Kuwait University

College of Engineering and Petroleum

Department of Mechanical Engineering

Engineering Design

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Phase 1 Report

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By

Abdulaziz F. Alfouzan	*2172132867*
Abdulaziz S. Alyouhah	*2181146563*
Abdulwahab T. Albassam	*2181146561*
Mosab A. Marafi	*2181143642*

Instructor

Dr. Ali Al-Saibie

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Introduction:

As it is known, Kuwait lies in a harsh desert environment. And regardless of having the black gold living under its sands (oil), Kuwait's economic engine, the desert is causing a lot of trouble to the country both on the health and economic levels. Sand likes to take a breath and fly with the hot summer winds and February's unstable climate, and once it finds an obstacle or a place to live in, it starts to accumulate.

Figure 1: An accident caused by the sand accumulations

Sand accumulation on the roads and streets is a significant problem causing the country to lose millions of dollars, opposing the expansion and development of new cities, and causing accidents. Every year, the sands block the roads, and it impedes the movement of trucks carrying essential goods (i.e., foods, medicines) coming from neighbouring countries on international routes, and the people who live in the new cities; it takes up to two days to clean the road and open the path. Also, those sand accumulations are causing some accidents on the streets **(Figure 1)**, especially for unaware drivers driving at high speed at night. The sand could cover an obstacle or

fill a pit, and when the vehicle goes over it, the car flips. Also, the sand stays in between the asphalt aggregate, and when the vehicle moves at high speed, this sand will fly and cause the vehicle in the back to be blinded.

Interview:

An interview was done with an engineer in the ministry of public works (MPW), and in the discussion, three significant parts were discussed. The first part is the problem itself and how the accumulated sands are causing big troubles in the country (introduction part). The second part is about the current solution and how the government deals with the case. And the last part includes the customer's needs and what is the expectation of the new product or solution.

Roads and Affected Areas:

