Freight & Passenger Transportation in Iowa

Senior Design Report

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Prepared by:
Chris Meyers
Kevin Olson
Cheng Sun

Dr. Nadia Gkritza
Supervising Research Professor

Dr. Tom Stout, PE
Senior Design Instructor
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1.1 NETSCORE-21 Research Project

The 21st Century National Energy and Transportation Sustainability, Cost, and Resiliency (NETSCORE-21) Research Project aims to develop optimal infrastructure designs for the U.S. energy infrastructure. Presently, electricity production and vehicle production account for a large part of the energy use in the country. The project aims to develop the optimal infrastructure designs while trying to balance sustainability, cost, and resiliency. The project team consists of faculty from multiple disciplines including Electrical Engineering, Mechanical Engineering, Computer Engineering, Industrial Engineering, and Civil Engineering. The Civil Engineering Project Investigator is Dr. Nadia Gkritza who will be supervising the Senior Design Team in their research. Dr. Gkritza will be assisted by graduate student Katerina Rentziou, who will be doing similar work to the Senior Design Team except on a national level, rather than for the state of Iowa.

1.2 Senior Design Team Project

The Civil Engineering Senior Design Team will be focusing their research on the state of Iowa and analyzing the transportation of commodities via rail and trucks, the highway infrastructure, and passenger vehicle movements. The first goal of the Senior Design Team was to collect relevant data regarding commodity flows, highway infrastructure, and passenger vehicle movements. The second goal of the Senior Design Team was to look at the data and begin to make observations with respect to the overall project goals. The third goal of the Senior Design Team was to formulate future scenarios and their respective energy outcomes based on the collected data and the observations made after analyzing the data. The group decided at the beginning of the project that the research could be most efficiently be conducted if each group member took a specific part of the research and became the leader of that portion. Chris Meyers led research efforts on commodity transport via rail in and out of Iowa. Cheng Sun led research efforts on commodity transport via trucks in and out of Iowa. Kevin Olson led research efforts on Iowa’s highway infrastructure as well as the passenger vehicle movements in Iowa.
2.1 Iowa Highway Infrastructure

According to the Iowa Department of Transportation (IDOT), the state of Iowa has more public road miles than interstate miles in the entire 50 states. Motor vehicles on Iowa’s public roads traveled an estimated 31.73 billion miles in 2005. Almost every vehicle and truck on the road in Iowa is fueled by non-renewable fossil fuels. The following graph shows the amount of vehicle miles traveled in Iowa over the time period beginning in 1980 and ending in 2007.

![Graph showing annual vehicle miles traveled in Iowa from 1980 to 2007]

*Figure 1: Annual Vehicle Miles Traveled (millions) in Iowa from 1980-2007*

Source: Iowa Department of Transportation (2007)

The increase in vehicle miles traveled over the 27 year period from 1980-2007 represents about a 1.8% increase per year in vehicle miles traveled. In 2007, the amount of passenger vehicle miles traveled as a percent of the total vehicle miles traveled made up for about 87% where trucks made up for the remaining 13% of the total vehicle miles traveled. The number of vehicle miles traveled will be used in the calculation of energy saving potential in the state of Iowa by switching type or mode of transit (Plug-In Hybrid Electric, High-Speed Rail). There is great potential in reducing the vehicle miles traveled. If multiple passengers were riding on a single train headed to the same location rather than each passenger driving their own individual vehicle the amount of vehicle miles traveled would be significantly reduced. The reduction would be even more significant if the train is placed in a corridor with large amounts of people making longer commutes to the same location.

The Annual Average Daily Traffic (AADT) is important in understanding the distribution of traffic flow throughout the state. AADT data is critical in identifying corridors in the state that would be most suited to handle a type of project like high-speed rail. AADT counts passenger vehicles and also takes into account truck traffic. The percentage of truck traffic is shown on the graph. The AADT for interstates in Iowa is shown in the following graph.
Interstate 235 in the Des Moines region has the largest AADT with 96% of the traffic being passenger vehicles. Interstates 680 and 80 have the highest percentage of trucks with 37% and 32% respectively. The interstate with the highest AADT is I-235 with an AADT around 80,000. I-235 leads to downtown Des Moines and with the large number of jobs downtown in a close area this would lend itself to an initial consideration for some type of rail transit system. The congestion relief on the interstate as well as the energy savings would be considerable.

