_1}
\end{cases} \quad (19)
\]

\[
O_{QRI} = \begin{cases} 
0 & \text{if } I_{GR_i} \leq 0 \text{ or } I_{ARR_i} + A_{SRRI} - LT_{21} \leq 0 \\
I_{ARR_i} + A_{SRRI} - LT_{21} & \text{if } I_{GR_i} > 0 \text{ and } I_{ARR_i} + A_{SRRI} - LT_{21} > 0
\end{cases} \quad (22)
\]

\[
O_{QRI1} = \begin{cases} 
0 & \text{if } I_{GR_i} \leq 0 \text{ or } I_{ARR_i} + A_{SRRI} + LT_{21} \leq 0 \\
I_{ARR_i} + A_{SRRI} + LT_{21} & \text{if } I_{GR_i} > 0 \text{ and } I_{ARR_i} + A_{SRRI} + LT_{21} > 0
\end{cases} \quad (23)
\]

\( (19) \sim (23) \) are the equations of variables in the ULT situation, and the other variables which were not include in the above expression are the same as the variables in the NLT situation. \( (19) \) is the transshipment rate equation. When \( I_{R_1} \geq C_{DR_1} \) or \( I_{R_2} \leq C_{DR_2} \), \( LT_{21} = 0 \); When \( I_{R_1} < C_{DR_1}, I_{R_2} > C_{DR_2} \) and \( (I_{R_2} - C_{DR_2}) \geq (C_{DR_1} - I_{R_1}) \), \( LT_{21} = C_{DR_1} - I_{R_1} \); \( (I_{R_2} - C_{DR_2}) \geq (C_{DR_1} - I_{R_1}) \), \( LT_{21} = C_{DR_1} - I_{R_1} \); \( (I_{R_2} - C_{DR_2}) < (C_{DR_1} - I_{R_1}) \), \( LT_{21} = I_{R_2} - C_{DR_2} \).

\( (20) \sim (23) \) express the variables changed in ULT, and their explanations are similar with NLT.

**BTL case.**

\[
LT_{12} = \begin{cases} 
0 & \text{if } I_{R_2} > C_{DR_2} \text{ or } I_{R_1} \leq C_{DR_1} \\
C_{DR_2} - I_{R_2} & \text{if } I_{R_1} < C_{DR_1} \text{ and } I_{R_2} < C_{DR_2} \text{ and } (I_{R_1} - C_{DR_1}) \geq (C_{DR_2} - I_{R_2}) \\
I_{R_1} - C_{DR_1} & \text{if } I_{R_1} < C_{DR_1} \text{ and } I_{R_2} < C_{DR_2} \text{ and } (I_{R_1} - C_{DR_1}) < (C_{DR_2} - I_{R_2})
\end{cases} \quad (24)
\]
Influence of Lateral Transshipment Policy on Supply Chain Performance: A Stochastic Demand Case

\[ LT_{21} = \begin{cases} 
0 & \text{IR2} \geq \text{CDR2} \quad \text{or} \quad \text{IR1} \leq \text{CDR1} \\
\text{CDR1} - \text{IR1} & \text{IR2} < \text{CDR2} \quad \text{and} \quad \text{IR1} > \text{CDR1} \quad \text{and} \quad (\text{IR1} - \text{CDR1}) \geq (\text{CDR1} - \text{IR1}) \\
\text{IR1} - \text{CDR1} & \text{IR2} < \text{CDR2} \quad \text{and} \quad \text{IR1} > \text{CDR1} \quad \text{and} \quad (\text{IR1} - \text{CDR1}) < (\text{CDR2} - \text{IR2}) 
\end{cases} \]  

(25)

\[ IR1(t) = IR1(t-1) + dt \times (ORR1 - SRR1 + LT_{21} - LT_{12}) \]  

(26)

\[ IR2(t) = IR2(t-1) + dt \times (ORR2 - SRR2 - LT_{21} + LT_{12}) \]  

(27)

(24) \sim (29) are the equations of variables in the BLT situation, and the other variables which were not included in the above expression are the same as the variables in the NLT. The explanations of above equations are the same as the ULT case, and the concrete explanations will be omitted.

3. Models Validation

The main criterion for system dynamics models validation is structure validity, which is the validity of the set of relations used in the model, as compared with the real process. For detection of structural flaws in system dynamics models, certain procedures and tests are used. These structure validity tests are grouped as direct structure tests and indirect structure tests. Direct structure tests involve comparative evaluation of each model equation against its counterpart in the real system (or in the relevant literature). Direct structure testing is important, yet it evolves a very qualitative, subjective process that needs comparing the forms of equations against real relationship. It is therefore, very hard to communicate to others in a quantitative and structured way. Indirect structure testing, on the other hand, is a more quantitative and structured method of testing the validity of the model structure. The two most significant and practical indirect structure tests are extreme-condition and behavior sensitivity tests [24]. Generally, the goal of extreme test lies in whether the equations are still meaningful or not and whether the model conditions are still reasonable or not under the situation of using extreme input. Behavior sensitivity test consists of determining those parameters to which the model is highly sensitive and asking if these sensitivities would make sense in the real system. If we discover certain parameters to which the model behavior is surprisingly sensitive, it may indicate a flaw in the model equations.

In view of the deficient of real data and the difficulty of gaining mass data, we only use the extreme condition test and the sensitive test in the indirect structure tests to carry on the validation for the models of this paper. We use the total inventory which is a main output of the system to confirm the performance in the extreme test and the sensitive test.

Suppose that the system is facing an extreme demand, we use Venple to test the models which are NLT, ULT and BLT, and compare the simulation results with the normal demand case. The results are shown in Figure 5. Although the total inventory becomes very big with the sharply increasing demand, the tendency is similar with the normal demand case. This indicates that the variables and the equations in the system still have effects, and the model displays a good robustness under the extreme input.

