PAVING THE MEGA CITY
MASTER THESIS REPORT
Gosha Galitsky

Umea Institute of Design
MA Advanced Product Design
in collaboration with
Umea Institute of Design
Part of the Atlas Copco Group
We can carpool, take public transportation, or buy hybrid vehicles all we want to help save the environment, but the truth of the matter is we still need roads to ride on.

Finding green methods to repair or replace existing roads deserves just as much attention as the vehicles that ride them.

Scott Wertel
Road Engineer
ABSTRACT

While the design and the technology behind the vehicles we drive has gone a long way, the chief principle in which we construct our roads today, the materials and the machinery we use to do it has hardly changed for the last 40 years.

This project will take a fresh look at an industry that has remained stagnant for several decades. Looking into a future in which large Mega-Cities will develop, the aim of this project will be to develop a new solution for constructing and maintaining the transport arteries in those cities.

This project will be performed in collaboration with Dynapac, a leading manufacturer of road construction equipment, with supporting feedback from NCC roads, the Scandinavian road construction group.
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INTRODUCTION

Today, a world without roads, cars, motorcycles and bicycles is almost unimaginable. The entire road infrastructure with its diversity of transport concepts now has a prominent position in our society. The question is therefore not so much whether there will still be a road infrastructure in the future, but rather how will society view these mobility facilities in, say, thirty or forty years’ time.

Comparing the road infrastructure and means of transport of today with those of forty years ago, it becomes clear that in the next forty years’ time everything will again look a lot different to how it looks today.
RESEARCH
ASPHALT

Since 1930 the majority of roads are paved with asphalt concrete. Asphalt is a mixture of approximately 95% crushed stones (aggregate) and sand, and 5% bitumen, which acts as the binder, or glue. Mixing is done while heating the material to 180 degrees Celsius. Bitumen is black and solid at room temperature. The viscous nature of bitumen allows the asphalt to sustain significant flexibility, creating a durable surface material. There are many different types of asphalt, each with its own combination of different amounts and type of bituminous binder and mineral aggregate, and each type of asphalt has performance characteristics appropriate for specific applications.

Advantages of asphalt roadways include relatively low noise, relatively low cost compared with other paving methods, and ease of repair. Disadvantages include less durability than other paving methods, less tensile strength than concrete, the tendency to become slick and soft in hot weather and a certain amount of hydrocarbon pollution to soil and groundwater or waterways.
Bitumen, the binder used in modern asphalt, is a black, highly viscous liquid or semi-solid present in most crude petroleum and in some natural deposits.

The bitumen binder that is used in road construction is a residue from the distillation process of crude oil.

Bitumen is separated from the other components in crude oil by the process of fractional distillation, usually under vacuum conditions.

Asphalt is typically stored and transported at a temperature of 150 degrees Celsius. The backs of trucks carrying asphalt, as well as some handling equipment, are also commonly sprayed with a releasing agent before filling to aid release. Diesel oil is sometimes used as a release agent, although it can mix with and thereby reduce the quality of the asphalt.
Modern asphalt roads have a multi-layered structure. The layered structure allows loads to be dispersed evenly across the road. Each layer of the road is optimally designed to fit specific demands.

The top layer of the road structure needs to create a good contact with vehicles' tyres. It needs to withstand environmental wear, temperature changes, be waterproof and drain water effectively. The top layer must not be slippery or develop cracks, potholes or other forms of deterioration.

The base course is an intermediate layer. It is designed to reduce rutting and withstand the highest stresses that occur about 50-70 mm below the surface course layer. Binder mixtures typically use a large aggregate size with a lower asphalt binder content.

The subgrade course is specifically designed to effectively distribute traffic and environmental loading, to ensure that underlying unbound layers are not exposed to excessive stresses and strains.

Last but not least, it is important that all layers have a strong bond to each other.

Like all structures, roads deteriorate over time. Deterioration is primarily due to accumulated damage from vehicles, however environmental effects such as frost heaves, thermal cracking and oxidation often contribute.

Rods are typically designed for a service life of 30-40 years, however some roads built today are expected to last 100 years or even more.

Passing traffic causes compression of the road, and with time the asphalt binder loses its elasticity. Once that happens pieces of the asphalt can become dislodged. The tyres passing on the missing patch will quickly enlarge the hole, creating a pothole in the road.

Trucks are a major source of wear on roads. It is estimated that a truck causes 7,800 times more damage to a road than a passenger vehicle would. In road design damage from passenger cars is often dismissed as insignificant.

Environmental damage occurs when water seeps under the asphalt. In cold climates this water will freeze, causing a separation between the layers of the road.

Asphalt is recyclable and recycling has increased significantly in recent years. Quantities recycled directly back into road surfaces vary from country to country, but can be as high as 70%, making it one of the most recycled materials on the planet (by volume). Asphalt recycling saving money and preserving non-renewable natural resources.

There are several limitations to recycling asphalt. Regardless of the recycling technique used, the recycled asphalt has a lower quality than “virgin” asphalt. Therefore the recycling process can only be done once, and it is usually limited to side roads and low traffic highways (these limitations vary according to legislation in different countries, but the general principal remains).

There are several methods of recycling asphalt:

**TRADITIONAL RECYCLING**

This method of recycling involves milling off the top layer of asphalt using a road milling machine also called a planer. This machine loads the milled material onto a
ANATOMY OF A ROAD

- Drain opening
- Sidewalk
- Electricity, telecom, gas pipes
- Electricity, telecom, gas pipes
- Wear course
- Base course
- Subgrade
- Drain pipe
- Water pipe
- Hot water pipe
- Road markings
- 2 degrees runoff angle
- Street light
truck, which takes it to the asphalt plant. In the asphalt plant the milled aggregate is mixed with fresh aggregate and virgin bitumen to produce Reclaimed Asphalt Pavement material (RAP). The RAP is then paved back onto the road using standard paving equipment.

The disadvantage of this method are the lower quality of RAP compared to standard asphalt, because the drum of the planer crushes the aggregate again.

Another significant drawback in this technique is the need to haul the material back to the plant which results in added air pollution and logistic complications.

To counteract those disadvantage, several "In Place" techniques have been developed.

### HOT IN PLACE RECYCLING

In this technique, the existing asphalt pavement is heated using infra-red heaters or microwaves. The heat is transferred to the aggregate, which melts the surrounding binder. The hot asphalt can be then scraped off the road using a small amount of force, mixed with virgin bitumen and re-paved back on the road. The mixing and re-paving are usually done on site using a dedicated "recycling train" that consists of a heater, scraper and mixer followed by a traditional paver.

Several companies manufacture self-contained machines that are capable of executing all functions of hot-in-place recycling in a single machine pass. The leading manufacturer of those machines is an American company “Angelo Benedetti” (www.angelobenedetti.com)

The advantages of the hot-in-place recycling method are a relatively quiet operation of the machine, and the higher quality of recycled aggregate it produces.

The disadvantages include the heating elements which are very energy-intensive and the heating process that is slower when compared to cold-in-place recycling. In addition, due to temperature penetration the depth of this technique is limited. If the surface beneath the recycled pavement is cracked, the newly paved road will exhibit "reflection cracking" soon after paving.

### COLD IN PLACE RECYCLING

This technique involves a specialized machine that is equipped with a drum that mills the wear course and also part of the subgrade course. The drum moves the milled material upwards, where it is mixed with virgin aggregate (sometimes foamed bitumen) and instantly laid back on the road, to produce a new base course. The leading manufacturers of cold recycling machines is the German company Wirtgen (www.wirtgen.de).