The next graph shows the number of passenger trips and their respective round-trip distances based on whether or not their origin and destination are in Iowa. This data will be important for planning high-speed rail systems and understanding the distances that passengers are willing to travel on the ground. The following data provides round-trip distances which will be critical in understanding at what distance passengers choose to fly rather than choose to drive. The data also gives insight into the different distances passengers coming to Iowa or leaving Iowa are willing to drive before they choose to fly within a given year.

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**Figure 2: AADT on Iowa Interstates**

Source: Iowa Department of Transportation (2007)
2.2 Iowa Passenger Vehicle Movements

The passenger vehicle movements are essential in understanding how to successfully implement plug-in hybrid electric vehicles (PHEV’s) into the transportation network. The key limiting factor of PHEV’s is their range in battery-only mode. The average person trip length data shown in the following table is essential to understanding how PHEV’s could work based on the current average person trip lengths for their daily trips.

Table 1: Average Person Trip Lengths for Daily Trips Less Than 50 Miles

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Daily Miles (Std Errors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not home-based</td>
<td>11.33 (1.95)</td>
</tr>
<tr>
<td>Home-based social/recreational</td>
<td>10.22 (1.14)</td>
</tr>
<tr>
<td>Home-based shopping</td>
<td>9.80 (1.46)</td>
</tr>
<tr>
<td>Home-based work</td>
<td>8.22 (0.73)</td>
</tr>
<tr>
<td>Other home-based</td>
<td>7.00 (0.67)</td>
</tr>
<tr>
<td>All</td>
<td>9.61 (0.80)</td>
</tr>
</tbody>
</table>

Source: National Household Travel Survey (2001)

The average person’s long trip length is also important data to look at to understand driving patterns. The table below shows how many miles passengers drove on trips over 50 miles based on if their purpose was to commute or not to commute. The average person long trip length data can be used to look at options for PHEV’s and high-speed rail. If a person chose to use a PHEV, that person would more than likely have to be able to recharge the PHEV on the other end of the trip based on the data for
commuters who drove longer than 50 miles. The average long trip length for those whose purpose was not to commute shows distances over 400 miles. This data is important for high-speed rail planning and understanding how far people would be traveling on average.

**Table 2: Average Person Long Trip Length**

<table>
<thead>
<tr>
<th>Purpose to Commute</th>
<th>128.49 (17.95)</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose Not to Commute</td>
<td>437.97 (47.17)</td>
<td>77</td>
</tr>
<tr>
<td>All</td>
<td>408.8</td>
<td></td>
</tr>
</tbody>
</table>

Source: National Household Travel Survey (2001)

A typical person will drive to work over 1000 times round-trip in the course of one year. The mode of transportation to work is critical in energy consumption. The data for Iowa shows a large amount of people that either drive them self to work or car pool in a passenger vehicle. The following chart shows that 89% of people in Iowa choose to get to work by either driving themselves or carpooling.

![Figure 4: Principal Means of Transportation to Work](image)

**Figure 4: Principal Means of Transportation to Work**

Source: BTS Iowa Transportation Profile (2000)
Data that complements Table 2 is available in the form of mode used for annual long distance trips. Similar to commuting patterns, 84% of passengers choose to use personal vehicles for their trips. 13% of the passengers choose to use air for long distance trips. Understanding how many people will choose to drive as opposed to flying for their long distance trips is critical for planning corridors with high-speed rail or trying to implement the use of PHEV’s.

**Figure 5: Annual Long Distance Trips by Mode**
Source: BTS Iowa Transportation Profile (2000)
3.1 Iowa Truck Freight

According to the Iowa Department of Transportation (DOT), trucking as a single mode is the most frequently-used mode for freight movements in Iowa. The mode split for trucks is 74 percent by tons, and 47 percent by ton-miles in 2007. In recent years, as trucking maintained its dominance, the number of trucks traveling on the nation’s highways steadily increased.

Truck freight transportation touches every aspect of Iowa as it carries the majority of freight in Iowa. According to the data we collected and analyzed, large quantities of farm products and raw materials are moved by truck on Iowa’s highway system.

Iowa Truck Freight Shipments

Table 3 indicates that over 232,544 thousand tons of goods were shipped out of the state in 2002. The value of these freight shipments in 2002, including domestic commodity exports and imports movements was $115,396 million. These large quantities of freight shipments were 107,728 millions in ton-miles.