![Figure 5. Total inventory in normal condition and extreme condition](image)
Through changing the demand parameters, we use Poisson distribution to test the models’ sensitivity, and the simulation experiment is also carried on the Venple. Figure 6 presents the result that compare with the normal parameters case. We can see although fluctuation range of the total inventory is inconsistent under the two kinds of demand with different parameters, the tendency displays as basically consistent. This explains that the models don’t sensitively response to the parameters, and this is conducive for the model’s practical application.

4. Numerical Simulation

We employ a numerical example to examine the influence of three different policies on system performance, and further analyze the simulation results and provide reasonable suggestions. In order to facilitate the numerical simulation, we set the initial value of the constants, \( A_{Q, S, R, T, i} = 1 \), \( D_{I, C, T, R, i} = 1 \), \( D_{I, C, T, R, S} = 2 \), \( I_{A, T, R, i} = 1 \), \( I_{A, T, S} = 2 \), \( O_{D, T, S} = 2 \), \( S_i(0) = 500 \), \( I_{R(i)} = 100 \), \( T = 200 \). Where \( T \) is the simulation time.
4.1 Same Distribution Demand Case

We assume retailer $i$ face same distribution demand that is Poisson distribution with range from 50 units to 150 units. Simulation results are shown in Figure 7, Figure 8 and Table 1.

From the simulation results, the system has the lowest total inventory in BLT case, the average size is 540.2057 units and the standard deviation is 192.2115 units; The following is that in ULT case with its mean is 546.1087 units and the standard deviation is 199.2071 units; Under the situation of NLT, the system has the largest total inventory, its average size is 671.9624 units and the standard deviation is 215.6611 units. It can be seen, lateral transshipments policy reduces the system’s total inventory. However, by comparing with BLT, we can find that ULT policy reduce more total inventory. In addition, from the standard deviation of the total inventory we can see that lateral transshipment policies make the system’s total inventory stabilized. Comparing with ULT, BLT cannot make significantly advantages. Thus it can be seen, in terms of the system’s total inventory, lateral transshipment policy can effectively reduce the size and fluctuation of total inventory, but if we view from effect, little difference can be seen between BLT and ULT.

From Table 1, we see that lateral transshipment improve demand customer satisfaction rate. In NLT, ULT and BLT, mean of CSRR1 are 0.622, 0.829 and 0.772, respectively; mean of CSRR2 are 0.630, 0.829 and 0.772, respectively. In addition, compared with the situation of NLT, customer demand satisfaction rate is more stable in lateral transshipment case. Furthermore, comparing with BLT, ULT is more efficiency in the system performance.

Table 1. Simulation results in the same distribution demand case

<table>
<thead>
<tr>
<th></th>
<th>NLT</th>
<th>ULT</th>
<th>BLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSRR1</td>
<td>0.622</td>
<td>0.829</td>
<td>0.772</td>
</tr>
<tr>
<td>CSRR2</td>
<td>0.630</td>
<td>0.773</td>
<td>0.731</td>
</tr>
<tr>
<td>TI</td>
<td>671.9624</td>
<td>546.1087</td>
<td>540.2057</td>
</tr>
</tbody>
</table>

Figure 9. Total inventory in the different distribution demand case

Figure 10. Customer satisfaction rate in the different distribution demand case
4.2 Different Distribution Demand Case

We assume retailer 1 face different distribution demand. Retailer 1 is still subject to the Poisson distribution as described above. Retailer 2 is subject to the Normal distribution with the range from 50 units to 150 units. Simulation results are shown in Figure 9, Figure 10 and Table 2.

Comparing with that in NLT situation, the system total inventory decreases in BLT and ULT cases, but slightly. In addition, viewing the standard deviation of total inventory in three varieties of policies, we can see that it decreases slightly in the ULT, while an increase in the BLT case. It shows that transshipment is not effective with the different distribution demand case.

From Table 2 we can see that lateral transshipment decreases the customer demand satisfaction rate in different levels, especially the BLT. In NLT, ULT and BLT, mean of CSRR1 are 0.633, 0.604 and 0.552, respectively; mean of CSRR2 are 0.618, 0.594 and 0.557, respectively. From this point, we deduce that lateral transshipment may be not compatible with the different distribution demand.

5. Conclusions

Taking the supply chain system that includes a supplier and two retailers as the research objects, this paper study the influence of lateral transshipments policy on supply chain performance based on system dynamics. We established NLT model, ULT model and BLT model. Through the simulation analysis of these three different models of the supply chain system by Venple, we found that: first, if the two retailers are facing the same distribution demand, lateral transshipments not only reduce total inventory but also increase the customer demand satisfaction rate. Moreover, the effect is more obvious in ULT case; secondly, if the two retailers are facing with the different distribution demand, lateral transshipments reduce total inventory of the system, but the extent is not obvious. However, it decreases the customer demand satisfaction rate of the supply chain system.

As to the first conclusion of this paper, we believe that lateral transshipments make the system handle inventory rationally. It decreases the total inventory, and improves customer demand satisfaction rate. It is an inventory control policy that is worth popularizing. For the second conclusion, we question the suitability of the lateral transshipments policy under the different distribution demand. The main reason may be that different distribution demand will make ordering and replenishment become extremely complex. Moreover, if the retailers still use a separate order-up-to policy, lateral transshipments may becomes impossible and difficult to improve system performance. Hence, considering lateral transshipment, how to find the optimal inventory control policy rather than simply use order-up-to policy in different distribution case will be our further research problems.

6. Acknowledgment

This paper was support, in part, by the Nantong University Social Science Foundation (No.09W021).