The advantages of this technique include a fast work pace, and the deep work area compared to hot-in-place.

The disadvantages include high noise and dust pollution, and the fact that after the machine passes a new (although thinner) wear course still has to be laid on for the road to be operational.

### ASPHALT ALTERNATIVES

In parallel with asphalt recycling and in anticipation of limited availability of oil resources in the near future, several alternatives to asphalt paving are being explored.

#### CONCRETE PAVING

Concrete is being used for paving in low percentages, primarily in highways in the US, Britain and central Europe. One advantage of cement concrete roadways is
that they are typically stronger and more durable than asphalt roadways. Disadvantages of concrete roads are that they typically have a higher initial cost, can be rougher to drive on and are difficult to repair.

In general concrete highways are better suited for trucks and heavy traffic, while asphalt roads offer better silence, comfort and safety which is crucial for passenger cars.

**RUBBER REINFORCED ASPHALT**

Recently experiments have been made in adding rubber from recycled tyres to asphalt mix. This reduces the amount of bitumen needed, allows tyres to be recycled and also results in a more adhesive road surface. However, since there are many reports both on the success and failure of this technique, I was not yet able to conclusively determine whether this could be a viable alternative for asphalt the future.

**RUBBER REINFORCED ASPHALT**

Bio-asphalt uses binder extracted from biologic oil rather than fossil oil. However, the process growing crops for bio-oil produces a lot of pollution per bio-oil liter, and therefore it is doubtful that this technique will have a significant advantage for the environment.

**AQUAPHALT**

Aquaphalt is a patented substance developed by an American company, that contains binder which reacts with water. More research on this material will follow.

**LOW TEMPERATURE ASPHALT**

Since significant amounts of energy are invested to heat the asphalt, different methods are being developed to produce asphalt which remains workable in lower temperatures (Warm Mix and Cold Mix).
MECHANISED PAVING

An asphalt paver is a machine used to distribute, shape, and partially compact a layer of asphalt on the surface of a roadway, parking lot, or other area. It is sometimes called an asphalt-paving machine. Some pavers are towed by the dump truck delivering the asphalt, but most are self-propelled. Self-propelled pavers consist of two major components: the tractor and the screed. The tractor provides the forward motion and distributes the asphalt. The tractor includes the engine, hydraulic drives and controls, drive wheels or tracks, receiving hopper, feeder conveyors, and distribution augers. The screed levels and shapes the layer of asphalt. The screed is towed by the tractor and includes the leveling arms, moldboard, end plates, burners, vibrators, and slope sensors and controls.

In operation, a dump truck filled with asphalt backs up to the front of the paver and slowly discharges its load into the paver’s hopper. As the paver moves forward, the feeder conveyors move the asphalt to the rear of the paver, and the distribution augers push the asphalt outward to the desired width. The screed then levels the layer of asphalt and partially compacts it to the desired shape. A heavy, steel-wheeled roller follows the paver to further compact the asphalt to the desired thickness.

Most manufacturers of asphalt pavers offer several sizes and models. Engine horsepower is usually in the 3-20 hp (2-15 kw) range for smaller, towed pavers, and may be in the 100-250 hp (75-188 kw) range for larger, self-propelled pavers. Most engines use diesel fuel because that is the fuel commonly used on other construction equipment.

Most larger, self-propelled pavers are about 5.8-7.0 m long, 3.1 m wide, and 10 ft 3.1 m high. They weigh about 9,090-18,180 kg depending on the hopper capacity, engine size, and type of drive system. The typical rate of asphalt placement is 31-92 m/min. The standard paving width is 8-12 ft 2.4-3.7 m up to a maximum width of 12.2 m with the use of screed extensions on some machines. The maximum paving thickness on a single pass is 152-305 mm.

Options include lighting packages, manual and automatic screed extensions, and various sensors and controls to alter the grade (fore-aft dimensions) and slope (side-to-side dimensions) of the layer of asphalt.

Asphalt as a paving material dates back to 1815, when Scottish road engineer John McAdam (or MacAdam) developed a road surface consisting of a compacted layer of small stones and sand sprayed with water. The water dissolved the natural salts on the stones and helped cement the materials together. This type of road surface was named water macadam in his honor. Later, coal tar was used as a binding material instead of water, and the new pavement became known as tar macadam, from which we get the shortened term tarmac that is sometimes used to describe asphalt pavement.

Tar macadam pavement was used in the United States up through the beginning of the twentieth century. Modern mixed asphalt pavement, which provides a more durable road surface, was introduced in the 1920s. Unlike macadam, in which the
stone and sand aggregates are laid on the road surface before being sprayed with the binding material, the aggregates in mixed asphalt are coated with the binding material before they are laid. At first, mixed asphalt was simply dumped on the roadway and raked or graded level before being rolled smooth. In 1931 Harry Barber, of Barber-Greene Company, developed the first mechanical asphalt paver in the United States. It traveled on a set of steel rails and included a combination loader and mixer to proportion and blend the components before spreading the asphalt evenly over the road surface. The rails were soon replaced by crawler tracks, and the first production paver came off the Barber-Greene line in 1934. This new machine quickly became popular with road builders because it allowed them to place asphalt more rapidly and with greater uniformity. Hydraulic drives replaced mechanical drives in pavers during the late 1950’s to give the operator even smoother control. Today, almost all asphalt is placed using paving machines.
MEGA-CITIES
Recent studies show that world population growth is projected to reach 9 billion by 2050. The Earth’s ability to support people’s current life styles will not last long. In addition to this, urbanization remains one of the absolute mega trends of the coming decade. Today, half the world’s population- 3 billion people- live in urban areas. Close to 180,000 people move into cities daily, adding roughly 60 million new urban dwellers each year (source: Intuit, October 2010). The fact that a vastly increasing percentage of people live in urban areas worldwide puts extra stress on basic energy resources, and on ecosystems.

These Mega Cities will cover only 2 percent of the Earth’s land mass, but they will account for seventy five of the planet’s industrial wood use, sixty percent of all human water use, and eighty percent of all human-produced carbon emissions.

“THE STRUGGLE TO ACHIEVE AN ENVIRONMENTALLY SUSTAINABLE ECONOMY FOR THE 21ST CENTURY WILL BE WON OR LOST IN THE WORLD’S URBAN AREAS.”
### Megacities by Population Growth

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<th>Rank</th>
<th>Megacity</th>
<th>Country</th>
<th>Continent</th>
<th>Population</th>
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<tr>
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<td>France</td>
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<td>1.00%</td>
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**Source:** www.mckinseyquarterly.com
The new generation that will occupy the Mega cities is born into a world where technology is everywhere, it is ubiquitous and it is taken for granted. People of the future will expect all the devices around them to be smart, connected and designed for almost intuitive ease of operation. Abundance of technology will allow a much more sophisticated data connectivity and smart asset management of the Mega City.

MORE PEOPLE
In the year 2030, the number of people on Earth is predicted to be around 9 billion. 65 percent of these people, a number almost equal to the entire planet’s population today, will live in cities.
MORE TRAFFIC
The traffic volume and axle loads are expected to increase sharply. The biggest increase will be felt in heavy traffic public transport and transport of materials into and out of the Mega-City.

MORE DEMANDS
In the future personal demands will be higher. Everybody wants to live in a modern city and to commute with ease to and from the work place, but no one wants to see the roads, smell car exhaust and hear the construction noise.