<table>
<thead>
<tr>
<th>State</th>
<th>Value ($ millions)</th>
<th>Tons (thousands)</th>
<th>Ton-miles (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa</td>
<td>115,396</td>
<td>232,544</td>
<td>107,728</td>
</tr>
</tbody>
</table>

Source: BTS Iowa Transportation Profile (2002)

Commodities

We analyzed the truck commodities originating from Iowa (exports) and commodities terminating in Iowa (imports) by tons and ton-miles. As we can see in Figure 6, the top commodities originating from Iowa by weight is animal feed and products of animal origin like pork and beef, which represent 43 percent of the total tonnage; followed by fertilizers (34 percent), and machinery, motorized and other vehicles, and base metal, which represent 8 percent, 6 percent, and 9 percent respectively.

The top commodities terminating in Iowa include agricultural products with 47 percent, which includes cereal, grain, and other foodstuffs. Mixed freight and base metal are the second top commodities coming into the state (17 percent). The percentage of others like prepared foodstuffs and fats and oils, and meat, fish, and seafood is 10 percent.
Figure 7 shows the ton-miles of commodities originating from Iowa and commodities terminating from Iowa. Regarding the commodities originating from Iowa, the top one is still animal feed and products of animal origin with 35 percent. The second top is machinery (21 percent). And others include prepared foodstuffs and fats and oils, agriculture products, mixed freight, and meat, fish, and seafood. The corresponding percentages are 23 percent, 16 percent, 16 percent, and 12 percent.

We can then compare the tons and ton-miles percentage movement between commodities originating from Iowa and commodities terminating in Iowa. Fertilizers make up a high percentage of tons in leaving from Iowa, but a lower percentage in ton-miles. Agriculture product shipments show the same trend as fertilizers, which have a high percentage of tons in coming in Iowa, but low percentage in ton-miles coming to Iowa. Base metal shipments represent a high percentage of ton-miles, but low percentage in tons. This is because some goods aren’t as dense and heavy as others, but are shipped longer distances, such as agriculture products, which are not as heavy as the base metal.
Figure 7: Truck Freight Transportation (Ton-Miles-Millions)  
Source: Commodity Flow Survey (2002)

Distance Traveled

Figure 8 shows us the relationship between value, tonnage, ton-miles and shipment distance. Most freight shipments by value and tonnage are moved by truck in a distance less than 250 miles. More than 82 percent (134,703 thousand tons) of the total shipments and 48 percent of the value ($44,503 million) moved in local and short haul shipments by truck in 2002. We can also see that for 55 percent of the total freight weight moved by truck, the shipment distance is less than 50 miles.

The next longer distance is between 250 to 999 miles; the value of shipment is 42 percent of the total, the weight is 16 percent of the total tonnage, but the shipment in ton-miles is more than half of the total, 54 percent.

Only 2 percent of total tonnage, 9 percent of the total value, and 19 percent of total ton-miles is shipped more than 999 miles by truck.

From the short haul, medium distance, and long distance shipment, we found that the percentage in value is close to half of the percentage in weight in short haul (Figure 8), but the value is 5 times of the weight percentage in long distance shipment. Most of the low-value goods seem to be transported in
short distances while the high-value freight shipments are moved longer distances. Low-value goods like agriculture products are available in Iowa while higher value products such as pharmaceuticals, instrument, and other manufacturing products cannot be obtained locally. It is not economical to ship low-value commodities to longer distances because of the higher transportation costs.

Figure 8: Shipment Characteristics by Mode of Transportation and Distance Shipped for State of Origin
Source: BTS Iowa Transportation Profile (2002)

Figure 9 shows the ton-miles of shipments originating from Iowa terminating in Iowa, traversing in Iowa, and transported within Iowa. We can observe that most of the freight is going through Iowa, which represents 52 percent of the total ton-miles. So, it means Iowa is an important point for the national freight transportation system and large quantities of goods are moved through Iowa. Commodities transported within Iowa represent 26 percent of the total ton-miles. Commodities originating from Iowa and commodities terminating in Iowa represent lower percentages compared to commodities traversing in Iowa and commodities transported within Iowa.
Shipment Weight

Growth in custom purchases over the Internet are influencing shipment size and contributing to a rise in smaller sized shipments. As we can see in Figure 10 as following, it shows lower weight shipments (less than 500 pounds) accounted for a 25 percent share of the value of all commodities shipments.