REFERENCES


Table 2. System simulation results under different distribution of the needs

<table>
<thead>
<tr>
<th></th>
<th>NLT Mean</th>
<th>NLT Stddev</th>
<th>ULT Mean</th>
<th>ULT Stddev</th>
<th>BLT Mean</th>
<th>BLT Stddev</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSRR1</td>
<td>0.633</td>
<td>0.426</td>
<td>0.604</td>
<td>0.577</td>
<td>0.552</td>
<td>0.447</td>
</tr>
<tr>
<td>CSRR2</td>
<td>0.618</td>
<td>0.442</td>
<td>0.594</td>
<td>0.470</td>
<td>0.557</td>
<td>0.450</td>
</tr>
<tr>
<td>TI</td>
<td>769.0258</td>
<td>229.2123</td>
<td>736.6729</td>
<td>211.6455</td>
<td>758.8274</td>
<td>240.3414</td>
</tr>
</tbody>
</table>

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Empirical Research on the Effects of Logistics Industry on Economic

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Received August 19th, 2009; revised October 6th, 2009; accepted December 18th, 2009.

ABSTRACT

Logistics Industry is regarded as the artery and basal industry of country economic development. Its degree of the development is one of the symbols of modernization and comprehensive national strength, and is described as the accelerator on promoting economic development. By using economic analytical method, the article takes the gross domestic product (GDP) as the explained variable and the value of cargo circular flow as the explaining variable, and sets up the economic model between gross domestic product and cargo circular flow; the interdependence between the logistics industry and the economic development can be revealed, and some corresponding suggestions about Dalian for the future development of logistics industry can be put forward.

Keywords: Dalian Economic, Logistics Industry, Econometric Analysis

1. Introduction

At the 1960s, America scholar Drucker brought forward the doctrine that Logistics is the gloomy mainland of economic field and more scholars start to study Logistics theory. In the hard environment, reducing cost has the limit with improving technological content and management level, so compressing the furthest current time and cutting down current charge are the most important thing to reduce the total cost. At the same time, Logistics industry has powerful correlative effect and promotes the development of Transportation industry, Finance industry, Information industry, Travel industry, and so on. It not only enhances third industry’s absolute quantity, but also advance the proportion high value-added industry and optimizes industry’s structure from different orientations; brings along further converge about commodity flow, capital flow, information flow, technology flow and is an important ligament in country economy’s circulation; besides, accelerates the formation of enterprise’ competitive advantages.

On the effects of Logistics Industry on Economic, domestic has a lot of research. Such as, by using qualitative research studying the relation between economic development and modern Logistics industry with the example of Taizhou in Jiangsu province, ZHANG Chunfa gets that they have strong relativity; at quantitative research, by using cointegration test and from the angle of cointegration theory setting up model of Logistics industry and economic development, LUO Hui tests the effect on Logistics industry on Jiangxi economic development; at the article of empirical research on effect of china Logistics industry on economic development, author adopts regress analysis, study them and bring forwards some advices developing Logistics industry; at the article of the effect of territorial logistics on territorial economic growth, author use the theory of economic growth, analyses their effect mechanism, at the same time, and study their econometric model. Besides, WANG Huiping, ZHANG Min, and so on, by using quantitative method research effect of other provinces on economic growth, for example, Henan province, Anhui province, but research between Dalian Logistics industry and economic growth has not been found.

Dalian has the predominant area and be on core ground on the northeast. 85%-90% of Northeast’s trade bargain in the Dalian port. Dalian is also the centre of northeast Asia and has the important effect of promoting Logistics cooperation about China, Japan, Korea; as one of the important economic developmental center and port in our country, Dalian has favorable base on developing Logistics industry. After the reform and opening-up policy, Dalian has got outstanding achievement on the economy and social development, but Logistics industry set the pace. From high standard of establishing district’s Logistics center, Dalian still has some problems, such as industry convergence not enough, logistics service shortage, modern Logistics personnel pinch. The article
carry through qualitative analysis on relation between Dalian Logistics industry and economic development; and then, by using econometric analytical method and setting up the econometric model, analyzes quantitative relation and determines Logistics industry contribution to economic development to offer necessary basis for establishing logistics industry’s status and setting down Dalian Logistics industry’s development layout.

2. Quantitative Analysis on Relation Between Logistics Industry and Economic Development

2.1 Interrelation between Logistics Industry and Economic Development

It is the interrelation between Logistics industry and economic development. On the one hand, by developing Logistics industry brings Logistics system’s reformation; on the other hand, by adding Logistics demand economic development accelerates Logistics industry. In a word, logistics shortage that disparity lies in logistics supply and logistics demand can be described and explained relation between Logistics industry and economic development.

2.2 Analysis on the Effect of Economic Growth on Logistics Industry Development

The effect of economic growth on Logistics industry development represents that economic growth brings up the increase of logistics demand and the increase of logistics demand can prompt Logistics industry’s development; on the one hand, the level of economic development decides development speed of Logistics industry.

As one of core city in the northeast, after entering into new century, Dalian economy continues to develop, economic strength enhances and microscopic economy benefit improves constantly. At the 2008 year, GDP reach RMB 385.2 billions. Economic fast development ask logistics demand change from quantity to quality; industry structural adjustability that Dalian develops new technology industry, accelerates modern service industry and advances industry all-around competition upgrade the quality of Logistics demand, and railway transportation descends, but highway transportation and navigate transportation ascends; Dalian modern commerce’s development also has lots of demand to city distribution.

2.3 Analysis on the Effect of Logistics Industry on Economic Development

That Logistics industry has the effect on promoting economy has two sides: if Logistics could adapt the need of economic development, it will sustain economic development; Logistics stimulates and promotes economic development. Logistics industry’s development may- boosts new industry configuration, optimizes industry structure and speeds industry upgrade.