LESS RESOURCES
In parallel to the increasing demands, the resources of fossil fuel and energy will become more scarce, and the protection of the environment will become increasingly critical for maintaining a normal lifestyle.
ROADS OF THE FUTURE

SMARTER ROADS
The abundance of smart ubiquitous technology will spread to roads as well. While roads today are by definition passive, in the future they will be able to report their condition and communicate with cars. Roads are able to adapt to environment condition and driving conditions—control friction, heat and drain themselves when needed. Smart speed bumps will regulate traffic and recover energy from vehicle braking.

SHARING FOR REDUCTION
Due to the large number of population sharing will be necessary to reduce traffic volume in the mega city. Studies predict that the volume of public transport in the future cities—light trains, metro systems and Bus Rapid Transit
Driving Automation

Automation of driving has been a growing trend since the 1990's, and it is predicted to continue in the future. Automated vehicles will be able to communicate with sensors in the road and drive independently while maintaining optimal distance and speed. The option of not driving will in turn revolutionize the definition and purpose of what driving means to people. When driving becomes optional it will be transformed from a necessity to a purely recreational activity.

Networks— will increase by more than 50 percent.
For city dwellers who will want to use private transport car sharing or car renting will often be a more attractive financial option than owning a car.
OBSERVATIONS
COCKPIT

The cockpit of the paver offers a limited view into the hopper and to the sides of the machine. Because the width of the machine the operator can only see what is happening on one side at a time. Although the machine is slow it is important to improve the operator’s field of view.

During the observation both operators stated that it is very important for them to have a movable work station so they can observe different points around the paver. Currently the situation is partly solved using tracking cameras.

One of the dangerous situations that was mentioned during the observation was when the truck backs up towards the paver, neither the truck driver nor the paver operator are able to see if a person comes in behind the truck in an attempt to direct it towards the paver.
The screed watcher’s job is labor intensive and manual. Screed watchers follow the machine on foot and monitor the stability of the screed as the machine advances.
VISIBILITY

Visibility of the machines and the crew plays a major part in the safety of working on the road, especially while traffic is passing by. This will become increasingly significant as more and more jobs will be done during night time.
Cleaning the paver at the end of every workday is a part of the job. During work some mechanisms become completely encased in asphalt and must be cleaned using diesel fuel.
SAFETY

The safety of working on board the paver can be improved a lot. Currently the machine has a lot of cluttered areas (some of them very close to the cockpit) that pose a significant safety risk even when the machine is not moving. Ergonomics and access issues must be re-considered to arrive to a better and safer solution for the operators.

The crew modified the paver with several storage places for manual tools, truck weight sheets that are placed in a postbox, a camera that tracks the hopper and an Infra-Red camera that films the material left by the paver.

Another important modification includes a steel sheet that makes the hopper curved instead of angular. This assists in material transfer and reduces asphalt separation.
INTERVIEWS
INTERVIEW 1

Carsten Bernhardt, 20 mins
13/2/2012

PRECISION AND LEVELING

Sensors in the machine—there are embedded sensors “PLC system” that measure the level of material, speed of material delivery through the “Tunnel”, the level of material in front of the auger. The machine measures its location according to a reference line, which is sometimes laid out in wire.

The parameters that need to be measured are paving profile and cross-profile evenness (parallel and perpendicular to the milling direction).

The PLC system is responsible for keeping the machine level.

The machine is able to achieve a wide range of paving profiles to create an angled road surface for water drainage.

Can GPS be used for machine positioning? GPS itself is not precise enough, the paver needs a precision of approximately 4mm. This can be achieved by a system called Millimeter GPS. This system focuses GPS data with a dedicated laser.

ASPHALT TEMPERATURE

90 percent of the energy invested in the paving process is spent at the mixing plant, where the aggregate is heated and mixed. The asphalt needs to achieve a temperature of 180 degrees to mix. There is some heat loss during the transport of the asphalt. If it cools below 150 degrees it becomes unfit for paving.

Therefore if a method is found to reduce the temperature of the asphalt, it will greatly reduce the energy needed for paving.

CONCRETE PAVING VS ASPHALT PAVING

Concrete paving is as energy consuming as asphalt paving. Concrete is very stable and stiff, but also difficult to repair and sensitive to salt (making it impractical in Northern countries). Asphalt is more flexible and easier to repair, but in heavy traffic it will become rutted faster. Asphalt can have more voids, which makes the material more permeable and reduces the danger of aquaplaning for vehicles. Asphalt is softer to travel on and is more comfortable for passenger vehicles.

Geographically England uses many concrete in paving, especially in highways.

Color roads are being paved today, sometimes sidewalks have a different color than the road.

In general concrete is better for heavy traffic, and asphalt is better suited for passenger traffic.

FUTURE TRENDS:

There will definitely be a trend in energy reduction for all machines, especially planers.

There is a trend today towards more automated processes.

Perhaps repair could be performed with lighter machines and lower energy demands (as opposed to full scale construction)

“A possible future trend is a more strict separation of roads for different types of traffic.”
THE BASIC DESIGN OF THE PAVER HAS NOT BEEN UPDATED FOR THE LAST 50 YEARS.

CARSTEN BERNHARDT
PRODUCT MANAGER, DYNA PAC

FOR HOW LONG WILL WE STILL HAVE AVAILABLE OIL? AND WHAT WILL HAPPEN TO ASPHALT PAVING WHEN THERE IS NO MORE OIL LEFT?

"
Problems with metal objects embedded into the road (bridge expansion seams, manholes, drain covers, reinforced concrete)-causes severe damage of the milling drum. How can this be prevented? Metal detector in front of the machine. Technique exists, but still creates too much malfunction from the steel body of the planer or it is a separate process, which increase costs.

OPERATOR PEACE OF MIND
It is a very important consideration. fully agree, as milling is due to the dust, safety and the vibration, caused by the milling process, not an “easy” job. Competition just launched as an possible answer a fully closed cabin, which is foldable for transport. We do see a trend in the milling business to minimize the dust exposure and following the negative effect on the operator’s health and the surrounding (and already some regulations are in place). For e.g. planers with a cutting width larger than 1 m must be equipped in Germany already today with an approved system, which reduces the dust below limits. If the planer does not have such technique, operators must wear a breathing mask. You can imagine that this would look scary if a planer works in a city with operators wearing a breathing mask and a woman with a baby buggy passed by.

WORKING SPEED
The achievable working speed depends on many parameters; mainly the cutting depth and the hardness of the pavement. Everything is possible between 1-30 m/min. 48m/min- max speed (looks like approx 6km/h) This is just the max transport speed, when a planer e.g. moves from one job to the next.

INCREASING PRODUCTIVITY
The recent trend is to use wider cutting drums (max 4,3 m for a full large milling job) with higher engine power (up to 1,000 hp). Another idea is to fine-tune the rotation speed of the milling drum to optimize the milling process and the material flow itself. And bit suppliers are looking for bits with a longer life time to decrease operating costs.

RELIABILITY/SERVICE
The planer is always a bottle neck machine at a road construction job. If a planer fails, the whole job stands still as there is no back up unit shortly available.

INTERVIEW 2

Unloading from trailer is scary, machine is very high and unstable this is indeed a problem, especially with a planer with 3 tracks or 3 wheels only.

NIGHT WORK
this trend can already be seen today in mega cities, but also on highways with high traffic load all over the globe.