The heavier weight shipments, more than 10,000 pounds, are often high value commodities which are mostly transported by express or parcel, postal, and courier services. In 2007, heavier weight shipments represented 93.5 percent by weight, 93.5 percent by ton-miles, and 35.2 percent by average miles per shipment. In 2007, shipments of less than 500 pounds were transported 1,389 miles per ton on average. The average for shipments of more than 10,000 pounds or more was 1,061 miles per ton in 2007, which is as the similar as the shipments of less than 500 pounds. Lower weight shipments (less than 500 pounds) comprised 1.5 percent of the commodities flow by ton-miles and 1 percent of the tons shipped.
Figure 10: Iowa Shipment Characteristics by Shipment Weight
Source: BTS Iowa Transportation Profile (2007)

Size of truck shipment

Although the lower weight and heavier weight shipments are transported to similar distance based on Figure 10, the light size truck shipments (less than 10,001 pounds) accounted for most of the primary freight shipment from 1992 to 2002. Figure 11 shows that the percentage of light trucks remained almost the same between 1992, 1997 and 2002 (at 93 percent).
Figure 11: Number of Trucks by Weight: 1992, 1997, and 2002
Source: BTS Iowa Transportation Profile (2002)
4.1 Iowa Rail Freight

We studied the originating and terminating commodities in Iowa as well the amount of ton-miles and tons of commodities that are transported by rail in and out of Iowa. We looked at the amount of rail movements that are made, railroad fuel efficiency, and also some of the economics of railroad transportation. Once we gathered the information about railroads, we compared our results with the truck freight and commodities moved by truck. After looking at the results and data, we have formulated a conclusion and a few scenarios that could be possibilities in making our state and country more efficient.

The top five commodities originating in Iowa by ton-mile include: cereal grains, prepared foodstuffs, animal feed, other agriculture products, and milled grain products. The top five commodities terminating into Iowa include coal, gravel and stone, cereal grains, base metal, and fertilizers.

Cereal grains, animal feed, and prepared foodstuffs account for almost 75% of what originates from Iowa. Iowa ships out products that are grown on farms. Almost everything that originates from Iowa comes from farms in Iowa. Everything else is shipped into Iowa including the top commodity coal. Coal makes up almost 65% of our terminating commodity into the state. Gravel and cereal grains make up around 25% per ton mile of the terminating commodities coming into Iowa.

![Commodities Terminating and Originating in Iowa (ton-miles)](source: Commodity Flow Survey (2002))
There are many differences in the tons of commodities that come into and out of Iowa compared to the ton-miles of commodities that move in and out. Figure 13 shows the tons of commodities that originate from and terminate in Iowa compared to Figure 12 that shows the ton-miles of commodities. Coal is being shipped into Iowa and makes up a high percentage of ton-miles, but doesn’t make up as high of a percentage in tons. This is because coal isn’t as dense and heavy as crushed stone, but is shipped into Iowa in large bulk every day. What this means is that there is much more coal being shipped in than anything else, but when it is categorized by weight, it’s not as significant as rock and gravel. Most rail cars in Iowa are traveling with coal and our main goal is to eliminate the use of coal and congestion on the rail system.

**Figure 13: Commodities Terminating and Originating in Iowa (millions of tons)**

*Source: Commodity Flow Survey (2002)*

Another piece of information we gathered about railroads was the amount of trips that railroads make in the state. The greater Des Moines area has very high density on the railroads and can become very congested from East to West and vice versa. We also gathered information about ton-miles versus miles operated. The reason for this increase in net ton-miles versus the constant number of miles operated...
could be because of the more efficient engines and train cars. Nowadays, we can put more on a train per mile and move it across country more efficiently than we did in 1985.

![Figure 14: Miles Operated vs. Net Ton-Miles](image)

Source: iowarail.com (2007)

Iowa’s railroad infrastructure has not changed much over the years. There are new tracks being constructed, but mostly there has been just reconstructing miles of track along the same path. The railroad industry isn’t looking into putting in new routes and tracks; they are more concerned with putting more tons per mile on the track, which is rendering the use of railroads for transportation more efficient.