The development of modern Logistics industry, advances Dalian investment environment, attracts more china and foreign investment and fosters new economic growth point. As we know, if Dalian Logistics cost fall one percent, it could create RMB2.5 billions at profit. At one time, modern Logistics industry promotes gross growth on third industry and service level, and accelerates Dalian course of industry superlative. Modern Logistics industry makes the best of Dalian distribution and radicalization function in the northeast economic area and northeast Asia, and also comes true effect of Dalian’s shipping center, commerce center, finance center and information center.


3.1 Selection about Measurement and Model

To reveal interdependence between Dalian logistics industry and economic development, the article uses econometric analytical method, taking the Dalian gross domestic product (GDP) as the explained variable (Y) to show the level of economic development; taking the value of cargo circular flow as the explaining variable show the development level of Logistics industry. In term of Logistics industry, it should include storage, kinds of distribution center and so on. Because our country’s industry system don’t carve up Logistics industry and has not integrated statistical index system, we can take transportation and storage as faint production value of Logistics industry. But up to now it is hard to gather all data, so we have to fail slice.

According to Dalian actuality of Logistics industry, cargo transportation (including railway, highway, waterway) is the main in the Logistics industry, so taking the value of cargo circular flow as the main economic index to describing the development of Logistics industry accords with fact. At the same time, the value of cargo circular flow is a practicality index and not influenced by price fluctuate, so this way is reasonable. According to Dalian Statistical Annual from 1998 to 2007, we clear statistical index up about the Dalian gross domestic product and the value of cargo circular flow (Table 1).

We use Eviews software to work out scatter figure about the explained variable (Y) and the explaining variable (X), as shown in Figure 1.

From the scatter figure we can see: first, Dalian product of Logistics industry ascends gradually (excluding 1998), according with growth trend of gross domestic product; at last, it shows nonlinear relation between Y and X (because of stylebook capacity being not enough, nonlinear relation is unconscious but it don’t influence...
Empirical Research on the Effects of Logistics Industry on Economic

Table 1. The dalian gross domestic product and the value of cargo circular flow

<table>
<thead>
<tr>
<th>Year</th>
<th>The value of cargo circular flow (a hundred millions ton kilometres)</th>
<th>Gross domestic product (RMB a hundred millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>475.95</td>
<td>820.60</td>
</tr>
<tr>
<td>1998</td>
<td>462.72</td>
<td>926.27</td>
</tr>
<tr>
<td>1999</td>
<td>601.75</td>
<td>1003.08</td>
</tr>
<tr>
<td>2000</td>
<td>731.97</td>
<td>1110.77</td>
</tr>
<tr>
<td>2001</td>
<td>771.25</td>
<td>1235.64</td>
</tr>
<tr>
<td>2002</td>
<td>802.21</td>
<td>1406.10</td>
</tr>
<tr>
<td>2003</td>
<td>1265.94</td>
<td>1632.59</td>
</tr>
<tr>
<td>2004</td>
<td>1622.27</td>
<td>1961.76</td>
</tr>
<tr>
<td>2005</td>
<td>1923.33</td>
<td>2152.23</td>
</tr>
<tr>
<td>2006</td>
<td>2503.22</td>
<td>2569.67</td>
</tr>
</tbody>
</table>

Figure 1. The scatter chart about X and Y

our judgment). From the form of scatter chart, the article adopts model:

\[ y_i = \frac{1}{\left( \frac{1}{u} + b_1 x_i \right)^{b_0^*}} \quad \text{for } t=1,2,3 \ldots n \]  

(1)

In fact, \( u \), \( b_0 \) and \( b_1 \) are estimated parameter, and the way of estimating parameter in linear model cannot be used direct, so the article adopts linear way, namely transforming Model 1:

\[ \frac{1}{y_i} = \frac{1}{u} + b_0 (b_1 x_i)^{b_0^*} \]

\[ \frac{1}{y_i} - \frac{1}{u} = b_0 (b_1 x_i)^{b_0^*} \]

\[ \ln \left( \frac{1}{y_i} - \frac{1}{u} \right) = \ln (b_0) + (\ln b_1) x_i \]

Assuming \( u \) is known, and \( y_i^* = \ln \left( \frac{1}{y_i} - \frac{1}{u} \right) \), \( b_0^* = \ln (b_0) \), \( b_1^* = \ln (b_1) \), we can get:

\[ y_i^* = b_0^* + b_1^* x_i \]

So we can make the best of linear model to estimate model parameter.

From theory Model (1) we know, \( b_1 \) lies in the scope of zero and one. When \( x \) inclines to infinity, \( y \) would incline to \( u \), namely \( u \) is saturation about \( y \). But \( y \) represents GDP, so \( y \) has not saturation; in fact, \( x \) (the value of cargo circular) don’t incline to infinity. The model is mainly used to analysis relation between logistics industry and economic development, so it is not necessary to take \( x \) as infinity. If we define GDP growth ratio every year as 10%, about seven years later, namely 2013, Dalian GDP will be RMB 500.8 billions, so \( u \) would be equal to 5008.

3.2 Model’s Parameter Estimation and Test

By way of OLS (Ordinary Least Square) estimating parameter \( b_0 \), \( b_1 \), we get the next result:

\[ y = \frac{1}{5008} + 0.001(0.999^x) \]  

(2)

\[ R^2 = 0.952491, \quad \text{Adjusted } R^2 = 0.946552, \quad F = 160.3885 \]

From the angle of statistical test, simulation extent is high, and salient level of the equation is more than 0.05; from the angle of economic sense, that \( b_0 \) belongs to area from zero to infinity and \( b_1 \) belongs to area from zero to one are right, namely assuring that GDP grow as the value of cargo circular grow.