INTERFACE WITH TRUCK
Trucks are always a bottleneck when paving. Either you have too many or not enough trucks. The logistic is indeed an issue on larger paving jobs. There are many improvements possible.

PROPULSION METHOD- TRACKS VS WHEELS
Tracked planers (usually larger than 1 m cutting width) are used for higher performance needs and larger jobs, whereby rubber tired units (usually up to 1 m cutting width only) are mainly used due to higher manoeuvrability for city road repair and maintenance works.

PRECISION AND USER INTERFACE
It can be improved, there is a trend in the milling business to use more GPS technology for levelling, but precision is still an issue. It is interesting to see that in
countries, where roads are fully renovated, you find more planers with advanced levelling systems in operation like for e.g. in Germany, where the milling jobs are mainly maintenance work. The geologic data - for a new job - are fully available in 3D and can be used easily also for GPS levelling.

MOVABLE MILLING DRUM

Japanese manufacturers (e.g. Sakai) are offering planers with hydraulically moveable cutter boxes to move around e.g. a steel man hole cover or to have the drum at the right side for the job (left side traffic / right side traffic). In some countries it is not allowed to mill against the traffic direction!

OPERATOR SAFETY

Again, Japan is a good example. I was on several night milling jobs in the city of Tokyo and the contractors often have only to mill&pave about 200 m asphalt pavement section in one lane of a 6 lane highway. Only the lane under construction and max the lane beside were closed. There were just one operator per planer but a dozen people around each machine (mills, pavers, broomer, trucks etc.) to take care of safety.

"THE PAVING INDUSTRY HAS BEEN ADVANCING IN INCREMENTAL STEPS SINCE THE 50’S.
SOON, A TIME WILL COME WHEN WE WILL HAVE TO RE-THINK THE PAVING PROCESS ALTOGETHER."

"TRUCKS ARE ALWAYS A BOTTLENECK WHEN PAVING. EITHER YOU HAVE TOO MANY OR NOT ENOUGH TRUCKS."
INTERVIEW 3
Juergen Seemann,
Marketing Manager Planer Sales

OPERATOR LOCATION

normally the operator stands on the planer to ensure best visibility to the cutting edge and surround visibility, but I have seen again in Japan planers, where the operator controls the mill via remote cable from the side and walks on the ground.

RECYCLING

As I understand, the new idea in this future concept is be to make the technique available in independent modules (milling chamber, screed, mixing units etc.) to decrease loads and dimensions. But on the other side, with each separate self propelled module the traffic load would be increased, wouldn’t it? Is this not contrary to the needs in the high traffic load in future Mega cities?

INFRA RED ASPHALT RECYCLER

I noticed this technique which re-heats the paved asphalt so it does not need to be milled, but instead you can just scrape it off the road using very little force.

Do you think such an application (followed by a mechanical brush, for instance) could replace the milling drum?

I assume the risk to the machine would be much lower in this case. As I mentioned earlier, today both technologies (hot and cold in place recycling) do exist as parallel offered concepts. Both systems have pro/cons (as always!). According my understanding the hot in place recycling (this is the one, you described above) concept has the advantages that the gravel is less destroyed by the scraping/milling process and that the reheated bitumen (some agents are still added) can be fully reused for the new pavement at a relatively high quality.

In cold in place recycling concept less energy is needed, but the gravel are cut via milling process and just some agents are added to the (not reheated) milled material. As a result this concept offers lower re-pavement quality.

FUTURE TRENDS:

Some future trends that are observed at Dynapac: Longer longevity will increase the population on the planet. Material movement will increase, especially the movement of raw materials and goods.

The traffic pattern will be more organized, especially in the case of material transport (road trains)

Swarm mechanics and traffic optimization are already being looked at by Mercedes Benz.

INFRASTRUCTURE

Roads are always connected to utilities and infra-structure. Therefore while repairing a road one must consider also infrastructures such as telecom, electric networks, heating systems, drainage etc.

MATERIAL COSTS

As costs increase recycling becomes more and more attractive. Stones are expensive, so recycled aggregate is economically viable, as it cuts down paving costs.

Currently bitumen is the best material for its cost. Only 10 percent of roads worldwide are built using concrete. New techniques attempt to reduce bitumen content in the asphalt, by exploring additives such as recycled rubber from tyres, plastic bottles etc. There are experiments on cement soil mix.
When the material is laid out the asphalt begins to cool and it will become un-workable after 25-30 minutes. In this time frame the rollers have to compact it. Recycling will require less transport of material into the city. Minimal disturbance to city life is important. Weight of machinery must be light so it will be possible to work it in narrow streets and overpasses. Tokyo could be a good reference. In Tokyo most repair jobs are done at night, sometimes the workers can only work on a 200m section at a time before they have to re-open the road, since they only have a 6 hours time frame before the traffic flow has to be resumed.
I am responsible on road paving in 55 percent of Sweden. We own 35 pavers. The work is done in the summer, since in the winter the ground is frozen 1m deep. During the winter the machines are stored in a depot.

**SHUTTLE BUGGY**
We use the shuttle buggy to achieve continuous feeding of the paver. The shuttle buggy is very useful not only to keep the supply constant but also to keep the material homogenous, so the aggregate and the binder do not separate. It is very important to keep the asphalt mix moving as much as possible, otherwise separation happens.

**CREWS**
The same crew works on the project from start to finish. They live in temporary caravans. They will eat together, they will sleep together, and they are together all the time. Therefore it is important that the crew is good and they like each other. The job will go from May to October.

Short road paving projects might take one season, others take 2 years.

**ASPHALT PLANT**
When we come to the site we bring our own mobile asphalt plant. It is transported in six containers, so we call it “Six Pack”. The plant will start producing asphalt in the same production rate as the paver can take (approximately 250tons/hour) and the material will be transported to the pavers. The plant is powered by diesel power. Once the paver starts, we will do our best not to stop it. The operator does not stop to eat; they will eat on the paver. Ideally the paver will go non-stop for the whole duration of the shift, which is 10 hours. There will be one paver working and two rollers behind it.

**SETTINGS OF PAVING**
When we come to the site first we will set up a testing site. We define the type of the road and the volume of traffic that will pass on it. Sometimes we design the right lane for heavy traffic. There we will test and establish all the parameters needed for paving: paver speed, screed settings, asphalt type, aggregate size, etc. There are numerous settings on the paver and if any of them is not entirely correct it will result in poor road quality. The void quantity in the asphalt is important- too tight and the water will build up on the road. If there are too many voids the asphalt will be brittle and it will degrade quickly in 2-3 years. Once all the settings are established they are documented and the sheet is put on the paver, so the operator knows which settings to follow.

**MAINTENANCE**
The maintenance of the pavers is done over the winter by the operators. We trust the pavers very much and it is very rare that a serious malfunction occurs.

**ASPHALT TEMPERATURE**
We build a curve that is called “risk curve” and try to keep the temperature of the asphalt even and always above the curve. We can see that with the shuttle buggy we have far less fluctuations. Asphalt is a tricky material, and it often happens that the asphalt will separate. This happens if the asphalt is too cold, the aggregate is coarse, and sometimes it also happens because of the pavers.

There is an ongoing effort to reduce the working temperature of the asphalt. Asphalt is produced at approximately 180 degrees, and becomes unfit for paving around 120 degrees. However, new types of asphalt are being developed that require lower temperatures to pave.
“90 percent of the fuel and energy invested in a paving operation is spent on heating asphalt at the asphalt plant.”