Overall, in Iowa there are 19 railroad companies that operate over 3,900 miles of track. In Iowa, there are around 50.6 million tons shipped in and 42.5 million tons shipped out on a yearly basis. The railroads carry around 43% of the freight tonnage. These numbers are very impressive but the most impressive number is the amount of ton-miles that the railroads in Iowa move: 66.8 billion ton-miles are transported yearly. This number has been increasing over time.

Iowa railroads spend around $391 million in maintenance and upgrading activities a year, which averages out to spending around $100,000 per mile of track in Iowa. Railroads are very important not only in Iowa, but around the country and that is it is essential that they are funded adequately to continue their operations.

Table 4 explains how important the railroad infrastructure is for Iowa. Class I railroads transport a lot of freight and have revenues over 270 million; Class II move less freight and have revenues between 20.5 and 270 million; and finally Class III railroads are local short lines that have revenues lower than 20.5 million.
Table 4: Railroad Classes

<table>
<thead>
<tr>
<th></th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Companies</td>
<td>21%</td>
<td>16%</td>
<td>63%</td>
</tr>
<tr>
<td>Miles Operated</td>
<td>66%</td>
<td>25%</td>
<td>9%</td>
</tr>
<tr>
<td>Tons Originated</td>
<td>71%</td>
<td>19%</td>
<td>10%</td>
</tr>
<tr>
<td>Tons Terminated</td>
<td>73%</td>
<td>20%</td>
<td>7%</td>
</tr>
<tr>
<td>Ton-Miles</td>
<td>91%</td>
<td>8%</td>
<td>1%</td>
</tr>
<tr>
<td>Revenues Earned</td>
<td>87%</td>
<td>10%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Source: Iowarail.com (2007)

Figure 15 shows the amount of freight that originates from and terminates in Iowa in tons. What we concluded from the chart is that the amount of freight that is moved around Iowa is very small compared to the amount that is moved around the country or arrives in Iowa from other locations. This is saying that while Iowa is a leading producer of grains and farm products, Iowa is dependent on other states for certain commodities. We have concluded that each state has its own special commodity or product that others need and the more you can become an independent state, the less energy you will consume for transportation purposes. Our goal could be to become regionally dependent on energy rather than relying on energy from further locations, in a view of the rising transportation costs of moving energy and the loss of energy in the process of transporting goods. There are better, more efficient ways to go about producing energy that would eliminate a majority of the transportation costs. These are discussed next.
We concluded that there is a need to invest more in research and development into electric railroads, which eliminates the amount of energy used by trucks per ton mile and decreases the amount of traffic and wear and tear on the highway systems, therefore decreasing construction and maintenance costs. There is a need to construct systems that are environmentally friendly and will be more efficient in the future. Our future plan should be to start and eliminate the amount of coal coming into Iowa on rail and replace it with wind turbines. This will help eliminate congestion on the railroad system, pollution from all of the coal, and all of the energy we are using to get the coal from point A to B. Since our railroads move a lot of grain and various materials that are a necessity in everyday life, we need to eliminate coal because it’s not clean and renewable and can be replaced by a cleaner more efficient source such as wind. We need to go green, use our technology and research to be greener and eliminate our consumption of coal which will make Iowa the greenest state. We need to look at the infrastructure to support the electric rail system we want to implement, as well as the infrastructure to gather cleaner electric to use by the railroad companies.
5.1 Energy Reduction Scenarios

Passenger Vehicle and Passenger Rail

Based on the collected passenger data, there seems to be a few scenarios worth examining in greater detail. The two technologies that seem to align most consistently with the traffic flow patterns in Iowa are passenger rail and PHEV’s. Passenger rail seems to make sense in a few highly traveled corridors in Iowa where strong ridership would possibly make the investment worthwhile. PHEV’s appear to have the capacity to support a majority of the daily short distance driving performed by passengers in Iowa.

The corridors that initially appear to be the most conducive to passenger rail would be I-80 from the East-West, and I-35 from the North-South. The biggest benefit of these two routes would be at their intersection in Des Moines near I-235 where AADT numbers get very high with all the morning and evening traffic in and out of downtown Des Moines. Table 5 shows the amount of energy required by personal vehicles and commuter rail.

<table>
<thead>
<tr>
<th>Table 5: Energy Usage by Transit Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Vehicle</td>
</tr>
<tr>
<td>Commuter Rail</td>
</tr>
</tbody>
</table>


The amount of energy required by commuter rail is about 60% less than that required by personal vehicles in terms of BTU per passenger-mile.