3.3 Analysis on the Effect of Dalian Logistics Industry on GDP Growth

According to Model (2), by way of marginal analysis and flexibility analysis, the article makes quantitative analysis on the effect of Dalian Logistics industry on GDP growth.

3.3.1 Marginal Analysis on the Effect of Dalian Logistics Industry on GDP

From Model (2) we can have Marginal effect:

\[ \frac{d_y}{d_x} = -b_0 (Lnb_1) \left( \frac{b_1^*}{b_0^* + \frac{1}{u}} \right) \]  

(3)

\( b_1 \) belongs to area from zero to one and \( Lnb_1 \) is less than zero, but \( b_1^* \) is more than zero and \( \left( \frac{1}{u} + b_0^* \right)^{b_0^*} \) is more than zero, so this shows that GDP grows when Logistics industry grows simultaneity. According to statistical data of Dalian Logistics industry (the value of cargo circular flow), when \( x \) is equal to 2503.22, we put it to Formula (3):
\[
\frac{dy}{dx}\bigg|_{x=2565.22} = 1.030 \quad \text{(RMB 0.103 billions)}
\]

Namely, when the value of cargo circular flow adds one unit (a hundred millions ton kilometers), GDP adds 1.03 units (RMB 100 millions) accordingly. Marginal effect \( \frac{dy}{dx} \) is more than zero all along, but

\[
\frac{d^2y}{dx^2} = -b_h (Lnb_1) \frac{b_1^{x-1}}{u + b_h^{x-1} \left( \frac{Lnb_1}{u + b_h^{x-1}} \right)} \left( 1 + b_1^{x-1} \right)^2
\]

(4)

From the equation \( \frac{d^2y}{dx^2} = 0 \) we know that \( x = 0 \) is equal to 1611. When \( x \) is less than 1611, \( \frac{d^2y}{dx^2} \) is more than zero; when \( x \) is more than 1611, \( \frac{d^2y}{dx^2} \) is less than zero.

Marginal effect can be divided to two phases: when \( x \) is less than 1611, Logistics industry has positive effect; when \( x \) is more than 1611, Logistics industry has negative effect; when Logistics industry reach considerable scale, marginal effect is unconscious. When \( x \) is equal to 1611, marginal effect is the best.

3.3.2 Flexibility Analysis on the Effect of Dalian Logistics Industry on GDP

At the basis of economy and flexibility concept, according to Model (1), flexibility coefficient

\[
e = \frac{dy \cdot x}{dx} = -b_h (Lnb_1) \frac{ux}{b_1^{x-1} + ub_0}
\]

(5)

That equation describes contrastive relation between growth rate of logistics industry and GDP. Because \( b_1 \) belongs to area from zero to one, \( Lnb_1 \) is less than zero, and \( u, x, b_0 \) and \( b_1^{x-1} \) are all more than zero, flexibility coefficient \( (e) \) is more than zero. That means they keep growth at one direction.

\[
\frac{de}{dx} = -ub_h (Lnb_1) \frac{b_1^{x-1} (1 + xLnb_1) + ub_0}{(b_1^{x-1} + ub_0)^2}
\]

Assuming the above equation is equal to zero, namely

\[
ub_h + xLnb_1 + 1 = 0
\]

(6)

this equation is a surmountable equation, and by the way of numerical value analysis we can get that \( x \) is equal to 1815.

At the moment, that \( e \) is 17.58 is the biggest. Namely, when the scale of Logistics industry grows 1%, GDP may grow 17.58%. When \( \frac{de}{dx} \) is more than zero, Logistics industry and GDP change at the same direction; when \( \frac{de}{dx} \) is less than zero, Logistics industry and GDP change at the adverse direction. Especially when Logistics industry reach considerable scale, its effect is limited to GDP growth. Of course, this analysis is the basis of Model (2). In the model, about GDP growth, the article only think about a factor promoting GDP growth—the value of cargo circular. It is possible that other promoting effects are attributed to Logistics industry, and this is localization about Model (2).

3.3.3 Brief Summary

Carrying through qualitative analysis and empirical analysis on the interdependence of Dalian logistics industry on economic growth, and setting up regress model. From marginal analysis we know: if the value of cargo circular added one unit, 1.03 units of GDP would grow accordingly; from flexibility analysis we know: if economic scale of Dalian Logistics industry adds 1%, GDP could grow 17.58%.

Relying on good district, Dalian logistics industry develops early and forms definite scale, so using Dalian data to test is representative and believable, and it can reflect level to some extent that Logistics industry’s development influences economy.

Having strong relativity between Dalian development of logistics industry and the level of economic development, so developing Logistics activity has obvious effect for drawing economy. Especially in recent years, the Logistics industry has boundless beneficence on high growth of Dalian GDP.

4. Conclusions and Suggestions

Dalian logistics industry has some extent development, but it is not enough to exert strong industry converge function. Therefore, first government should mend to open up, build and consummate Logistics district, logistics base and integrative Logistics center, and make it become some extent specialization district, enhance competition and comes true scale effect of Logistics industry. Second, Logistics enterprises should make own great efforts to increase technology input, strengthen to research and develop new service, and improve technology level continually. At last, strengthen Logistics build of information and network specialization.

When the trend of society division and enterprise management’s segmented will be obvious, talents demand of Logistics subsection field enlarge increasingly. So Dalian should innovate training pattern, expand channel and strengthen training, not train multiple Logistics talents; consummate talents’ training and absorbing mechanism, build loose mechanism to employ persons, create the environment of talent showing itself for standout, and also adopt flexible policy, for example,
holding stocks, using technology to become a share-
holder or improving salary, to attract professional talents.

