ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | SK

ENGINEERING OUR FUTURE

A DISCUSSION PAPER

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In Saskatchewan, Graham held public sector roles as a Director General and Federal Economic Development Coordination with the federal government and Economic Secretary, Chief Economist and Deputy Minister of Public Participation for the Saskatchewan Government. Graham is the author or two books on Saskatchewan's economic future entitled "This Year Country" and "Saskatchewan Rising" and a large number of articles and papers on various aspects of economic development. Graham now lives in Calgary near to his grandchildren.

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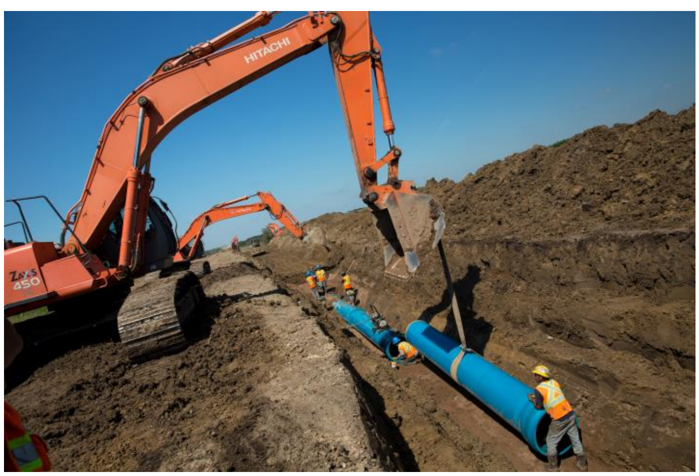

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EXECUTIVE SUMMARY

- The scope of Engineering is wide, including civil, mechanical, marine, agricultural, hydrological, chemical, electrical, environmental, military, biological, health and many other sub-disciplines, many of which are represented in the Association of Consulting Engineering Companies - Saskatchewan (ACEC-SK).

- There are some 4,105 professional engineers in Saskatchewan and a further 4,570 supporting technicians to create an engineering skill base of 8,675, about 1.5% of the provincial labour force. This may seem a small share provincial employment. In reality it underlies a far more significant contribution by engineering to provincial economic activity offering services that influence billions of dollars of provincial economic activity. ***Engineers support and improve the productivity and competitiveness of major provincial export and revenue generators.***

Table ES-1 Summary of Some Economic Impacts of Engineering in Saskatchewan.

IMPACT AREA	IMPACTS	IMPACT AREA	IMPACTS
# of ACES Disciplines Offered Major Disciplines Sub-Disciplines	 30 265	# of SK Economic Sectors Purchasing Engineering Services as % of All 34 SK Economic Sectors	 32 94%
Total Labour Force Employment: Engineers Engineering Technologists Total As % of Total Labour Force	 4,105 4,570 8,675 1.5%	Value of Engineering Purchased by Economic Sectors Value of SK Economic Sectors Purchasing Engineering Services	$4.3 Billion $122.5Billion
Estimated Annual Wage & Salaries Forecast 2025	$800.88 million $905.25 million	Value of Engineering Services Purchased by Major SK Trading Sectors Value of Trade Affected by Engineering	$2.6Billion $204.7Billion

- Engineering came to Saskatchewan in the earliest days of 19th and 20th Century settlement. Engineers helped build the Canadian Pacific Railway, ran steam threshing machines, constructed grain elevators, serviced early trucks and cars and explored for minerals. Early land clearances for agriculture, building roads and railways for the grain export economy, designing and building grain elevators, towns, villages and cities and supplying them with water, drainage and sewage systems, all required engineering. ***Engineers designed and built the engineered infrastructure platforms that became a foundation for a century of growth.***

- Success in modern economic development requires economies to remain competitive in global and national markets. For Saskatchewan's land locked natural resource economy, competitive access to distant export markets is a persistent reality. ***Saskatchewan stands at a cross roads today where status quo approaches can constrain and weaken future economic growth.***

- Traditionally, our understanding of economic growth has been seen in market size, natural resources and investment working with innovation and technological change to enable access to new markets, products and processes and new forms of public and private organizations. Innovation has been a central and repeating central factor in economic development. Saskatchewan has benefited from these innovations with new crop varieties, water, transportation and energy infrastructure. The Province has developed new products, markets and processes by the application of new technologies and engineering to Saskatchewan conditions. ***Engineers as problem solvers are often central to introducing changes that enabled economies to grow and respond to the social, economic and environmental challenges of the day.***

- The impact of engineering in past has been substantial but in the future may be even greater. ***A 1% increase in an Engineering Index score can lead to a 0.85% increase in GDP per capita - translating into an increase in per capita GDP of over $5,000 in Saskatchewan or nearly $6 billion.***

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- Canadian engineering has not kept pace with global developments. Growing Saskatchewan will require31` an additional hundred engineers for every extra 100,000 people. While the future of Saskatchewan requires increases in the numbers and skills of provincially trained engineers, ***ACEC-SK identifies fourteen engineering disciplines with shortages critical to meeting to the long-term economic development of the Province.***

- ***Saskatchewan faces major 21st century challenges.*** Global warming is changing many of the fundamentals of the large agricultural economy providing warmer temperatures and both more and less water. Transport infrastructure that worked in the 20th century no longer has the capacity to sustain growth at levels anticipated in provincial growth plans. Public and private financing for infrastructure requires attention to maintain the province's competitive position in the world and maintain access to capital.
- Engineers have been central to meeting the challenges of Saskatchewan's past. ***New generations of engineers will again be required in coming decades for the Province to address its significant development challenges in water, transport, climate and human resources and to realize its potential for the economic growth that can support continuing improvements in Saskatchewan's quality of life.***

- The challenges in Saskatchewan's economic future are well known. Engineering skills can contribute to resolving them working with government, industry and society. ***Decisions taken today can determine where Saskatchewan will be for the rest of the 21st Century.***

- This paper ***"Engineering in Our Future"*** has been prepared by ACEC-SK to open a dialogue on emerging economic, social and environmental priorities Saskatchewan. In a province with opportunities to supply food, fertilizers and fuels to the world there are also great challenges in distance from markets, the size of the province, effects of climate change, a changing human resource base and introducing new technologies. ***New platforms for economic development in the fields of water, transportation, carbon management and human resources are identified as key priorities for attention.***

- ***ACEC-SK invites a wider dialogue on Saskatchewan's future to ready the Province with a Roadmap for 21st century economic, social and environmental success.*** It is anticipated that federal, provincial and municipal governments, Saskatchewan stakeholders in the economy, society and environment will all have interests in that future and become a part of a dialogue on Saskatchewan's future.