The PHEV technology would prove to be most beneficial in the short distance daily trips. Assuming a PHEV-40, which means the battery can go 40 miles before switching to gas, almost all daily trips could be accomplished with no gas and only electricity. The following two tables explore the possible reduction in BTU/Passenger-Mile (BTU/PM) based on different mixes of PHEV’s, passenger rail, and personal vehicles. Before calculating the percent reduction the 17% of trucks in the total VMT was deducted from the total VMT. The energy usage for PHEV was taken for a Toyota RAV4 EV equal to 887 BTU/PM (Electric Auto Association, 2003).

<table>
<thead>
<tr>
<th>Table 6: Energy Reduction Scenario 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>33 PHEV</td>
</tr>
<tr>
<td>33 Passenger Rail</td>
</tr>
<tr>
<td>33 Personal Vehicle</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>45.2%</td>
</tr>
</tbody>
</table>
Table 7: Energy Reduction Scenario 2

<table>
<thead>
<tr>
<th>Percent</th>
<th>BTU/PM</th>
<th>Total BTU/PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>PHEV</td>
<td>887</td>
</tr>
<tr>
<td>0</td>
<td>Passenger Rail</td>
<td>1466.6</td>
</tr>
<tr>
<td>10</td>
<td>Personal Vehicle</td>
<td>3564</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2878287134</td>
</tr>
</tbody>
</table>

As shown in Tables 6 and 7, there is plenty of room for reduction in BTU/PM. Scenario 1 looked at an equal 33% mix of PHEV’s, passenger rail, and personal vehicles. Scenario 2 looked at an extreme market penetration of 90% use of PHEV’s and only 10% of personal vehicles and no use of passenger rail. PHEV’s are still only being assumed to be driven by one person with about one occupant. Passenger trains on the other hand can carry a large amount of people and still use relatively the same amount of energy and is maximized with the more people that ride the train. There is ongoing research being conducted by members of the Electrical Engineering Department at ISU investigating what percent of market penetration by PHEV’s and the corresponding load increase on the electric grid. The initial results indicate the load increase to not be as large as might be expected. The results are positive and indicate more incentive to move toward PHEV’s and away from internal combustion engine vehicles.

Truck Freight

Truck freight accounts for 74 percent of the weight of shipments moved on Iowa’s highway infrastructure. Given that truck freight transportation uses 15 times more energy compared to rail freight transportation (RFT), energy use is a major concern.

Figure 16 shows the trend of the annual energy use for freight activities from 1963 to 2004, which is important for understanding the energy consumption in Iowa. The slope of line we estimated is 1.7312. In 2004, the energy consumption was 87.2 trillion BTU, it is 5.4 times higher than the energy consumption in 1963. During the 41-year period, the value keeps increasing on average 6.5 percent per year. We will analyze the rate of growth in the future later in this report.
Figure 16: Annual Energy Use for Freight Activities, Iowa, 1963-2004
Source: U.S. Department of Energy Transportation Profile

The conventional primary sources of energy used in the transportation are included in Figure 17. These are motor gasoline, distillate fuel (diesel), jet fuel, ethanol, and natural gas. Motor gasoline is leading the energy consumption in Iowa, which is the general energy source for vehicles of Iowa and represents 63 percent of the total energy use. The other primary energy consumption source is distillate fuel, which services truck in Iowa and represents 29 percent of the total. Other energy sources used in the transportation sector are not included in this analysis—methanol, liquefied petroleum gas, residual fuel oil, compressed natural gas, and other alternative fuels that are beginning to contribute to the transportation supply mix. Especially the electric automobiles are developed by many automobile manufacturing firms, and will become increasingly reliable for short distance trips.

Figure 17: Transportation Energy Consumption by Energy Source (Trillion Btu)
Source: BTS Iowa Transportation Profile (2004)

The distance and the weight of the cargo being hauled measured in tons and ton-miles, respectively, is correlated with energy consumption. The weight of goods moved and the distance of goods moved to are more closely associated with the amount of energy consumed than with the value of the product transported. If more tons of cargos or longer distance of cargos are moved, then more energy is expended.
Based on the truck freight transportation data in Iowa from 2002, and the rate of growth (Figure 16), we estimate the truck freight shipment developing in the future. Figure 18 shows the forecast for total shipments by truck in Iowa for 2035. The rate of increase for 2035 is estimated to be smaller than that from 2002 to 2007.