Increasing to opening to the outside world and
strengthen to cooperate with international Logistics or-
ganization in the field of Logistics and distribution tech-
nology, logistics management and consultation, and so
on; fetching in positively domestic excellent Logistics
enterprises and strengthen territorial Logistics coopera-
tion and multinational entrance; strengthening layout and
build of Logistics basal establishment, mending distribu-
tion development of Dalian city, going along of intercity
and interprovincial and push international development
of Logistics industry would become Dalian the most im-
portant logistics hinge.

In a word, Dalian Logistics industry has strong effect on
promoting economic development, but in fact, comparing
fasting development of Dalian economic with the devel-
opment level of Logistics industry, its development pace
still improves. Quickening development of Dalian Logis-
tics industry, enhancing its' supply ability and translating
huge Logistics demand into effective demand still are
emphases in the future of Dalian Logistics industry.

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Research on Enhancing the Effectiveness of Staff-Training in Private Enterprise

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Received September 25th, 2009; revised October 29th, 2009; accepted November 31st, 2009.

ABSTRACT

In 21st century, the enterprise competition is a comprehensive competition based on talent, capital, technology and energy. Especially, among all these elements, talent is the most important one. How to culture and set up the enterprise’s own personnel training system is the foundation to improve the business competition strength. Training is one of the best approaches, while how to apply the training contents in practical work and to achieve the expected goal, has great economic and social significance to help Private Enterprise develop much better. According to the relevant theories of staff training, this paper indicated that it was meaningful to enhance the effectiveness of staff training in Private Enterprise after analyzing its current situation of staff training. Meanwhile, it also summed up the practical training procedures, particularly for the Private Enterprise, and provided some constructive suggestions to establish and to perfect the efficient training system in China.

Keywords: Private Enterprise, Staff training, Effectiveness

1. The Significance of Enhancing the Effectiveness of Staff Training in Private Enterprise

In view of the present situation, it is one of sensible choices to improve the comprehensive strength of private business via enhancing the training effectiveness. Whether considering the recent financial crisis or concerning about the business long-term development, enhancing the training effectiveness will become the booster for business development.

1.1 To Help Revitalize the National Economy and Boost Chinese Confidence

At present, the private economy has surpassed more than 50% of the total GDP of the National economy, solved more than 85% of employment problems, and settled more than 50% of the financial revenue. It has become a regional economy, especially as an indispensable support of County economy, however, the average life expectancy of China Private Enterprise is only 3.5 years. Faced with such an urgent reality, government is increasingly attaching importance to support the development of private enterprise. Beside policies, capital and other external supports, it is more important to help private enterprise to establish scientific management system and educating mechanism.

Private enterprise must realize that enhancing the effectiveness of staff training is not only the natural choice for enterprise itself development, but also the requirement of the times to revitalize the National economy and fulfill social responsibility. In view of the microenvironment, the improvement of enterprise-wide learning ability, will greatly enhance the enterprise competitiveness and stimulate innovation capability. To build a loyal, professional, and efficient management team and implementation team, so that the private business will go further in the future development.

1.2 To be Favorable for Getting Rid of Financial Crisis and Realizing Leapfrog Development

The global financial tsunami induced by the American sub-prime crisis, presented great challenges to the advanced private business as never before. Since China has a vast domestic market, the Chinese economy has maintained stable under the government's strong macro-control. People are full of confidence that Chinese economy will be the first to recover in the near future. The private business as an important component of Chinese economy, it should seize the opportunity to accumulate strength through various forms of learning, to expand and enhance the overall level of business, so as to adapt to a
more intense, more standardized, and more sustainable development competition.

1.3 To Accord with the Private Business’s Own Development Requirements

Most Private enterprises pay little attention to staff training of knowledge and skills, which is a common problem nowadays in private enterprises. As many enterprises were just in the form of workshop at their prior periods, mostly depending on emotional management, and practitioners were of low quality and poor skills. As corporate manager always wanted to reduce costs, very little money was invested in staff training, so that once the business turned to be bigger and stronger, some employees would be uncomfortable and work under pressure, especially the sales department, without proper training, it would be completely impossible to have staff sales achievement in proportion to his selling skills. In the limited time, use of the limited resources, greater enhancement of the training effectiveness, will greatly promote the development of private business.

2. The Chinese Private Business Status and Problems of Staff Training

At present, the employee training situation in Chinese private business is not optimistic. It can not imitate the practice in the major companies, which can run their own training schools or virtual educating. It is also very restricted to get training experiences from other medium and small enterprises.

2.1 Staff Training is Lack of Scientific Planning and Execution is Poor

Now the effect of staff training in Chinese private business does not perform well, since the lack of social services in the appropriate training market, or because these companies have not groped an effective approach. As staff training can not keep up, private enterprises always can only focus on “hardware” investments, but not improving the staff quality at the same time, resulting in enterprise “software” development can not keep up with “hardware” development demands. As hardware and software do not combine well, the effective result of investment in technological upgrading is not satisfactory. As a result, private enterprises are increasingly feeling complicated with staff training, realize that they can not neglect it, but have no idea how to start with it, so that there is an acute shortage of staff training activities, even form a vicious circle in human resources management.

Most private enterprises lack of scientific norms in the annual training plans. Mostly, personnel departments and trainees just go through the motions to complete task. Especially, in the production and sale type-based enterprises, all the members work hard to make achievement in the busy-season. Everything is achievement-oriented, so that no more time to talk about training. Only in the off-season, it will do training symbolically as a way of regulating work, even if doing annual training plan, the final curve will be also performed only in the form of a few random lectures, which is a fundamental departure from the purpose of training.