> *"Our engineers may be regarded in some measure as the makers of modern civilization. The problems of political history cannot properly be interpreted without reference to the people themselves – how they lived and how they worked, and what they did to promote the civilization of the nation to which they belonged. Hence English engineers are not unworthy to be considered in the history of their country. For what were England without its roads, its bridges, its canals, its docks and harbours. What were it without its tools, its machinery, its steam engine, its steam ships and its locomotive.*
>
> *Are not the men who have made the motive power of the country, and immensely increased its productive strength, the men above all others who have tended to make the country what it is?"*

Smiles, S., Lives of the Engineers, Volume I., John Murray, London, 1874, p. xxvii. Commenting on the role of Engineers in the growth and development of the nation.

I. INTRODUCTION

Engineering is a profession that that applies science and technology to the design, building and use of machines, constructions and infrastructures. The Royal Academy of Engineering in the United Kingdom defines engineering as the '*creative application of scientific principles that are put in practice to invent, design, build, maintain and improve structures, machines, devices, systems, materials and processes.*' It is a broad definition recognizing that engineering demands are continually evolving due to the dynamic nature of engineering intensive industries in a changing economy.

Engineering covers many different types of activity. Engineers make things; make things work and make things work better. They also use their creativity to design solutions to the world's problems and help build the future. (CEBR, 2018)

Accordingly, the scope of the profession is wide encompassing civil, mechanical, marine, agricultural, hydrological, chemical, electrical, environmental, military, aerospace, chemical and process, computing and communications, energy and power, materials and mining, manufacturing and design, health, medical and bioengineering, transport and mechanical and many other sub-disciplines.

Engineering has a long history in Saskatchewan and will become even more important in the years ahead. Statistics Canada reports in the 2016 Labour Force Occupational Census 4,105 professional engineers in the Province. In addition, there are a further 4,570 technicians in support of the engineering activities to create a skill base of 8,675 professionals or 1.5% of the provincial labour force.

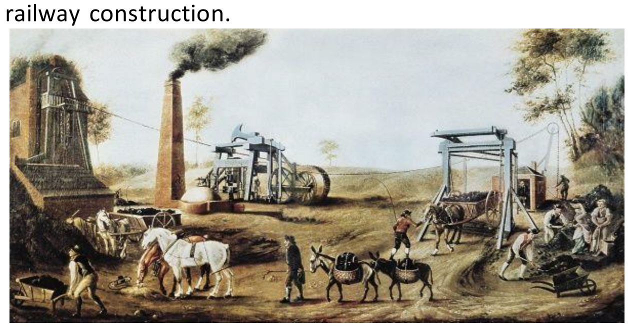
The engineering discipline came to Saskatchewan in the very earliest days of western settlement in the 19th Century. The profession was essential to building the Canadian Pacific Railway, for constructing grain elevators, servicing early trucks and cars and exploring for minerals. Early land clearances for agriculture, required steam engines in the fields, roads and railways for a grain export economy and many new towns and villages. Drinking water, drainage and sewage systems were all designed and built with engineers and engineering for a rapidly growing population.

In 1907, the University of Saskatchewan started as an Agricultural College training agricultural engineers and by 1912 an Engineering College teaching Civil Engineering was started at the new University. A faculty of Engineering was started at the University of Regina in 1973, offering classes in electronic, environmental, industrial, petroleum and software systems engineering.

Engineering has been a staple of successful economic growth and infrastructure development for centuries. The Archimedes Screw lifted water from the Nile in ancient Egypt to irrigate dry farmlands, provide reliable crops and grain exports to strengthen the economy.

Archimedes Screws

The British industrial revolution was founded on engineering innovation that brought steam power to manufacturing and transportation supported by advances in bridge, canal and railway construction.



The English Industrial Revolution

In short, engineers have for centuries been at the start of agricultural and industrial transformations that led to increases in wealth with improved standards of living for the population and sustained economic growth.

"Our engineers may be regarded in some measure as the makers of modern civilization. The problems of political history cannot properly be interpreted without reference to the people themselves – how they lived and how they worked, and what they did to promote the civilization of the nation to which they belonged. Hence English engineers are not unworthy to be considered in the history of their country. For what were England without its roads, its bridges, its canals, its docks and harbours. What were it without its tools, its machinery, its steam engines, its steam ships and its locomotives. Are not the men who have made the motive power of the country, and immensely increased its productive strength, the men above all others who have tended to make the country what it is?"

Smiles, S, (1874), Volume I., p. xvii.
Commenting on the role of engineers in the growth and development of the nation.

This paper has been prepared for the Association of Consultation Engineering Companies – Saskatchewan (ACEC-SK – the Association) to open a discussion and identify priorities and improved frameworks for the application of engineering skills to the sustainable growth and development of the Provincial economy.

The Association has 78 member offices from 57 companies in the province accounting for about 2,000 professional engineers or about one half of the provincial total. The engineering skills of the Association are distributed across a wide range of disciplines.

Table 1. Engineering Disciplines Offered by ACEC-SK Member Companies.

Engineering Disciplines		
Aerospace	Geotechnical	Hydrological Engineering
Agriculture	Industrial	Civil Engineering – Roads, Bridges
Building Science	Marine and Coastal	Environmental Engineering
Chemical Engineering	Materials	Structural Engineering Buildings & Industry
Cold Climate Engineering	Mechanical	Surveying and Mapping
Communications / Telecommunications	Mineral Geoscience	Interpretation / Imagery
Computer Science	Mining Engineering	Resource Surveys
Electrical	Municipal	Transportation
Energy	Occupational Health and Safety	Surveying and Mapping
Environmental Geoscience	Petroleum Engineering	Interpretation / Imagery
Fisheries	Planning	Resource Surveys, Exploration
Forensic	Pressure Vessels	Planning Temporary Works
Forestry	Project Management	Exploration and Planning
Geophysics	Research	Temporary Works

Source: Annex A.

Over time, requirements for engineering skills grow and change. Today our Saskatchewan economy is based on rapidly meeting the needs of an expanding global economy, a changing climate and in response to the need for competitive efficiency in both public and private investment and global trade.

Just as the industrial revolution changed the face of Britain in the 18th Century, advances in science, technology and engineering in this 21st century will be fundamental to success for Saskatchewan.

The purpose of this report is not limited to engineering's role in the provincial economy. Rather it takes a broader look at Saskatchewan's future growth requirements, drivers, challenges and opportunities through the rest of this century.