“Once the paver starts working, it must keep moving.”
Even a small decrease in temperature allows us to save a lot of energy needed for the heating and save large amounts of fuel. There are new techniques that use.

The asphalt is transported to the pavers via dedicated trucks. The trucks have double hulls which insulate the asphalt and keep it warm. However, the maximum range for asphalt transport remains 100km, therefore for remote jobs we will need the mobile plant.

The trucks are covered to preserve the temperature of the asphalt.

There is a special technique of loading the material from the asphalt silo to the truck—first the front part of the truck is filled, then the rear, and then the middle. This results in a homogenous mix.

Despite all this, when the trucks change in front of the paver the last batch material dumped from the truck will usually be colder than the rest. This results in “Cold seams” on the road, which have lesser quality and will deteriorate faster in the future.

We use a thermal camera that is mounted at the back of the paver to monitor the temperature of the material that is being laid down. Using this camera we can see temperature fluctuations on the material.

**PAVING CONTINUITY**

If we make a mistake on the road we can not stop. If the paver stops for more than 5 minutes we will have to stop the job and continue afterwards. When we stop the paver a mill makes a continuous grade downwards and then the paving resumes, so there will not be a visible seam on the road.

The crew meets before the project and all the members sign a document.

**RETROFIT**

We retrofitted our pavers with several modifications:

1. Extra screw behind the large auger. This reduces separation and pushes the material under the thumping unit in a more even way.

2. “Ladder”- measuring wheel in front of the paver. The wheel lets us know when the paver is about to come over an unevenness in the road, and we can compensate with the movement of the screed.

3. Side seam heater- when the paver cannot pave all the lanes at the same time we want the seam between the lines to be very slight. For this purpose we installed a heater on the side of the paver. It uses gas fuel, and the system is separated from the screed heater.

**PERSONNEL TRAINING**

Usually it takes only one year to train a person to operate the paver. Of course other people can learn at a slower rate. A person would usually start learning on a roller (which is a mistake in my opinion, since the roller is the last machine on the road, so if the paver operator makes a mistake an experienced roller driver will still be able to fix it).

After that the person becomes one of the “Screed watchers”- they walk behind the paver and adjust the screed if needed. After that they move to the operator’s post in the paver, which in fact is quite easy to operate- you only need to watch that the settings are right and the paver goes on as planned.

There are usually five people operating each paver.

Truck drivers are not part of the paving crew, but they usually know each other. Truck drivers usually haul wood during the winter and asphalt during the summer.
JOB TYPES
We have several teams:
1. Large paver team (full scale highway paving)
2. Medium paver team (Urban paving)
3. Small paver team (Fixes/Urban)
4. Manual Repair team (they work by hand with small manual thumpers)
5. “Snabbil”- a truck that is able to pour asphalt through a hose in front of it.

SMALL MARKET
All of Sweden buys less than 10 pavers a year. Therefore a new concept must appeal to all users, not only for the Swedish or even the European market.

Propulsion- we use wheeled pavers because they are more agile than tracked ones.

COMPONENTS THAT COULD BE IMPROVED
Hopper- very bad interface, a legacy from older machines. Some other solution needs to be found.
Conveyor belt- causes material separation.
Screw- can cause separation of the material.
Double screw could be a good solution.

OPERATOR COMFORT
it is very important that the cabin can move sideways, so the operator has a good view of what is happening around the machine.
Operator protection- closed cab.

SCREED STABILITY is a big issue- trucks that bump the paver will cause a bump in the road. Therefore it is important that the truck stops before the paver, and then the paver will come up to the truck and start pushing it.

Risk curve and temperature monitoring results
Note blue stripes.
(Image courtesy of NCC)
DYNAPAC GERMANY

As part of the research process, I had the opportunity to visit the Dynapac factory in Wardenburg, Germany. The visit was organized by Jorg Knoublach and Juergen Seemann, managers of engineering and marketing departments for Dynapac. During this visit I could observe the various pavers being assembled in the factory, and later to discuss the previous research findings with experts in the paving field.

In addition, I was able to present my initial concepts to the executives at Dynapac and have a feedback discussion about the feasibility and the potential interest of such concepts for Dynapac.
technology

The main challenge will be to define the right technology in Dynapac portfolio. Achieving milling unit and milling depth control is important.

Existing technology by using a standard or high spreading auger system and systems is also Dynapac core technology.

The challenge is to achieve the required road properties and also the way how...
Paving Today

IDENTIFIED PROBLEMS

LOGISTICS AND TIMING
Feeding the paver requires constant attention and complex planning. Multiple machines are involved in the process, and they all have to be synchronized in precise orchestration to be able to pave efficiently and achieve high paving quality.

TEMPERATURE AND ENERGY LOSSES
A massive amount of energy is required to bring the asphalt to a working temperature of 180 degrees. Once it is hot, there is a constant struggle to maintain the temperature of the asphalt high and steady, otherwise it becomes unworkable and the paving quality is reduced.

OPERATOR DISCOMFORT
Road working machines often work in running traffic, which increases risk for working personnel. Work is increasingly done at night, which created problems with visibility and fatigue. Being so close to the machine, the operator is constantly exposed to fumes, noise and vibration.

DISRUPTION OF TRAFFIC
A key problem during road maintenance is the necessity to shut down traffic while maintenance is being performed. This leads to a tendency to delay minor road repairs until the condition of the road deteriorates and the road demands a full reconstruction.
ROLLERS MUST COMPACT WITHIN 20 MINUTES BEFORE ASPHALT BECOMES COLD

PAVER MUST NOT STOP FOR MORE THAN 5 MINUTES

SHUTTLE BUGGY (MANDATORY IN THE US, OPTIONAL IN EUROPE)

IF TRUCK BUMPS PAVER BUMP WILL BE PAVED ONTO ROAD

WATCH OUT FOR METAL OBJECTS IN THE ROAD

TRUCKS RETURN MILLED AGGREGATE FOR RECYCLING

MILLING MACHINES REMOVE UPPER LAYER OF ASPHALT

PLANT-SITE DISTANCE LIMIT 100KM

SUPPORT MACHINERY (TRANSPORT TRAILERS, LIVING CARAVANS, FUEL TRUCKS)

MMGPS SYSTEM (GPS+LASER) TRACKS MACHINES WITH 4MM PRECISION

ASPHALT PLANT MANUFACTURE VOLUME SIMILAR TO PAVER CAPACITY

180°C

150°C

TRUCKS MUST ARRIVE EVERY 20 MINUTES

PAVER MUST NOT STOP FOR MORE THAN 5 MINUTES

ROLLERS MUST COMPACT WITHIN 20 MINUTES BEFORE ASPHALT BECOMES COLD

IF TRUCK BUMPS PAVER BUMP WILL BE PAVED ONTO ROAD

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WATCH OUT FOR METAL OBJECTS IN THE ROAD

TRUCKS MUST ARRIVE EVERY 20 MINUTES
VERTICAL EXPANSION

As more and more people flow into the cities and continuously occupy a limited land space, the Mega City will be forced to expand vertically both above and underground.

With the advance of tunneling technology more utilities and facilities (such as goods depots and power supply stations, for example) will be able to move underground. Street level space will become prime real estate and there will be an increasing demand to utilize it with maximal efficiency.

TRAFFIC SEGREGATION

Today’s roads are built while taking into considerations multiple forms of transport and their demands, which often contradict each other. As a result, the current road is a common “fit for all” design that does not optimally fit neither vehicle.