2.2 Private Business Employees and Managers are of Low Quality

The employees in private business are of lower literacy, lower level of education, and lower quality than the ones in state-owned enterprises and foreign enterprises. Based on an investment in private business in certain place, found that education situation in private employees are really worrisome: primary 17.76%, middle school 45.74%, high school 32.24%, tertiary and higher 4.26%; while the distribution of age structure, the young people (30 years of age) are in the vast majority of private enterprises employees, reaching 62.92%. 30–40 years of age are accounted for 21.07%, two together are accounted for 83.99%. Private enterprises in other places also generally like this case, but in the technology-intensive private enterprises, the situation will be better, but young people in the workforce and the proportion are the same.

In addition, a considerable number of private enterprises do not have human resource management departments, the ones possess of human resources management department, of which the managers’ quality and ability are not high. Private enterprises do not have high-quality human resource management professionals, and human resources managers of low quality fail to reflect the role of human resource management, so even simply ignore the human resource management, it would go so far as to have not a full-time Personnel Administrator in an enterprise of thousands of people. While in Europe enterprises with the same scale, most of them employ more than 10 human resource practitioners.

2.3 A Serious Shortage of Investment in Staff Training

At present, the Chinese private business has already exceeded 60% of the total number of Chinese companies, which is the largest business group in China, accounting for more than 50% share of GDP. However, enterprise investment in staff training is relatively low: only 8% of the companies, of which the enterprise investment is accounted for above 3‰-5‰ of the total sales incomes, while 48.2% of enterprises, of which the enterprise investment is accounted for less than 0.5‰ of total sales incomes. In the view of enterprise development and the actual needs for talent competition, the low-input in training will seriously affect their quality.

As many Private businesses suspect employees loyalty, them only focus on the use of employees, without attention to training, are only willing to spend money on talent,
not willing to invest in training personnel. As a staff, he
does not only consider the issue today to earn a living, but
also consider the future earning capacity, if he felt work-
ing conditions not conducive to a better future develop-
ment, he would be reluctant to make long-term stay, and
to leave once there is a suitable opportunity. At this it will
form a vicious circle of human resources management.

2.4 Staff Training Form in Chinese Private
Business is Raw and Single

Private businesses basically use the traditional training
methods such as seminars, conferences and other forms,
which are really boring. By a survey of staff training in
private enterprises, found that private business staff train-
ing was still quite raw. Front-line operator training was
mainly aimed at new staff, only 38% of front-line opera-
tional employees had received pre-job training, and it was
mainly through meetings and the form of one by one, of
which the main contents were business history, post basic
skills, safety awareness and quality consciousness. The
training time was 1–2 days. Most front-line employees
were just simply ordered by the master, and then directed
by old workers, to become familiar with jobs within a
week or so. Some employees even immediately got ap-
pointment without any training. Managers complained
that staff quality was too low, someone tried to train the
front-line staff in way of courses, but staffs couldn’t
understand.

The managers above middle level, whether private
owner members or non-private owner members, hardly
get any training, despite the private business owners are
usually discontent their managers. Private enterprises are
accustomed to ready-made talent recruitment, only a
handful of managers who are wished to be reused or to
be promoted have training opportunities. The full-time
learning opportunities are naturally very small, usually
only when companies will introduce new equipment or
new technology, and such opportunities are always given
to private owner members. As government’s request, the
financial members usually have to participate in training
organized by the relevant government departments,
training and study time is about two weeks.

2.5 The Lack of Scientific Evaluation System and
a Low Conversion Rate

Private business almost never make training assessment,
private business owners may think that training can bring
little or no return on investment; managers and trainers
may lack of the expertise to conduct training assessment;
managers and trainers do not want to assess the input
time and energy; private business itself is lack of staff
training and does not regulate, nor taken seriously. It is
precisely because of no training assessment; the effi-
ciency of conversion from training contents into practical
productive is very low, obviously, the training will not be
able to play its expected role. Managers believe that the
training led to little practical significance, the staffs think
that enterprises do not attach importance to staff devel-

oneptment. In a long time, enterprise management will re-
sult in errors, reducing the staff-to-business sense of be-
longing, or even quit.

3. The Countermeasure to Enhance the
Effectiveness of Staff Training in Private
Business

After the completion of start-up, most of the private
businesses enter the most dangerous growth stage. One
of the roots is there is not a clear development strategy in
e enterprise, when the business scale is keeping expanding,
the management can not control it. Enterprises short-
lived and disappear instantly. As private business man-
ger, it is required to firstly clear business development
strategy and objectives, then gradually introduce and
implement the scientific systemic management systems
and tools. The training and management are mutually
reinforcing, both cooperation and coordination, will ac-
celerate the steady growth in business.

3.1 To Establish the Correct Concept of Staff
Training, Increase Investment in Human
Capital

In connected with the private business problems in per-
sonnel quality and staff training, firstly, it should focus
on the personnel training and reserves. Through the
methods of the training and introduction of talent, etc, it
can make up the disadvantage of a relatively low overall
staff quality. As management team, it is more required to
enhance learning, to master the systematic and practical
management knowledge, skills, and enhance the pattern
of operation and management as soon as possible. If
conditions permit, it should be appropriate to use profes-
sional managers in the enterprise operation and manage-
ment. In addition, the reasonable investment to ensure
the smooth conduct of training, private enterprises must
be willing to invest in training, to improve the training
budget. Considering the current status of private business,
learn from the most advanced training concepts to effec-
tively enhance the effectiveness of staff training in pri-
ivate business.

3.2 To Develop Practical Training Programs and
Goals

There should be plans and objectives in training, it must
proceed from the corporate strategy, and corporate cul-
ture characterized by a combination, so as to meet both
of organization and staff needs.