Undoubtedly engineers will play a role in that future, as will many others working in government, the private sector, universities and communities. This work has incorporated the preliminary views of many directly engaged in Saskatchewan's economic future.

Sustainable wealth creation is not an easy task. In its short history Saskatchewan has seen periods of strong and sustained economic growth as well as dramatic reversals of fortune.

In the early decades of the 20th Century the province's population surged from 91,000 in 1901 to 921,000 by 1931. Growth came to an abrupt halt by the Great Depression followed by a decade of droughts – the Dirty Thirties - and the Second World War.

It is important to note, however, that both the initial rapid growth in the economy and population and the recovery from drought and depression took the skills of engineers working with political leaders of the day to address the challenges, issues and opportunities.

Creating the growth foundations for today's Saskatchewan in the first decades of the province required railroad engineers, steam engine specialists to operate the tractors and threshing machines, agricultural engineers to design and test new farm machinery.

Following the droughts water and civil engineers built dams and reservoirs to provide secure water supplies and to lay the foundation for an agricultural development opportunity that continues to the present.

Drought proofing Saskatchewan started with a political commitment to the best science and water management strategies that were available at the time. They are seen today in the Gardiner and Qu'Appelle Dams and farmer management practices that adapted to droughts and minimal rainfall. Similar stories exist for the expansion and diversification of the provincial economy into energy (uranium, oil and gas) and potash mineral exports that play such a large part in today's provincial resource revenues.

Many of these engineering developments established the foundations for long-term economic growth from infrastructure investments started in earlier decades.

In the 21st century the requirements for engineering led by technological change and innovation remain a foundation for economic progress that is examined in more detail in the following sections of this paper that review:

- **Engineering in Saskatchewan** outlining the economic, fiscal & social impacts of engineering in the Province;
- **Sustainable Economic Growth, Technology, Innovation & Engineers**
- **Emerging 21st Century Drivers & Challenges** for **Engineering in Canada and Saskatchewan**, and finally,
- **Measuring Economic, Fiscal & Social Impacts of Engineering in Saskatchewan**

II. ENGINEERING IN SASKATCHEWAN

Engineering in Saskatchewan covers many different types of activity. Engineers make things and make things work better. They also use their creativity to design solutions to the world's problems and help build the future. These activities have long been critical to infrastructure and process developments that have transformed the provincial economy from the earliest settlement.

Today, engineering employment is a small proportion of Saskatchewan's total employment, estimated at only 1.5% in 2016 consisting of 4,105 professional engineers and a further 4,570 technicians in support of the engineering activities to create an engineering skill base of 8,675 professionals.

However, a small share of employment says very little about the impact of the sector.

The direct annual wage of the engineering sector, including professional engineers and Engineering Technologists, exceeded $800 million in 2018 and is expected to approach nearly a billions dollars by 2025.

Table 2 Estimated Wage Impacts of Saskatchewan Labour Force Engineers and Technologists, 2018 & 2025.

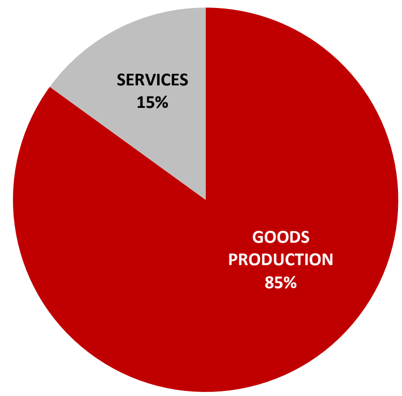
Engineering Discipline	Employment	Annual Wage Impact	
		2018	2025 Estimate
Units		$ Millions	$ Millions
Professional Engineers	4,105	$423.61	$479.42
Engineering Technologists	4570	$377.27	$425.83
TOTAL SK ENGINEERS	8,675	$800.88	$905.25

Source: Derived from Statistics Canada, (2016) and Engineering Canada, (2015)

Statistics Canada Input-Output tables measure the transactions between all sectors of the provincial economy. An examination of the Statistics Canada Symmetric Input-Output Tables of the Saskatchewan economy defines the industrial sectors that purchase engineering services. This reveals a very different picture and shows the significant role engineering plays in the provincial economy.

In 2011, direct engineering and engineering construction services from Saskatchewan purchased from provincial economic sectors amounted to $4.3 billion or 3.4% of all purchases from the provincial economy. However, engineering contributions to Saskatchewan final demand from mainly construction services amounted to $7 billion or nearly 10% of Total Final Demand in 2016. Statistics Canada's allocation of engineering services by sector suggests that Saskatchewan engineering was directly involved in nearly one fifth of the provincial $72 billion economy. Eighty five percent of the engineering services purchased were in direct support of the goods producing and often exporting sectors of the provincial economy.

Figure 1 Engineering Services Purchased by the Saskatchewan Economy, 2011



Source: Derived from Provincial Symmetric Input-Output Tables, Saskatchewan , Industry Accounts Division , Statistics Canada, 2018

The goods producing sectors of the provincial economy include the major natural resource sectors (agriculture, oil & gas and mining), manufacturing, utilities and construction and the export transportation infrastructure. These support large fiscal resource revenues for the Province and the source of much employment and income in the service sectors of the economy, including retail trade, professional services and government workers. A more detailed breakdown of the relationships between engineering services in the provincial economy is shown below.

Table 3 – Major Purchasers of Engineering Services* in the Saskatchewan Economy, 2011

ECONOMIC SECTOR	% OF ENGINEERING PURCHASED BY ECONOMIC SECTOR	
GOOD PURCHASING		85%
Agriculture Plus **	1.80%	
Mining, Oil & Gas	3.60%	
Utilities	1.00%	
Construction	74.90%	
Manufacturing	0.60%	
Wholesale Trade, Transport & Storage	3.00%	
SERVICE PRODUCING		15%
Trade Retail	1.60%	
Services	3.90%	
Government	9.50%	

Note: * Engineering and Construction Engineering Services
**"Plus" includes 0.2% of Forests and Fisheries

Source: Derived from Statistics Canada, Industry Accounts Division, Provincial Symmetric Input-Output Tables, Saskatchewan, 2011

Some sectors of Saskatchewan's economy are dependent on engineering services for their regulatory and economic productivity. Engineering services in 2011 account for 13% of goods producing inputs and nearly 7% of government service purchases. Saskatchewan construction has over 40% of its service inputs from engineering.

Table 4 Engineering Services Purchased into Saskatchewan Economic Sectors and Final Demand, 2011.