However, there is a rising trend today in building custom-made roads for specific type of traffic (for example, there is a tendency to pave different lanes on a highway with different material properties- the right lane uses stiffer pavement to withstand heavy traffic of trucks and buses, while the left lane which is mainly used by passenger cars is paved with softer material to increase safety and comfort while reducing noise.

In future Mega Cities it will be possible and practical to route different types of traffic into separate lanes or even dedicated roads. This in turn will enable the roads to be custom made for the type of traffic they will carry, and optimally tailored for the traffic needs.
Automated highway—cars are optimally guided using swarm mechanics to achieve maximum speed and efficiency. Autopilot drive with manual override option. Linked to elevated roads and parking silos.

Elevated road for scenic view. Manual drive. Cars are limited to low speed (fun over efficiency)

Buildings serve as additional “vertical roads” (combination of car and elevator)

Street level is reserved for pedestrian traffic and light vehicles

Sewers, electricity, telecom

Mass transit—metro or BRT system

Automated parking silo
Linked to passenger elevators

Heavy duty tunnel for semi-automated road trains that transport cargo.
Linked directly to loading docks and freight elevators
WHERE?

AREA FOCUS

CONCEPT FOCUS

Type of Road | How does it look like? | Who goes there? | How is it built?
--- | --- | --- | ---
Cargo Roads | Heavy duty, largely automated | Cargo road trains BRT system | Tunnel Boring Machine+large scale paver
Automated Highways | Smart, semi-automated | passenger vehicles (automated mode) BRT system | large scale paver
Elevated Roads | Light, manual | passenger vehicles (manual mode) | pre-fab and assembly on site
City Streets | Light, thin, flexible, unstoppable! | Taxis, shared cars, light delivery vehicles, 2 wheeled transport (pedal and electric), pedestrians | medium size paver

"Unstoppable - can't stop the city!"
"Lighter, thinner street pavement"
"less power" | "lighter cars"
"smarter cars" | "safer cars"
Heavy traffic will be restricted on city streets (already exists today)
WHAT?
ACTIVITY FOCUS

I WANT TO....

go to work ➔ metro/taxi/shared car/private car (auto)

get groceries ➔ delivery van

drive and enjoy the view ➔ shared car/private car (manual)

move my apartment ➔ moving company/rental van

go out with my friends ➔ taxi/shared car/private car (auto)

visit my uncle in another city ➔ train/bus/plane

CONCEPT FOCUS

Type of activity

Pave

• Large scale
• No ongoing traffic

Resurface

• Medium scale
• Ongoing traffic exists

Repair

• Small scale
• Manual work
• Ongoing traffic exists

Challenge level
WHEN
TIME FOCUS

Too close, project will be limited to making cosmetic improvements to existing Dynapac products.

Suitable for outgoing and enticing yet recognizable and realistic project!

Too far, prediction is too fuzzy to be a practical foundation for a project.

It is difficult to predict what will happen so far into the future and whether there will be a valid need for road paving machinery in this context.
WHEN?

FUTURE VISION

Google car is street-legal
First automated highway launched
Driverless cargo trains start using NYC metro grid during the night
Price of oil barrel rises above 200$

CONCEPT FOCUS

More than half of USA lives in cities with population above 1 million people

1990 2000 2012 2030 2050

MEGA CITIES

6 billion people
7.5-11.5 billion

powerful, heavy, manual transport (personal)

manual, heavy (trucks) transport (cargo)

fossil fuels resources

general, asphalt, passive roads

evolved to

efficient, light, semi-automated, shared

heavier, automated (rail transport, road trains)

renewable alternatives
dedicated
optimized
smart

6 billion people
7.5-11.5 billion

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manual, heavy (trucks) transport (cargo)

fossil fuels resources

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efficient, light, semi-automated, shared

heavier, automated (rail transport, road trains)

renewable alternatives
dedicated
optimized
smart
SUMMARY

CONCEPT OVERVIEW

Following an ideation workshop with the designers in Industrial Design Competence Center in Orebro, the key aspects of concept were focused and defined as follows:

Concept definition
Compact street paver for mega cities of the future.

Concept capabilities:
• Paving of new roads using recycled material
• Rapid resurfacing of existing roads

Focal points for concept:
• Use local material
• Transport in and out of the city
• Smart repairs to minimize traffic delays
• Protect the operator
GOAL 1:
Develop a concept that adapts the paving process to future mega cities:
• Tight quarters
• Transportation to and from the working site
• Highly customized roads
• Minimal intrusion while working

GOAL 2:
Make the paving process more environmentally friendly:
• Reduce asphalt working temperature,
• Decrease energy consumption
• Increase amount of recycled material

GOAL 3:
Make the paving process easier, healthier and safer for the operator(s)

WISH:
Enable the usage of environmentally friendly road paving materials through the use of this concept.
IDEATION
<table>
<thead>
<tr>
<th>SAFETY</th>
<th>HEAT</th>
<th>LOGISTICS</th>
<th>VISIBILITY</th>
<th>TRAFFIC DISRUPTION</th>
<th>MATERIAL</th>
<th>NOISE</th>
<th>PRECISION</th>
<th>TRANSPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walkway gates</td>
<td>Pellets that melt together</td>
<td>Roller pressure activities causing with broken</td>
<td>Sections of the road are taken to the plant, repaired and returned</td>
<td>Localised impact for consecutive (e.g., sewage, machine)</td>
<td>Paver runs on temporary rails</td>
<td>Liquid road</td>
<td>Aerial construction (bridge)</td>
<td>Tracks drive onto paver</td>
</tr>
<tr>
<td>Vampire road</td>
<td>Light the road on fire</td>
<td>Heat</td>
<td>Real-time asset management</td>
<td>Road lighting on the road</td>
<td>Smart tiles to protect</td>
<td>Peel off road layers</td>
<td>Entered instead of all</td>
<td>Mobile screen construction cell</td>
</tr>
<tr>
<td>Operator position</td>
<td>Light the road on fire</td>
<td>Heat</td>
<td>Passenger cars get paid to deliver asphalt</td>
<td>New</td>
<td>Smart tiles</td>
<td>Super-fast side loader</td>
<td>Extension instead of all</td>
<td>Mobile screen construction cell</td>
</tr>
<tr>
<td>Vapouroso road</td>
<td>Covered hopper</td>
<td>Heat</td>
<td>Covered hopper workers will not fall in</td>
<td>Advanced synchronisation system for entire fleet</td>
<td>Paver descends on road, paves short section and lifts end of</td>
<td>Docking, side-loader</td>
<td>Insulated asphalt machines</td>
<td>Insulated wheel mobile</td>
</tr>
<tr>
<td>Vapouroso road</td>
<td>Thermomatic hopper</td>
<td>Heat</td>
<td>Thermomatic traffic brings asphalt</td>
<td>Pavement</td>
<td>Paver descends on road, paves short section and lifts end of</td>
<td>Docking, side-loader</td>
<td>Insulated asphalt machines</td>
<td>Insulated wheel mobile</td>
</tr>
<tr>
<td>Vapouroso road</td>
<td>Roller wheels disperse asphalt</td>
<td>Heat</td>
<td>Roller wheels disperse asphalt</td>
<td>Paver</td>
<td>Paver descends on road, paves short section and lifts end of</td>
<td>Docking, side-loader</td>
<td>Insulated asphalt machines</td>
<td>Insulated wheel mobile</td>
</tr>
<tr>
<td>Vapouroso road</td>
<td>Application of heat is local and fast</td>
<td>Heat</td>
<td>Application of heat is local and fast (paving)</td>
<td>Paver</td>
<td>Paver descends on road, paves short section and lifts end of</td>
<td>Docking, side-loader</td>
<td>Insulated asphalt machines</td>
<td>Insulated wheel mobile</td>
</tr>
<tr>
<td>Vapouroso road</td>
<td>Reversal of docking truck</td>
<td>Heat</td>
<td>Reverse of docking truck</td>
<td>Paver</td>
<td>Paver descends on road, paves short section and lifts end of</td>
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<td>Insulated asphalt machines</td>
<td>Insulated wheel mobile</td>
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<tr>
<td>Vapouroso road</td>
<td>Heat is created by chemical reaction</td>
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<td>Paver descends on road, paves short section and lifts end of</td>
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<td>Insulated wheel mobile</td>
</tr>
</tbody>
</table>