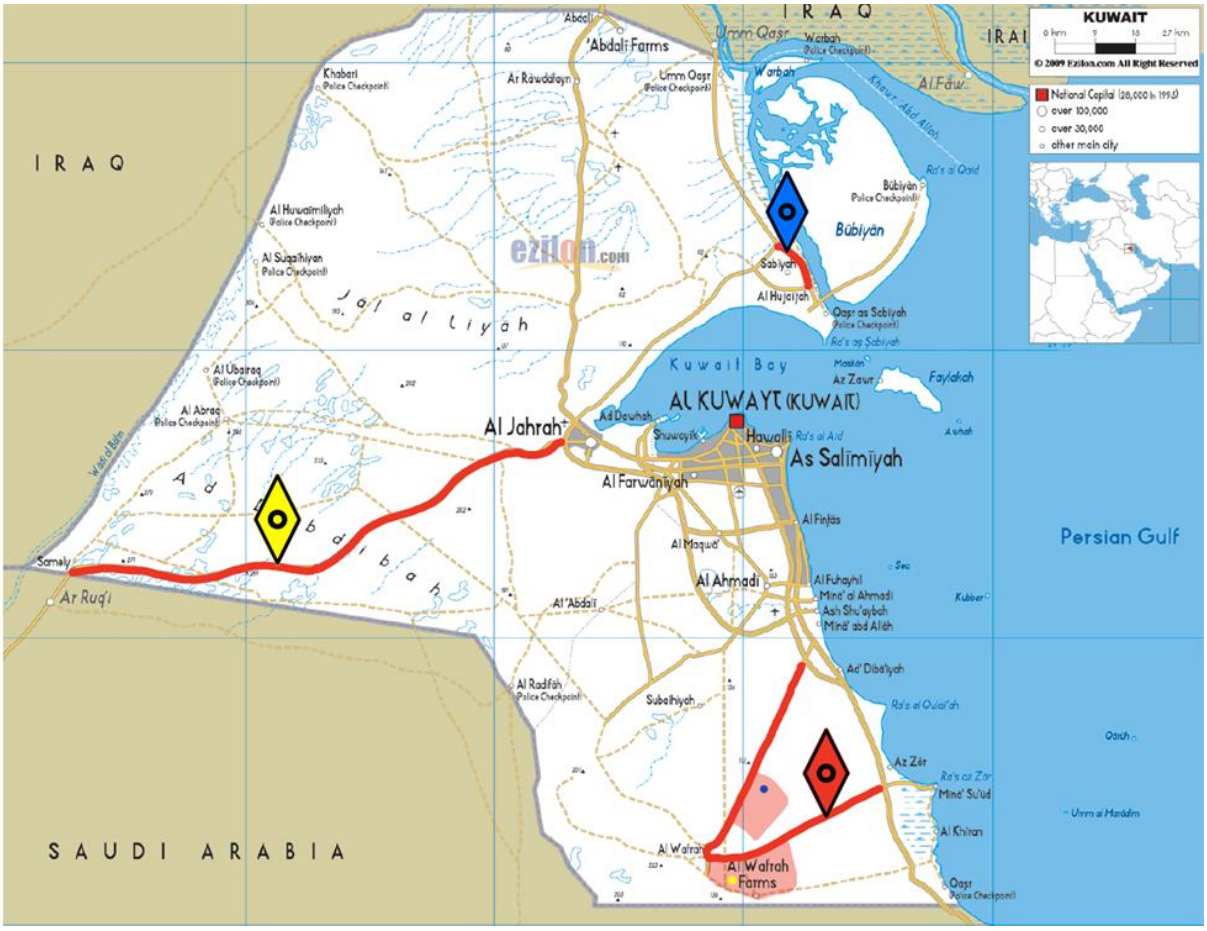

Figure 2: *Roads affected by sands accumulations*

Figure 3: *Map keys*

The sand accumulation affects many major and vital roads, as shown in **Figure 3**. Al-Salmey motorway is the most affected road; this road serves international transport trucks that carry essential goods such as food and medicine from Saudi Arabia, Jordan, and Syria. Last summer, this road was blocked for more than 48 hours because of the sands, and the military and Kuwait national guards intervened to save the situation. There will be a new city behind Al-Salmey road, Nawaf Al-Ahmad city.

The second and third vital roads are Om Sufag and Sabah Al-Ahmad city roads. These roads serve Sabah Al-Ahmad city residents. Each summer, sand blocks these roads, and the residents are trapped, and their movement is suspended until the road is cleared. Also, the Wafrah farms suffer from this kind of sand.

Winds and sandstorms are very active in February and summer, especially at noon (10 AM) when the sun is vertical.

Current Solution:

Figure 4: Contractor's loader cleaning the road from sands

Each road vital road has its contract with a contractor, which lasts for three years. The contractor is responsible for keeping the road clean and passable, and loaders (**Figure 4**) are used to remove the sands and move them to the road shoulders; and afterwards, the road sweepers clean the remaining sand, which is kept done throughout the year.

Figure 5: Contractor's loader cleaning the road from sands at night

The MPW is a regulator and supervisor only; a three-year contract does everything with a contractor. Most of the time, the contractor takes care of the sand accumulation, but sometimes the MPW uses its vehicles (they are very few). The contractor is paid to place the loaders and road sweepers at a specific point on the road or every particular amount of kilometers. The payment is made to the contractor even if the vehicles are idle and not running.

Disadvantages of the current solution:

The process is very inefficient; it takes up to (48hrs), money, and resources. In addition to that, the loaders cannot remove the sand entirely from the ground; it needs the road sweeper to come after it and remove the remaining sand, making an effort to double. Also, the street level is not constant. It is challenging for the loader's driver to maintain a consistent level from the ground, resulting in contact between the loader and the asphalt, causing the last to be destroyed.

On the other hand, this process is very costly; the MPW pays the contactor even for the idled vehicles, whereas the MPW engineers are paid for doing nothing, just supervising.

The last thing is that the MPW owns thousands of SUVs; these vehicles are often not used in the right way or purpose; many engineers are using them for their personal tasks. So, it is good to take them back to duty.

Estimated Cost:

The rent of the loader is 50KD per day, and if four loaders are needed for every 10km of a 120km road (Al-Salmey Motorway), then it will cost the country around 876,000 KWD. This estimate is not conservative, and it is believed that the need for loaders and road sweepers is much more.