ECONOMIC SECTOR	% SHARE OF TOTAL SECTOR PURCHASES & FINAL DEMAND	
GOODS PRODUCING		**13.2%**
Agriculture Plus**	2.0%	
Mining, Oil & Gas	1.6%	
Utilities	5.8%	
Construction	42.7%	
Manufacturing	0.5%	
Wholesale Trade, Transport & Storage	7.3%	
SERVICE PRODUCING		**5.2%**
Trade Retail	**4.7%**	
Services	**3.3%**	
Government	**6.8%**	
Source: Derived from Statistics Canada, Industry Accounts Division, Provincial Symmetric Input-Output Tables, Saskatchewan, 2011		

These statistics reveal a deep and critical involvement by engineering in the Saskatchewan economy influencing some $14 billion of annual economic activity. In practice the impact is much larger since these natural resource sectors also support many of the service industry activities.

The scope of specialized engineering skills currently being employed by consulting engineers reveals eleven major professional engineering disciplines and a much wider scope of individual engineering specializations essential for the operation of much of the provincial economy. Table 6 on the next page shows the 277 skills areas of ACEC-SK members in 30 business sectors.

Table 5 Saskatchewan Professional Engineers by Skill Area

PROFESSIONAL ENGINEERING DISCIPLINES	Labour Force Status		
	Total	Employed	Unemployed
CIVIL, MECHANICAL, ELECTRICAL & CHEMICAL	**3,065**	**2,920**	**150**
Civil	1,205	1,140	65
Mechanical	865	825	40
Electrical & Electronics	815	770	45
Chemical	185	185	0
OTHER ENGINEERS	**1,040**	**995**	**40**
Industrial & manufacturing	235	225	0
Metallurgical & materials	40	40	0
Mining	200	195	10
Geological	60	60	0
Petroleum	200	180	15
Computer	190	185	0
Other	105	100	0
TOTAL SASKATCHEWAN	**4,105**	**3,915**	**190**
Source: Statistics Canada, 2016 Census of Population, Statistics Canada Catalogue no. 98-400-X2016295. Occupation - National Occupational Classification (NOC) 2016 (693A)			

Today's reality is that engineering has become an essential service to maintain the competitive position of Saskatchewan's natural resource economy, to meet statutory requirements for engineered activities and are often critical in building new and expanded sectors of the provincial economy.

Many engineering innovations have been required to obtain the growth in the provincial economy that exists today. In many cases new engineering techniques allowed the natural resources to become commercial reserves, internationally competitive and grow the provincial economy, increasing fiscal revenues and provincial exports. For example:

Potash Mining

Underground potash deposits in Saskatchewan are the evaporation of an ancient inland sea creating three major levels of potash separated by layers of salt. Many deposits are 3,000 - 3,500 feet underground around Saskatoon and even deeper in the south beyond conventional shaft mining techniques.

Discovered as a resource in 1942 during oil exploration, new mining engineering techniques were required to sink shafts through deep unstable water logged salt deposits around Saskatoon, achieved by freezing the Blairmore layers in advance of mine shaft construction and using solution mining techniques further south around Regina.

Lanigan Potash Mine

Application of the techniques created over 100 billion tons of recoverable ore and a long-term major addition to the provincial natural resource economy.

Oil Production

Weyburn Pumpjacks

Similarly, in the late 1980s horizontal drilling was pioneered in Lloydminster, Winterfield and Weyburn in the Nottingham field. Global leadership was achieved with C02 flooding in Saskatchewan that accounted for 50% of the high productivity wells.

Through the 1990s there were more horizontal wells drilled in Saskatchewan than Alberta. Provincial oil reserves for refining and export increased dramatically.

Large Scale Irrigation Development

The droughts of the 1930s led to a political and economic necessity for the Province to adapt to frequent and recurring droughts.

Gardiner Dam Lake Diefenbaker Reservoir Operations

The solutions were found in a combination of water reservoir constructions across southern Saskatchewan, the largest of which were the Gardiner and Qu'Appelle Dams creating the 200km Lake Diefenbaker.

The engineering skills required to create the reservoir on the South Saskatchewan River led to world leading earthen dam construction techniques that were later replicated in many areas of the world.

Irrigation Pivots

At home the engineering accomplishment was the foundation for a large scale irrigation industry to supplement dryland farming and effectively secured water supplies for over a million irrigable acres in Saskatchewan – and opportunity never fully realized in the 20th century.[1]

Engineered Platforms for Economic Growth

Over time from settlement to today engineering priorities have changed to meet the opportunities of the marketplace, the global economy and the economic and environmental challenges of the province. Periodic changes are therefore required in the engineering profession to meet the emerging challenges in the economy, the environment and the future.

The diverse set of engineering skills based on science, technology and experience has often been transferred between sectors. Thus an engineering company that may have started with structural and civil engineers building roads and bridges, may apply those skills to mining roads and building mines to provide engineering innovation to mining industries.

With each generation of the economy growth inevitably requires the latest engineering skills to meet global competition and develop new infrastructure platforms as foundations for new rounds of economic growth.

New infrastructure platforms are the foundation for the next generation of economic development and employment. However, they do not happen overnight and take vision, foresight and planning to occur. We often see glimpses of the new infrastructure platforms for the next Saskatchewan economy.

Diversification in crop production and irrigation requires improved trade export routes on land, sea and air with reliable water supplies. Global warming opens up delivery routes through the north and challenges water supplies in the south. Energy transformation with increased electricity production is creating new generating and transmission requirements for construction. New and emerging technologies in robotics, communications, plant genetics and carbon sequestration will all have very direct applications to Saskatchewan conditions.

A strong sustained and growing provincial engineering construction sector is often the start of the next generation of growth and prosperity for Saskatchewan. New platforms for economic growth require long term planning and a commitment to future economic growth that transcends the political priorities of the day.

It was in the past! It still is today! It will be Tomorrow!

New platforms for economic growth in the past have created the revenues for provincial government spending[1] from natural resource revenues and a broader base of taxation. The challenge for the engineering profession, industry and government is to determine priorities for the next platforms for economic growth. The next two sections of this report therefore examine sustainable economic growth in Chapter III and some of the 21st century drivers and challenges facing today's Saskatchewan economy in Chapter IV.

III. SUSTAINABLE ECONOMIC GROWTH, TECHNOLOGY, INNOVATION & ENGINEERS

Sustainable economic growth has been an elusive concept through much of human history. Equally important the distribution of the benefits from growth has often been highly variable. Many do not always participate in the benefits of the new economy.