**Notes:**
- SAFETY: Walking comes, yellow workers, problems.
- HEAT: Vapouroso road, heat, problems.
- LOGISTICS: Roller wheels disperse asphalt, problems.
- VISIBILITY: Heat, problems.
- TRAFFIC DISRUPTION: Roller pressure activities, problems.
- MATERIAL: Localised impact, problems.
- NOISE: Paver runs on temporary rails, problems.
- PRECISION: Aerial construction (bridge), problems.
- TRANSPORT: Tracks drive onto paver, problems.
ENCAPSULATED BINDER

GEOTEXTILE

ROLL-ON
COMPACT

+ Operator comfort
+ Temperature
+ Clean machine
+ Material recycling (?)
* Are mirrors more effective in helping drivers pass in tandem?

* Smart safety bots project data on road, also serve as post-crash collision units?
- 2-3 miller units per each paver unit (stackable?)
- keep flow constant

"dance"
CONCEPT DEVELOPMENT
It was decided that out of the multitude of problems found during the research, the most interesting one to attack would be the disruption of traffic during road maintenance.

Following that decision a number of concepts were developed to perform road paving with minimal disturbance to traffic.

The prevailing concepts included a relatively narrow paver with an extending “arm” that enables traffic to pass intermittently, and a machine with an unfolding “bridge” that enables traffic to pass over the work site.

The concepts were developed and evaluated using 3D animation to explore the mechanical movements, after which several sketches were made to explore the possible product character. The sketches were presented to Dynapac and the concept relevance was discussed with them.
A 1:1 mockup was constructed in the UID workshop to achieve a correct perception of the machine's dimensions and size. The mockup helped me to understand the human scale in relation to the machine.

There were several aspects I wanted to test with the mockup. The first one was where the operator can be situated and how good is the field of view that he will have in each position.

The second point was the safety of road workers around the machine and the third was the accessibility of various modules for maintenance.
At this point those concepts were rejected after receiving feedback from external tutor Anders Smith, who pointed out that all of them still occupy one line of traffic while paving. Therefore they offer no significant advantage over simply shutting down one lane of traffic at a time and paving it with a conventional machine, which is sometimes done today.
KEY ADDED VALUES:

- New configuration which combines planing and paving into a single recycling machine
- Minimal disturbance to ongoing traffic in the Mega City
KEY SKETCHES
Following the sketching phase, I proceeded to validate the concept and to make sure that it has a firm grip in reality.

I analyzed situations in which cars are required to pass through confined spaces (such as underground parkings, toll booths, ferries, car washes, gas stations etc) and tried to understand whether it will be feasible for a drive-on machine to exist on the road.

In addition, I tried to see which attributes need to exist in this machine so drivers will feel that it is safe for them to pass over it.
To further validate the concept, I built a test rig in the same dimensions of the intended machine, and asked a driver to pass through it in various driving speeds.

I asked the driver to feedback regarding the speed that she felt was safe for this operation.

The driver was able to drive through the obstacle at a constant speed of 30km/h, and stated that “If needed, I could go even faster”
CONCEPT VALIDATION

The next step of validation was a feedback interview with Roger Lundberg from NCC. He stated that the overall idea seems interesting to him, and stressed the importance of re-filling the paver with virgin binder, even if it was acting as a recycler.

Following the conversation I continued to calculate a car’s dimensions (a Volkswagen Golf was used as a benchmark city car) to make sure that the machine can accommodate the appropriate approach and departure angles.
CONCEPT REFINEMENT
IF POSSIBLE...

SMALLER RADIUS

POST 1005, A BIT TIGHT
TRAFFIC DIRECTION

Since the paver will be working in running traffic, thought was given to its interface with drivers on the road. I tried to imagine which shape and configuration will be welcoming enough for drivers without scaring them away, while at the same time maintain the appearance of a working vehicle which has to have a certain presence on the road.

Another topic discussed in length was the direction the paver will travel- should it travel with the traffic, or in the opposite direction?

Multiple discussions on this topic were held with Thomas Degn, APD program director, the external tutors Anders Smith and Mikal Hallstrup and the Transport program director, Demian Horst.

The main advantage of having the paver travel with the traffic was a reduced fear factor (drivers are more used to overtaking another vehicle than seeing one coming towards them)

On the other hand if the paver were to travel against the traffic it will mean that from the moment drivers meet the paver and onward they will be driving on a fresh, recycled road. This would make the concept’s story stronger. Practically speaking, the paver’s extremely low speed of travel (5km/h) will be negligible compared to the driving speed on the road.

The final decision was that the paver will be designed to travel with the direction of the traffic, but it will offer the possibility of traffic running the other way. For this purpose, the indicating arrows on the paver’s “back” will be able to change direction to signal drivers that it is now safe to cross. (See page 123)
CONTROL METHOD
OPERATOR OR AUTONOMOUS

At some point during the project a discussion was raised about the necessity of the operator.

In modern paving, the role of the operator is more of a supervisor, and the need for him/her to be physically driving the machine seems to be lessening.

The pros for a human-operated machine were that its implementation will be faster and the concept will be more realistic for Dynapac.

On the other hand, in the research it was found that there are many adverse factors in play on the operator if he is located physically on the machine itself. The road is a danger zone, and especially if the paver is operating in running traffic it would make sense to remove the operator from that scene. In addition, the machine produces harmful temperatures, fumes and vibrations which all have negative effects on the operator.

Furthermore, in today’s work the machine travels in a straight line most of the time, and user input is quite minimal. This eases the transition to robotic operation. Finally, removing the operator from the scene will enable Dynapac to increase the productivity of the machine.

A third option of a transitional machine (one that can accommodate either a cabin for the operator or an autonomous command module with sensors and communication relays) was considered.

Eventually it was decided that the concept will be designed to be remotely-operated or autonomous, with the operator serving as a supervisor of the paving job.
Another point considered during the development process was the refilling method of the paver.

When the recycling process takes place, the paver needs to be refilled with fresh binder that is added to the recycled mix.

Two methods of refilling were considered- one using a pre-filled cartridge that will be dropped from a dedicated van as it will pass on the paver and drive on with the traffic, or an internal binder tank that will be refilled using a tanker-type vehicle.

The most important positive feature of a cartridge-type refill method was a faster cycle time, therefore reducing disturbance to traffic.

However, it was argued that a cartridge this size and weight would require a complex mechanical crane to lift it, additional infrastructure will be required to pre-fill and store the cartridges, thus generating additional waste and an adverse impact on the environment.