The Mission Statement

Mission Statement: [Devising a way to mitigate sand accumulation on roads by a car attachment]

Product Description	A low-cost light car attachment with road sweeping and bulldozing capabilities, and specialized for removing the accumulated very fine sand on the roads.
Benefit Proposition	• Low cost • Suitable for hot temperatures • Easily attachable • Durable • Light • Fast • Novel approach • Does not damage the road
Primary Market	• Governments with desert climates (GCC, Africa, Mugabi desert (China)) • Construction companies contracted for roads in Kuwait
Secondary Market	• Residents of remote areas • Farm owners • Volunteers
Assumptions and Constraints	• Capable of withstanding the high heat and weather • Capable of removing sand without damaging the road • Capable of removing the sand that is lying between asphalt aggregate. • Materials and parts are available in Kuwait • Manufacturable in Kuwait • There is a maximum velocity for safe removal of sand
Stakeholders	• The producers • Governments • Volunteers • Operators and workers

The Customer needs and Target specifications

From the previous interview, the customer statement in this case the engineer was made into a table and were translated into interpretated needs as illustrated in table (1)

Table 1: Customer statement and interpreted needs

Customer statement	Interpreted need
منتج مصنوع من مادة قوية أن يكون التدعيم قوي	Rigid structure
أن تكون الشفرة بشكل مائل إلزاحة الرمال لجانب الطريق أن تكون الشفرة مائلة من ومقعرة من الأمام	Designed to slide the sand to the road shoulder
أن يحتوي على بروشات في خلف الشفرة	Brushes attached behind plow
أن يكون قابل للطيء ووضعه في حقيبة السيارة	Foldable design
أن يكون خفيف	Light
أن يمكن تركيبه من شخص واحد سهل الفك والتركيب	Easy to attach and detach
صديق للبيئة ، لا يخرج بقايا ب سبب الاحتكاك ويلوث البيئة (البروش)	Environment friendly, strong brush hairs
أن لا يستهلك بطارية السيارة وكهرباء السيارة	Does not consume the car battery
أن يحتوي على انارة تنبيهية (فلشر)	Light indicators
وجودة كاميرا خلف السيارة تبين مدى نجاح العملية ، في الظروف الغبارية	Has a method to check for functionality
أن يمكن تؤدي عملية تنظيف الشارع ب مفردك بأمان	Safe to use
صيانة قليلة	Low maintenance (few parts, few consumable parts)
قابل للتطوير (بزيادة مالية) بحيث يتحول الجهاز الى مكنسة لتنظيف الشوارع	Modular (upgradable to include a vacuum cleaning system)
قيمته تكون في متناول اليد	affordable

The customer statements had some overlapping, and the table shows the multiple customer statements that were interpreted into a single need. These interpreted needs were then organized into a hierarchy relative to importance and grouped into similar categories. With the number of starts noting the importance of need and the exclamation mark noting the triviality.

The plough is easy to attach and store

***Lightweight

**Easily attachable and detachable

*! Foldable design

The plough is safe to use

**Light indicators attached

***Safe to use

**! Does not consume the car battery

Plough removes sand efficiently

*** Able to remove sand from both lanes using multiple ploughs

*** Designed to slide the sand to the road shoulder

*** Brushes attached behind the plough

The plough is very purchasable

**Low maintenance cost

*Modular (upgradable to include vacuum cleaning system)

*** Low cost

*** Strong and durable attachment

The plough is environmentally friendly

Has a method to check for results of the plougher

Metrics were then obtained using the customer needs as references and a table was made with a column after each metric to determine their importance relative a 1-5 numbered scale with 5 being the most important. This is illustrated in table (2)

Table 2: interpreted Needs and their importance

No.	Needs	Imp.
1	Strong and durable attachment	4
2	Designed to slide the sand to the road shoulder	5
3	Brushes attached behind the plough	5
4	Foldable design	1
5	Lightweight	3
6	Easily attachable and detachable	3
7	Environment friendly (i.e., strong brush hairs)	2
8	Does not consume the car battery	1
9	Light indicators attached	2
10	Has a method to check for results of the plougher	3
11	Safe to use	5
12	Low maintenance	2
13	Modular (upgradable to include vacuum cleaning system)	1
14	Low cost	4
15	Able to remove sand from both lanes using multiple ploughs	5

A needs-metrics-matrix was constructed and illustrated in table (3) to identify which metric corresponds to which interpreted need and from that information and table (2) the team can identify and set ideal and marginal values for the various metrics obtained. These can be seen in table (4)