[1] Amounting to $1.5Billion or 15% of revenues I the 2018/19 Budget.

Causes of economic growth have been seen as market size, investment and technological change as they enable new products, processes and new forms of organizations.[2] Innovation has been a central and repeating central factor within the economic development process.

These foundations for growth interact and may change over time. For example, increased investment may be a prerequisite to install new technology that may require a larger market size to justify the new investment. Similarly, organizational structures in the private sector such as joint stock companies or public sector regulatory agencies may also be enablers or constraints on the rate of change or progress in the economy.

Through thousands of years of economic and social evolution our adaption to the technologies that we have created helped to mould and re-mould our economic, social and political institutions and our behavioral patterns.[3]

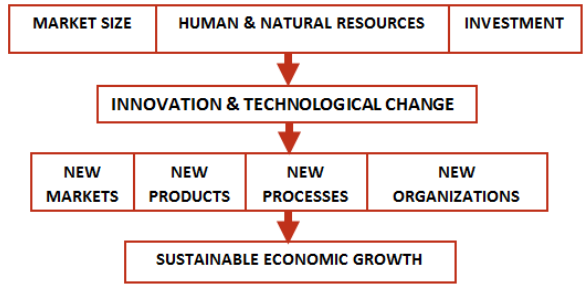
Traditionally, our understanding of economic growth has been seen as market size, natural resources and investment working with innovation and technological change to enable access to new markets, products and processes and new forms of organizations. ***Innovation and innovation is a central and repeating central factor in the economic development process.***

Saskatchewan has benefited from these innovations with new crop varieties, water, transport, mining and energy infrastructure. New products, markets and processes emerged from innovation with the application of new technologies to Saskatchewan conditions. (Figure 2)

Engineers as problem solvers were often central to introducing many of these changes into the society and economy that enabled economies to grow and respond to the social, economic and environmental issues of the day. Thus railroad construction brought access to distant markets much larger than those available in Saskatchewan. Following the 1930s droughts, the Prairie Farm Rehabilitation Agency (PFRA) was created as an engineering and scientific centre of excellence to drought proof the southern Prairies by applying the best science and technology available at the time. Rural electrification brought light and electric power into farm communities. All of these innovations occurred in both the private and public sectors as the Province adapted to the changes and opportunities of the day.

In addition, the organization of society and government is well known as critical for sustainable economic growth. Specifically, innovation for economic and social development requires not only the skills of engineers, but also the creation of institutional environments to allow long term and sustainable innovation. (Figure 2) Too often, this has not been the case.

Figure 2 Elements in Sustainable Economic Growth



Economic development results from investment in the generation of new ideas through innovation and the creation of new goods and services, the transfer of knowledge and the development of viable infrastructure. Examples of economic development include the creation of infrastructure, not just roads and bridges, but also digital and communications infrastructure, and the creation of knowledge through education and training, which can be utilized by businesses to create new goods and services. Investment in research and development and support for entrepreneurship and innovation makes a significant contribution to economic development, as they identify new opportunities and then bring them to market to realize value, which will in turn lead to increased productivity within an economy.[4]

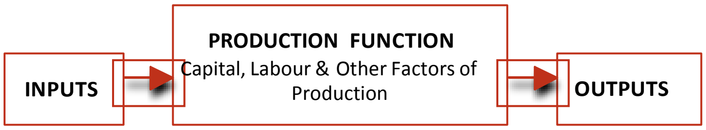
By investing in infrastructure, such as transport, bridges, dams, communication, waste management, water supply and sanitation as well as energy and digital infrastructure, countries raise their productivity and enhance other economic variables. A well-developed transport and communications infrastructure allows countries to better access goods and services to market and move workers to jobs. A strong communications network allows a rapid and free flow of information, helping to ensure businesses can communicate and make timely decisions. ***All of these infrastructure projects require engineering and engineers.***

Success in modern economic development also requires economies to remain competitive in a global economy and a national marketplace For Saskatchewan's land locked natural resource economy competitive access to distant export markets has always been a persistent reality.

Sustainable economic, social and environmental change and growth is not a short-term concept. Many public sector investments in infrastructure set the stage for decades of growth, transforming the future and creating jobs and economic diversification while adapting to the reality of climate change.

Our understanding of how economies work has evolved over time. Traditionally, neoclassical economic models looked towards a simplistic production function in which inputs were entered into a black box production function containing capital, labour and other factors from which output was created.

Figure 3. Neo Classical Aggregate Production Function



Within this aggregate framework output is derived through a black box of effects in which it is difficult to determine the causes of productivity gain reflected in higher labour or capital productivity. Factors of production such as education, technological advancement, labour skills or the role and structure of governments and industry organization cannot easily be disentangled within the black box.[5]

In the modern era economies change quickly as they innovate and adopt new technologies. The process is continuous and can be seriously constrained by the institutional structures that provide the frameworks for economic development in both public and private sectors.

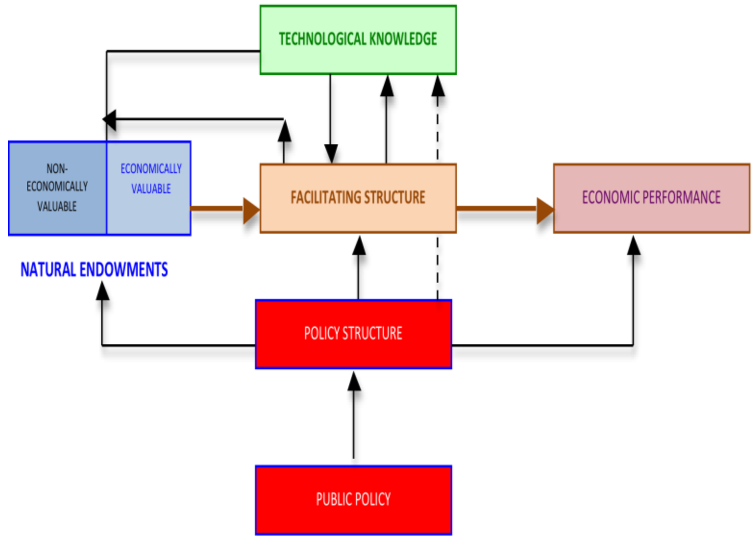
While economies in Saskatchewan and around the world are developing new products, applying new technologies and adapting to market and climatic realities, institutional and regulatory structures in the public and private sectors do not always keep pace with the competition and can constrain current and future economic and social growth. This is most evident in the current Federal Liberal Government's changes to pipeline development regulations that has quickly stalled investment and development in Western Canada.