![Bar chart showing total shipments by truck in Iowa for 2002, 2007, and 2035.]

**Figure 18: Iowa Truck Freight Transportation (Forecasts for total of shipments and by mode, tons-thousand)**

In order to estimate the future energy use of the truck freight activities in Iowa, we use the equation \( y = 1.7312x - 3382.1 \) (Figure 16). The energy use is forecasted to be 140.89 trillion BTUs in Iowa in 2035. This assumption is dependent on the current transportation system. If the electric automobile or other saving energy technology becomes popular in the future, the energy use should be lower than our current energy consumption.
Rail Freight

Coal is the commodity that we examined further. If we could eliminate the energy we use from coal and replace it with wind power; how many wind turbines would we have to build? After some research on coal and how many tons of coal comes into Iowa, we have made the following calculations:

In terms of energy being delivered by a typical wind turbine, the average energy is roughly around 150 million KWhr over a course of a year. This breaks down to having around 311,000 wind turbines in the state of Iowa. If we look at having one turbine on every 20 acres, we calculate out that around 56,276 SQ. Miles in Iowa needs to be covered with wind turbines. In conclusion, we have determined that approximately 17—20% of Iowa needs to be covered with large wind turbines.

- These numbers can be changed depending on acres per turbine and other assumptions. A further analysis could be conducted to figure out the amount of trains that we could eliminate per turbine and break it down into the amount of energy we can save in transportation, and energy we use to extract the coal from the mine.
Additional scenarios for further research:

What if:

- We went to Electric Trains and set up power grids in all of the land owned by the railroad companies?
- Trains could be charged on the tracks while they were driving by somehow having electrical current in the tracks?
- We connected the 5 main cities and Midwest states by High speed rail (Minneapolis, Des Moines, Omaha, Chicago, Kansas City)?
- We processed our grains here in Iowa instead of shipping the raw material out and then shipping it back into the state?
- We eliminated Coal all together and used only Wind and Biomass?
- We used the railroad right-of-way and build more wind farms along the tracks, then railroad companies would produce their own energy and move closer to electrical train engines?
- Build our power transmissions lines on the Railroad right-of-way from east coast to west coast
- Used the rail systems that are class III to move passengers around the state?
5.2 Future Research Opportunities

Passenger Vehicle and Passenger Rail

There is an opportunity for further research with respect to passenger rail and passenger vehicles. Before major investments are made, especially in a state with a population density like Iowa, there needs to be a better understanding of what levels of ridership will be required to justify the investment in passenger rail. Another key step will be to understand if those levels of ridership that justify the investment are attainable in the state of Iowa. There is also a need for research into the area of trip length and getting an understanding of what lengths of trips are economically competitive on passenger rail. An interesting proposal for future research would be to see if the long range distance of electric cars increased, if they could compete with passenger rail in terms of energy consumption and economics. There are also opportunities for further research with regards to PHEV’s. PHEV’s have not penetrated the market in large amounts yet, so driving patterns with PHEV’s have not been tracked. Further research could examine how closely PHEV driving patterns replicate current vehicle driving patterns. Members of the ISU Electrical Engineering Department are currently conducting research in this area paying special attention to the load impacts on the electrical grid.

Truck Freight

Future research on truck transportation can be based on the new energy uses. The traditional truck transportation system needs to be replaced by a new energy truck freight transportation system which will consume less energy. The amount and type of commodities that can be moved by the new system need to be studied further. Also, a cost-benefit analysis of potentially moving freight shipments from truck to rail is a promising avenue for future research.

Rail Freight

Another option for research in Iowa and the rail system would be to look further into limiting the coal coming to the state. Also, there is a need to look into the amount of investment we need to change over railroads to electric and how we could use the land owned by the railroads to install wind turbines. While the railroads are very efficient nowadays and have maximized the amount of goods they can carry on one load they need to use renewable energy to move the commodities. We have the infrastructure for railroads, but not the infrastructure to eliminate the coal. The only way to eliminate coal is to begin building infrastructure to replace the energy we get from coal, such as wind turbines. We can eliminate the amount of trips into Iowa and help with any density problems that are becoming a problem. We need to start small with the elimination of incoming coal and begin building an infrastructure to support our energy needs in the state of Iowa.
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