Table 3: Needs-Metrics-Matrix

No.	Needs	Metrics	Strength of Plough	Strength of Brushes	Angle of tilt	Total Mass	Installation time	Cost	Power consumption	Sand removing capacity	Sand height	Maximum car speed	Number of parts	Biodegradable	Camera system	Number of light indicators	Minimum storage space
1	Strong and durable attachment		●			●							●				
2	Designed to slide the sand to the road shoulder				●					●	●						
3	Brushes attached behind the plough									●	●						
4	Foldable design						●						●				●
5	Lightweight					●	●	●									
6	Easily attachable and detachable					●	●										
7	Environment friendly (i.e., strong brush hairs)			●										●			
8	Does not consume the car battery								●						●		
9	Light indicators attached															●	
10	Has a method to check for results of the plougher														●		
11	Safe to use											●					
12	Low maintenance						●	●									
13	Modular (upgradable to include vacuum cleaning system)												●				
14	Low cost							●									
15	Able to remove sand from both lanes using multiple ploughs				●					●	●						

Table 4: Marginal and ideal values for metrics

No.	Need Nos.	metrics	Imp.	units	Marginal Value	Ideal Value
1	1	Strength of Plough	5	MPa	>169	>542
2	7	Strength of Brushes	3	MPa	-	-
3	2,15	Angle of tilt	5	degrees	10<x<40	20<x<30
4	1,5,6	Total Mass	5	kg	<150	<70
5	4,5,6,12	Installation time	3	s	<900	<300
6	5,12,14	Cost	4	KWD	<700	<300
7	8	Power consumption	1	W	<1200	<600
8	2,3,15	Sand removing capacity	5	m^3/s	>2	>8
9	2,3,15	Sand height	3	cm	>2	>10
10	11	Maximum car speed	2	km/h	>10	>40
11	1,4,13	Number of parts	2	#	<10	<5
12	7	Biodegradable	2	unitless	-	-
13	8,10	Resolution of Camera system	3	Pixels/in	>480	>1080
14	9	Intensity of light indicators	4	cd	>0.5	>1
15	4	Minimum storage space	5	m^3	<.423	<.317

The power consumption marginal and ideal values were obtained using a winch has reference with some winches consuming up to 1200 W so the marginal value would be within this value other values were obtained using the same concept and previously mentioned. The target specification and concept development as a whole are not a fixed process and therefore some needs, metric and values may be revisited to ensure that these values are logical. While other metrics such as the strength of brushes has not been established however should be similar the road sweepers and other brushes doing somewhat the same application.

Initial design concept:

After the customer needs were obtained, it was convenient to start working on initial designs. The team searched the internet for designs close to the idea in mind. There were no designs found that could serve the exact purpose of the project (sand removal). However, many products found were close to the idea in mind despite that they were dedicated for snow plowing **Figures (6 & 7)**.

Figure 6: Snowplow attachment

Figure 7: Snowplow attachment side view

The initial design for the project should start from this product and modify it such that it can be used for sand removal as it would be more appropriate to start where others stopped. This product is a snowplow attachment that can be attached to a pickup truck or an SUV. It is attached from the front receiver hitch as shown in **Figure (8)**. It also has a mechanism that lowers and raises the plow which is powered by the car's 12-volt battery.

Figure 8: Attaching with a front receiver hitch

Figure (9) shows a sketch of the suggested modification for the design. It is modified to include sweeping brushes placed behind the plow to sweep the remaining sand that could not be removed by the plow, which was directly stated in the customer requirements. The sweepers would be powered by a 12-volt dc motor, such that it could take its power directly from the car's battery.