Recently Lipsey, Carlow and Bekar (2015) have provided improved approaches to understanding the growth, change and evolution of economies, taking into account the effects of organization, technology, education and other factors that previously existed within the "black box production function." This broader approach provides for a *Structuralist-Evolution Decomposition of the Economy*, where inputs into the production function also generate outputs (Figure 4).

The arrows in the figure show the main internal flows of influence within an economy, many of which have a direct effect on whether natural resources have, or do not have, value in the marketplace. These are:

i. **Technological knowledge** inducing changes in the facilitating structure and also moving the boundary between valuable and non-valuable natural endowments;

Figure 4 Structuralist-Evolution Decomposition of the Economy



Source: After Lipsey, R.G., Carlaw, K., and Bekar, C.T., Economic Transformations, 2015), Fig. 3.2

ii. **Facilitating Structures** can affect the accumulation of technological knowledge and also move the boundary between valuable and non-valuable endowments and influence performance;

iii. **Public Policies** embedded in the policy structure and operating through that structure can also move the boundary between valuable and non-valuable endowments, directly affecting the accumulation of new technological knowledge, influencing elements of the facilitating structure and performance.

Technological Knowledge is codifiable and stored in blueprints and instruction manuals. Other technological knowledge is tacit and can only be acquired by experience and can only be stored as human capital. All product, process and organizational technologies have elements of both tacit and codifiable knowledge often contained within the engineering discipline and experience.

Engineering Codes of Practice are the hands-on codifiable science that crosses generational lines and allows for the introduction of new science and technology. From natural resource exploration and development, to water, transport and communications infrastructure, to food production to energy generation and distribution to urban and rural housing to medical facilities to recreational activities – all exist with a framework of engineering skills and expertise.

Facilitating Structures define the ways in which technological knowledge is embedded in physical objects, people, and structures. To be useful technological knowledge must be applied and includes such items as:

- Physical capital, consumer durables, housing.
- People and their knowledge of how to operate existing value creating facilities.
- Physical organization of production facilities.
- Managerial and financial organization of firms.
- All infrastructures.
- Educational institutions.
- Public & private research institutions and activities.
- Government owned industries and structures.

Agents who take most of the decisions concerning these elements are firms and households, with some input from the public sector, particularly in Canada for infrastructure.

Natural Endowments are the basic materials used to produce output from the production processes within the facilitating structures. New technologies and public policy frameworks and policies can reduce the value of some resources and increase the value of others depending on the practices adopted.

Public Policy is the framework of ideas to meet the objectives of legislation, laws, rules, regulations, procedures and precedents as set by past and present governments. It can set the environment for future growth and investment or constrain or stop growth. Getting it right matters!

Engineers are embodied within this evolutionary framework for economic development as catalysts for technological change. Engineers often deploy and diffuse new engineering technologies that are central to nearly all aspects of modern life.

Engineering contributes to sustainable economic growth in several ways by making:

1. **Direct additions to economic output** from the work they do as measured by engineers' earnings or payrolls plus profits earned.
2. **Contributions of engineering activity** to the output of the various sectors in which they work and the benefits these sectors have throughout the economy in terms of purchases from suppliers, spending by workers and so on, often measured by the direct, indirect and induced effects of the engineering project.
3. **Transforming the fundamentals of economic competition** when infrastructure, technology, communications change production costs allow access to new resources and markets. Commonly engineers are constructing the new platforms for economic growth.
4. **Innovations to resolve issues of the day** using engineering science and technology transforming the

costs of using materials, infrastructure and transportation assets.

Also, engineering is a professional and intergenerational repository of knowledge, technology and experience central to many economic activities. These include for example, engineering contributions to the knowledge economy and sustainability and the long run return to the economy of the improvements in physical infrastructure. [6] The role of engineers in economic transformations has been critical in the past and remains central to realizing future economic development opportunities in two key areas.

1. Addressing Capacity Constraints

Engineering expertise has been critical in addressing critical capacity constraints on the growth of economies. Thus export production is constrained when goods cannot be exported.

Railways, canals, roads, ports and bridges have all addressed these issues throughout history and around the world. Often these constraints have involved new engineering technologies of design, construction and implementation from both trained and practical engineers.

Thus aqueducts designed by civil engineers supplied water to roman cities and allowed them to grow. Mining engineers froze the saturated soils of the Blairmore layer and allowed the production of what became one of Saskatchewan’s largest exports.

Designing pipeline routes, railway loading facilities and looking for new export routes have all been major factors in increasing natural resource exports over the past two decades and will remain even more important in the future.

2. Constructing New Infrastructure Platforms

Throughout the world engineers have been central to the design and construction of the new infrastructure platforms for economic and social development. Building the railroad across Saskatchewan to connect the province to the export distribution points transformed the province from a landlocked economy with a small population to the breadbasket feeding millions of people around the world.

As domestic and global technologies change so do the infrastructure requirements. Engineers have been at the forefront of planning, developing, building and maintaining the new infrastructure platforms, within the framework of supporting public policies. There is considerable evidence that investing in new infrastructure platforms for future economic growth have been significant in achieving sustainable economic growth in many parts of the world.

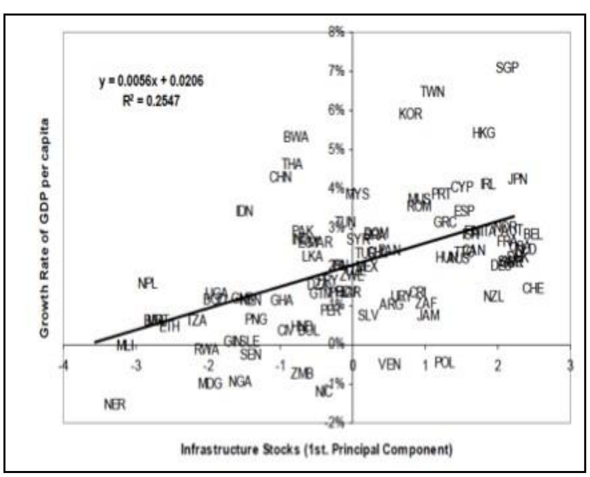
For example, Calderón and Servén (2004) studied a large cross-country data set applicable to Saskatchewan conditions and found positive and significant output contributions from telecommunications, transport, water and power assets.