Training program development should be modeled
according to enterprise development plans, be fit to it so
as to become business forward boosters. For private
business, with long-term development goals, there must
be an assorted training program to promote the development of enterprises. In addition, the process of planning is also the process of excavation needs. Refine the needs of enterprises and employees in order to enable the training targets.

At the same time, before the start of training, it should set its goal to achieve according to the development strategies. Not only convenient for the effectiveness of training to do tracking assessment, but also can enhance the trainees self-confidence, promote training carried out smoothly.

3.3 To Combine the Training with Staff Career Planning

As private business, it should focus on human resource development and management, preparing for enterprise long-term development to accumulate enterprise personnel. The training is important content in human resources development and management. Companies must combine staff career planning into the training plans, promote staff active learning, and apply training contents to the actual work, only need to well lead the strategy and direction. Set up training programs in turn, will get the psychological identity from staffs, stimulate them self-interest in learning, and promote training to achieve better results. If the staff performance is improved, the entire team performance will be followed to be improved, so as to achieve the enterprise's growth. A good learning atmosphere will be good to promote training to carry out the work; otherwise, will be constrained to carry out the training and enterprise development and growth. Private enterprises must not only to strengthen the hardware, but also should pay attention to soft power enhancement.

3.4 To Design the Suitable Training Contents

After set up good training programs and goals, it’s required to design the suitable training contents according to the actual needs of private enterprise, also including training methods and choosing trainers.

1) Select appropriate training methods

For training, the popular is not the best, but only suitable for enterprises actual situation is the most important criterion. First, for the training methods, companies can have a variety of options, mainly divided into two categories, namely house training and external training. Can either choose the traditional classroom teaching model, or can use video to expand indoor training, outdoor training, such a variety of ways to expand.

2) Select appropriate courses

For course selection, training directors should not be affected by the trend, but have to keep calm and rational choice. It is necessary to take into account the role of the curriculum of business, but also take into account the cost of the training budgets. Ultimately must be clear that effective curriculum should not only actual combat, but also minimizing the costs.

3) Select appropriate trainers

With a good curriculum, but also have to select a good trainer, it must be cautious no matter from internal or external. Companies do not have to choose the trainer of big name, but to learn more about the trainer's knowledge, experience, and personality charms. And then compare it with the enterprise training culture whether fit or not, this will make training more effective.

4) Prepare the necessary tools for training, equipment and venues.

In order to successfully carry out the training to reach the desired objectives, training requirements should be well prepared. Used properly, can not only stimulate the enthusiasm of staff, but also help to strengthen the effectiveness of training.

3.5 To Emphasize on Training Conversion

The most crucial aspect of training is how to apply the content of the training and to promote the work of the actual performance improvement. The errors of this part will fall short of the whole training, but also a serious impact on the follow-up implementation of the training program. As enterprise, it is required to fulfill the following aspects:

1) Make good unity of the training spirit in the ideological aspect

Trainees must be noted with learning objectives before training, training organizing department or full trainees should take sharing experience and seminars. Training department should give trainees the appropriate learning tasks, to enable participants possess of the learning purpose. After training, trainees are the light of their own learning experience and corporate practice, work-sharing discussions with the staff, firstly make good unity of the training spirit in the ideological aspect.

2) Learn to meet practical needs in the applications aspect

It should provide the opportunities of applying learned skills in various forms for the trainees. Training contents are based on the corporate strategic planning to develop, and enterprises have to provide more application opportunities as possible. Managers have to track the implementation, such as by methods of trainees’ feedback. And it is to be combined with the staff performance appraisal and work responsibilities together, to develop a formal implementation of the provisions, promote enterprises to form the learning atmosphere of to meet practical needs.

3.6 Do Well the Effectiveness Assessment and Feedback

For the training effectiveness assessment, there are many methods and practical tools. As to the status of Chinese private business and the effect in the actual training assessment, integrate a set of suitable methodology for training assessment in private business:
1) Identify the assessing level
Enterprises assessment level is of 1–4, including reflecting level, learning level, behavioral level, and results level. First-level mainly uses the questionnaire, interviews of participant, observation and other methods; second level mainly include examinations in courses; third level, investigate trainees three months after training, according to workload and changes in the performance; fourth level, will be linked to performance appraisal, if trainees can achieve the standards of post-work requirements, then the training is effective.

2) Select the assessment methods
Training assessment methods, including testing methods, behavioral observation, target achievement of assessment method, cost-benefit assessment methods, learning reporting of the assessment method, assessment method. Private enterprises should make flexible choice in conjunction with training practice.

3) Emphasis on the application of assessment data and feedback.
With the improvement of enterprise training mechanisms, advocacy private business sum up in line with job responsibilities of the competent model, construct a good foundation for the smooth operation and management work, and for the standardized and scientific management system. Completion of the training does not mean the end of training. As a manager, should considerate from business global development, based on the training evaluation data, sum up each advantage and disadvantage of training to provide the most useful supplement for next time. To make the training work can be carried out more smoothly, gradually form a complete and efficient training system and promote management system to be more structure and maturity.

From the above, sum up the operation flow as Figure 1 for practical training system in private enterprise:

Figure 1. The operation flow of practical training system
4. Conclusions

In the view of the enterprise organization forms, more and more private enterprises have adopted the modern enterprise system. From the development model perspective, the private enterprises have been gradually expanding from pure pursuit of quantity to the operational scale, technology level, product quantity and quality, high effective management, cost-effective direction. Training has been more and more concerned by private enterprises, in-depth research on enhancing the effectiveness of training in private business, is bound to provide a good reference and protection for the rapid development of private enterprises. To change the short life expectancy of private business, so that it can avoid market risks, develop to standardization, persist, and large-scale direction.

5. Acknowledgements

This paper is supported by China Postdoctoral Science Foundation (supporting ID: 20090460995).

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