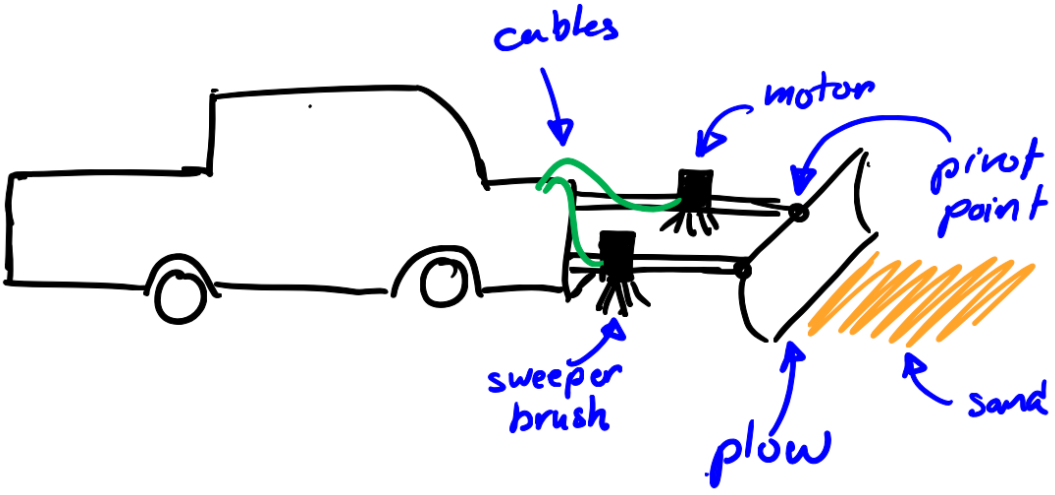

Figure 9: Sketch of the initial design

One disadvantage of this concept is that it is limited to cleaning one lane of the road at a time, and if the sand was accumulated near the concrete road divider, it would be difficult to get it to the other side, where it can be thrown aside of the road. However, these difficulties can be easily encountered by using multiple plowing vehicles instead of one as shown in **Figure (10)**.

Figure 10: Snow-plowing convoy

In order to proceed with this idea, it was necessary to check whether the car battery can supply enough power for the sweepers. To estimate the power needed to sweep the sand, an experiment was done. A broom was attached to an electric drill powered by a 12-volt battery, such that the broom car rotate and sweep the sand. The electric drill managed to sweep the sand which

indicates that a motor with the same power rating could serve that purpose. The drill power rating was about 100 Watts. This experiment was not very accurate, however, it gave a rough estimate of the needed power as a start. The device should have about 3-4 sweepers of a larger size than the one that was tested, so an initial estimate for the motor's power is about 600 Watts.

After the needed power was estimated, it was necessary to know how much power the car battery can supply. It was convenient to lookup for benchmarks of car battery-powered devices such as the starting motor and towing winch **Figure (11)**, the starting motor approximately draws around 150 amps for a four-cylinder engine and about 225 amps for a V8 engine, while towing winches' current ratings start at 100 amp and could exceed 300 amps. A 100 amps towing winch powered by a 12-volt battery uses 1200 Watts of power, which is more than the needed power for the project. It can be concluded from the previous discussion that the project is feasible in terms of technical parameters.

Figure 11: Towing winch

The Manufacturing Process:

The investigation in the manufacturing process started with a trip to Shuwaikh industrial area to find a blacksmith workshop that could manufacture the product. After looking in more than 20 different workshops where almost neither of them agreed on cooperating, the instructor suggested checking a specific workshop owned by a manufacturer who had worked with another design group last semester. After contacting that guy, a meeting was scheduled on the 10th of April, at 10 PM, in the workshop located in the Khaitan residential area **(Figure 12).**

Figure 12: The workshop located in Khaitan

Figure 13: Snowplow attachment

After sating down and negotiating the whole design project while showing illustrative pictures of products that have the same function but are used in a different environment, the manufacturer stated the following :

- The density of the sand is way higher than the density of the snow, so designing a product similar to the one shown in **Figure (13)** would be unpractical or even inapplicable, as sand accumulation at the front of the attachment is a much more complex problem to deal with as the attachment might get stuck in the ground.
- In terms of design specifications, if the intention is to manufacture a sand removing attachment, it will be a heavy-duty product. It cannot be a lightweight one as the design group planned it to be.
- Specialists should manufacture it, as it requires a lot of work and the design group is restricted with time while having little experience.
- While working with sand, installing the attachment in the back could be more effective.
- A specific four-wheel vehicle such as the one shown in **Figure (14)** must be selected to take its measurements, do all the analysis required, and design a product that can fit perfectly with this vehicle, as one attachment cannot be suitable for all the vehicles since it is a heavyweight product as mentioned previously, and the heavier it gets, the more restricted the cars options will be.

Figure 14: The car provided by the manufacturer to test the product