Easterly and Rebelo (1993) found that public expenditure on transport and communications significantly raised growth. Sanchez-Robles (1998) found summary measures of physical infrastructure are positively and significantly related to growth in GDP per capita. Calderón and Servén (2004) measured the impact of infrastructure development from stocks of infrastructure assets and improved quality of their services on economic growth and the distribution of income for a sample of 121 countries over the 1960-2000 period. Their main results were:

- The volume of infrastructure stocks has a significant positive effect on long-run economic growth.
- Infrastructure quantity and quality have a robust negative impact on income inequality.
- The results, following a variety of statistical tests results, reflect causal, and not merely coincidental, effects of infrastructure on growth and inequality.
- Empirical country findings are significant both statistically and economically showing gains in long term per capita growth ranging 1.1% and 4.8%
- Infrastructure both raises growth and lowers income inequality helps raise the income of the poor more than proportionately.

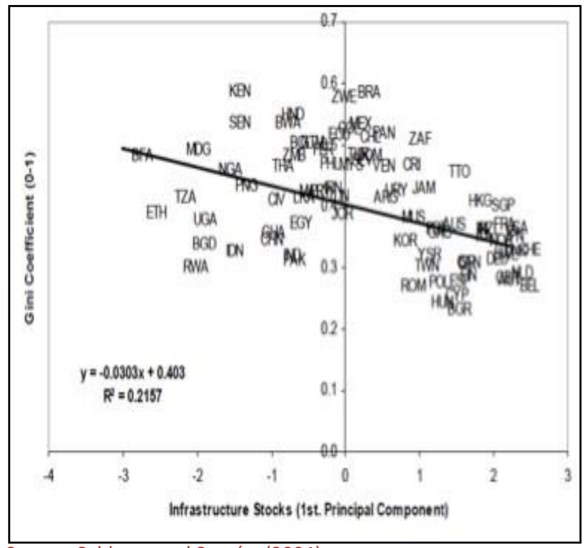
This economic analysis of the relationship between infrastructure and growth shows clearly that as infrastructure quantity and quality improves then the growth rate in per capita Gross Domestic Product - the sum of all economic activity in society - increases. That is the linear relationship shown in Figure 5 rises with the growth in stock of infrastructure.

Figure 5 Infrastructure Stocks VS Economic Growth Rate (GDP Per Capita)



Equally significant, as the stock of infrastructure grows then ***inequality in society is reduced***. The linear relationship shown in Figure 6 for income inequality (the Gini Coefficient) declines as infrastructure stocks increase.

Figure 6 Infrastructure Stocks VS Income Inequality



Source: Calderon and Servén (2004)

These findings have direct application to Saskatchewan in so far as there are many small countries in the study base with sizes and natural resource economies not dissimilar to Saskatchewan's and, like the province, have developed significant infrastructure deficits. Building for the future requires long-term commitments to infrastructure investment, that the empirical research from the World Bank and others suggest would improve economic growth and reduce income inequalities.

New approaches are required to the long term planning of development infrastructure based upon the realities of new and emerging opportunities in the marketplace. For Saskatchewan there is widespread agreement on directions for economic growth through the next decades.

Realizing them within the constraints of annual budget cycles, traditional funding administrative approaches and periodic election and leadership changes becomes a challenge for governments and industry. Engineering the future nearly always requires a longer term view of emerging possibilities and opportunities.

In southern Albert in the 1980s a commitment to rehabilitate leaking irrigation canals and develop supporting diversified food processing infrastructure transformed the drought-ravaged drylands in the south east to the highest value agricultural lands in the province.

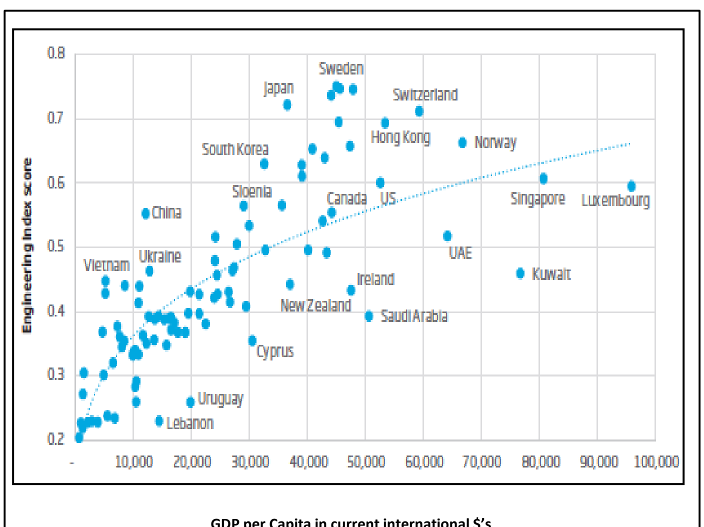
Engineers help to develop the physical infrastructure we all rely on – transport networks, roads, bridges, water and energy supplies, and waste management. They also plan and construct our digital infrastructure – the communications and navigation networks that are not only central to life, but also when applied to traditional natural resource and transportation sectors, can transform the market access and long term productivity of those sectors.

By building the infrastructure for the next generations of economic development, engineering has had a much wider and more lasting impact by fueling economic growth. Well-built housing and sanitation improves the quality of life for all residents. Good transport links make it easier for businesses to trade their goods, and enables the workforce to be more mobile. High-speed internet can boost productivity, improve efficiencies, and help an organization look beyond its local or national borders.

The impact of engineering in past has been substantial and in the future may be even greater. A 2016 study by the UK Royal Academy of Engineering (RAEng), looked for a measureable link between engineering and development. The global study connected an Engineering Index to known measures of economic and social development including economic models that incorporated the quality of life and openness to trade, known to have an impact on economic growth. The study found: ***"A 1% increase in the Engineering Index score led to a 0.85% increase in GDP per capita".***

In Saskatchewan this would translate into an increase in GDP per capita of over $5,000 or nearly $6 billion.

Figure 7, Correlation between GDP per capita and the Engineering Index



Source: World Bank, CEBR Analysis for the Royal Academy of Engineering 2017,p.55.

Significantly, Canada and the United States have an Engineering Index, well below twenty other countries with an Engineering Index higher than Canada's – sometimes as much as 20% higher including Australia, Belgium, Denmark, Finland, France, Germany, Japan, Netherlands and Norway (see Table 6).

Table 6 List of Countries with an Engineering Index Higher than Canada

Country	Engineering Index Score %	% Points Above Canada
Australia	69	14
Belgium	64	9
Denmark	75	20
Finland	65	10
France	61	6
Germany	74	19
Japan	72	17
Netherlands	75	20
Norway	66	11
Republic of Korea	63	8
Slovenia	56	1
Sweden	75	20
Switzerland	71	16
United Kingdom	63	8
United States	60	5
Austria	66	11
Hong Kong	69	14
Luxembourg	59	4
Rwanda	57	2
Turkey	59	4
China	55	0
Canada	55	-

Source: RAEng(2017), pp.60-73.