Eventually it was decided to base the design on a tanker-type refill, with a dedicated quick-refill terminal with which the tanker van will interface.
autonomous/remote control unit

refill terminal

laser projected "virtual wall"

ramps fold up
HYBRID SKETCHING

The chosen and validated concept was refined using a combined method of sketching and CAD. The computer assisted me in keeping the correct package and dimensions, and the rapid sketching technique enabled exploration of multiple approaches to the character of the product and its functional details.

The design was divided into several topics and several options were explored for each topic, such as: the ramp, the wheels assembly, the tow arms etc.

Special care was given to preserve the Dynapac design language previously developed by Atlas Copco Industrial Design Competence Center. The digital sketching technique enabled rapid sharing of the work with different members of the team in Orebro, and mutual suggestions on the design.

Special thanks go to Ex-APD Philip Normand Andersen for his great help during this phase!
Sketches on these pages are contributions and collaborations with Paco Lindoro and Philip Nordmand Andersen.
Sketches on these pages are contributions and collaborations with Paco Lindoro and Philip Nordmand Andersen.
YELLOW line should be continuous with other side and follow rail

SMALL CHAMFER ON EDGE

If possible, the line or other edge should be continuous with other side and follow rail (but you probably thought of that already).
METHOD

The project was developed in close collaboration with Dynapac, a leading manufacturer of road paving machines, and based on feedback from NCC Roads, one of the largest road construction companies in the Nordic region. Work processes included interviews with road construction companies in Sweden and interviews with road paving machine manufacturers. The focus was on developing a machine that produces new asphalt while enabling traffic to continue.

RESULT

Dynapac RediPave utilizes an existing technology called ResiMag. The machine heats the existing road surface, turning it into a reusable material. The reclaimed asphalt is then lifted and mixed with a small amount of fresh binder and aggregate, while enabling traffic to continue.

The concept also solves the problem of energy-intensive processes. It replaces the existing, road-restricting process with a more efficient and less intrusive one, allowing for ongoing traffic while road maintenance is performed.
Width: 2550
Height: 3825
Length: 6120

Width: 2780
Height: 1870
Length: 5475
batteries

mixing tank

binder tank (heated)

heat exchanger

MW heater

hub electric motors

screed

auger

tamper knives

weight plates

rollers
REFLECTIONS
SCHEDULE AND PLANNING
Planning is paramount during a degree project. Careful planning and sticking to the plan is very difficult especially in a project where other parties are involved (See sponsors), but it must be done to successfully perform the large amount of work required from such a project. I consider the ability to plan, manage and execute a wide project from start to finish, including modeling and exhibition planning as one of the major learning outcomes during the thesis.

INPUT AND DECISIONS
Gathering inputs from all people involved is important for the quality of the project. However after gathering all the possible information one needs to remember that the decisions need to be made by the designer. It is important to recognize that the ultimate responsibility to make those decisions on time and to be able to advance with the project is on the designer. If one of the parties (sponsors, users) fails to provide the necessary information on time, the designer should do his best to fill in that information, and to make the best possible decisions with the data at hand, even though it might be incomplete.

In the context of the degree, a wrong choice is a much better option than no choice at all.

SPONSORS AND USERS
User groups are extremely important for the project. Without users it is virtually impossible to assess the relevance of the work. Contact with users must be established very early into the project (some contacts required a three month setup to achieve a single meeting). Preparation before meeting the users (recording equipment, premade questions, mockups etc) is critical to gather the necessary information.

Clear communication with the sponsor is important for the success of the project. Understanding the sponsor’s motivation and the expectations from the degree project is key to satisfaction both of the sponsor and the designer who is working on the degree project. That being said, one does not have to follow the sponsor’s needs blindly. Often challenging the limits of the sponsors’ thinking and technology will result in a far more interesting project.

ENERGY DISTRIBUTION
The degree project has an unusual span of 14 weeks. Care must be taken to distribute the energy evenly over this time and not to arrive to the final stages of the project exhausted. Maintaining a healthy work day schedule of 9-5 (or 10-6) helps.

Maintain your excitement and fun levels throughout the project. If it was fun doing it, it will show!

DESIGN METHODS
Combined sketching method (Digital sketching on top of a rough CAD underlay) has proved itself as a very fast and efficient way of working. It frees the mind from thinking about the package sizes, and enables quick exploration of various options before the time investing CAD phase begins.

Keeping the work visible (as sketches on the wall, post-its, interview extracts) helps to focus the mind on the task at hand and invites discussion with fellow students, tutors and users. This in turn improves the project- the more questions are asked about the project, the better.

This project contained a specific Analysis phase, during which I summed and sorted all the information gathered during the research. This stage was important in helping me focus on a single idea within a sea of problems. Sorting and grouping the ideas, producing conclusions and supporting them with facts is crucial when dealing with a wide and complex topic.
CONCEPT DEVELOPMENT

MARCH

Week 10
Mo 5  Tu 6  We 7  Th 8  Fr 9
Week 11
Mo 12  Tu 13  We 14  Th 15  Fr 16
Week 12
Mo 19  Tu 20  We 21  Th 22  Fr 23
Week 13
Mo 26  Tu 27  We 28  Th 29  Fr 30
Week 14
Mo 2  Tu 3  We 4  Th 5  Fr 6
Week 15
Mo 9  Tu 10  We 11  Th 12  Fr 13

CONCEPT REFINEMENT

APRIL

Week 10
Mo 5  Tu 6  We 7  Th 8  Fr 9
Week 11
Mo 12  Tu 13  We 14  Th 15  Fr 16
Week 12
Mo 19  Tu 20  We 21  Th 22  Fr 23
Week 13
Mo 26  Tu 27  We 28  Th 29  Fr 30
Week 14
Mo 2  Tu 3  We 4  Th 5  Fr 6
Week 15
Mo 9  Tu 10  We 11  Th 12  Fr 13

Orebro Brainstorming

German Brainstorming

Ideation

Sketching

Tutoring

Rough CAD

Presenta- tion Prepa- ration

Half-Way Presentation

Report Weekly

1:1 Mockup

Concept Finalization

Detailed Design

CAD for production

Plan model production

Contact model sub-

contractors if needed
PROJECT SCHEDULE

PRESENTATION MATERIALS

Week 16
- Mo 16
- Tu 17
- We 18
- Th 19
- Fr 20

5 Weeks To Go Presentation

Detailed Design

Week 17
- Mo 23
- Tu 24
- We 25
- Th 26
- Fr 27

Presentation Preparation

Week 18
- Mo 30
- Tu 1
- We 2
- Th 3
- Fr 4

Design Freeze

Week 19
- Mo 7
- Tu 8
- We 9
- Th 10
- Fr 11

Report Weekly

Week 20
- Mo 14
- Tu 15
- We 16
- Th 17
- Fr 18

Report Weekly

Week 21
- Mo 21
- Tu 22
- We 23
- Th 24
- Fr 25

Deadline Digital Report

Model Production

Poster Design

Examination

Video, Presentation

Model Production

Model Production

Tutoring

Report Weekly

Tutoring

Poster Print

5 Weeks To Go Presentation

Master Thesis Report | Gosha Galitsky | Umeå Institute of Design | gosha_id@yahoo.com | 2012
PRESENTATION MATERIALS

JUNE

<table>
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</tbody>
</table>

- Finalize Report
- Degree Exhibition Opens
- Exhibition Preparation

DEGREE EXHIBITION OPENS
Finalize Report
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