A competitive standard for the level and quality of engineering capacity should not be based on a domestic comparison alone, but rather on an improved understanding of the global competition. Many of the countries with higher engineering index scores than Canada are smaller countries, sometimes more comparable to Canadian provinces.

Table 7 No. of Engineers Per 1,000 people Canada, Provinces and Territories, 2015.

	Engineers	Persons (000s)	Engineers/ 1000 People	% Change from Canada
YK	759	36.8	20.6	+275%
AB	43,898	4,175.4	10.5	+91%
SK	7,670	1,134.4	6.8	+24%
NL	3,580	525.8	6.8	+24%
QC	42,895	8,245.5	5.2	-5%
ON	66,285	13,750.1	4.8	-13%
NS	4,236	942.9	4.5	-18%
NB	3,189	753.3	4.2	-24%
BC	18,141	4,666.9	3.9	-29%
MB	4,979	1,292.2	3.9	-29%
NWT & NU	254	80.1	3.2	-42%
PEI	266	146.3	1.8	-67%
CANADA	196,152	35,749.6	5.5	

Source: Engineers Canada 2017

However, the 2015 Provincial report from Engineers Canada shows that measuring the number of engineers per thousand of the population within Canada provinces showed Saskatchewan tied in third place with Newfoundland and Labrador with 6.8 engineers/thousand people to be 24% above the Canadian average although 67% below the Yukon and 35% below Alberta.

While the number of engineers per thousand people for Saskatchewan may seem to be acceptable it should be realized that in a growing province every extra 100,000 people requires an additional hundred engineers related to the growing demands of a growing provincial economy. Thus growth based on mining expansion looks for mining engineers, while agricultural expansions require a new brand of 21st century agricultural engineers.

In practice the number of engineers in the province can change rapidly with engineering demands from other parts of Canada and the United States.

Can a New Generation of Enginers help design and develop Saskatchewan's New Infrastructure Platforms?

"We can't solve problems by using the same kind of thinking we used when we created them."
Albert Einstein

M1 Canal – Part of a New Infrastructure Platform for Water Management

Arctic Shipping – A New Saskatchewan Export Route?

Other factors also affecting the availability of engineers in the Province to support growth include:

- The retirement of the large engineering immigration booms from the 1960s;
- The capacity of the University of Saskatchewan and Regina to graduate enough engineers to meet the demands from a growing economy.
- Engineering course structures in the Universities of Saskatoon and Regina that will have to adjust to the rapidly changing economy. It took years for example before potash mining courses were provided at the University of Saskatchewan.
- The health of the corporate structure of Saskatchewan based engineering companies who provide the foundation for engineering training and employment in the province.
- The tax treatment by the federal and provincial governments of in house training and research in support of economic development priorities.

IV. EMERGING 21 CENTURY DRIVERS & CHALLENGES FOR ENGINEERING IN CANADA, SASKATCHEWAN & THE WORLD

Saskatchewan's economic future in the early 21st century has been well documented. Premier Wall's Saskatchewan Plan for Growth defined the future planning horizon as:

*"Growth will be a result of **continued investments in a competitive economy, infrastructure and a skilled workforce**. Building on our **agricultural and natural resource advantage**, Saskatchewan will be a global leader in **export and trade** by 2020 and will invest in **knowledge and innovation** in the development of Saskatchewan's future economy. **Capital investments in new projects and expansions** will grow our economy, and Saskatchewan will continue to welcome newcomers from across Canada and throughout the world to live and work in our province."*

SASKATCHEWAN PLAN FOR GROWTH
VISION 2020 AND BEYOND

Government of Saskatchewan, Regina, 2012

ELEMENTS IN THE SASKATCHEWAN GROWTH PLAN

1 Investing in the infrastructure required for growth.

2 Educating, training and developing a skilled workforce.

3 Ensuring the ongoing competiveness of Saskatchewan's economy.

4 Supporting increased trade, investment and exports through international engagement.

5 Advancing Saskatchewan's natural resource strengths, particularly through innovation, to build the next economy.

6 Ensuring fiscal responsibility through balanced budgets, lower debt and smaller, more effective government.

All of the six core growth activities identified as foundations for the Growth Plan have implications for engineering in Saskatchewan. The Provincial Economic Plan recognizes the opportunities available to the Province in food, fertilizers and fuels and develops infrastructure and new technology to grow the Province into growing global markets. Saskatchewan's agriculture, mineral and energy resources will continue to have global appeal for many distant rapidly growing world markets. It is an approach towards provincial economic development that is widely shared by most major provincial economic stakeholders in the Province, by leading specialists in Canadian economic development and by a federal government expecting to expand agricultural exports from Canada by 33% by 2030.

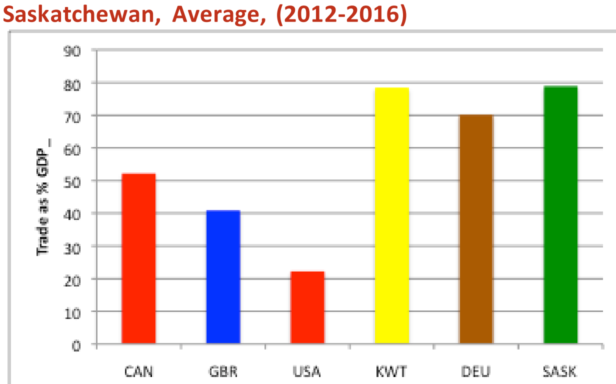
Saskatchewan's ability to meet the Growth Plan requires an understanding of the ***Fundamentals, Drivers and Challenges*** for the Province. These have been developed from surveys and discussions with Saskatchewan engineers and economic leaders in the Province and Western Canada, recent developments in economic growth theory and experts in public sector institutional reform. They all incorporate the common requirement for *innovation using the latest engineering with emerging science and technology.*

FUNDAMENTALS

The Global Marketplace Is Competitive & Growing

Saskatchewan is one of the most trade intensive economies in the world. Trade to the rest of Canada and the rest of the world accounts for three quarters of Provincial Gross Domestic Product. Saskatchewan's 79% five year 2012-2016 average level of trade dependence far exceeds Canada's at 52% and was also well above Germany (DEU) at 78% and comparable with Kuwait (KWT) at 78%.

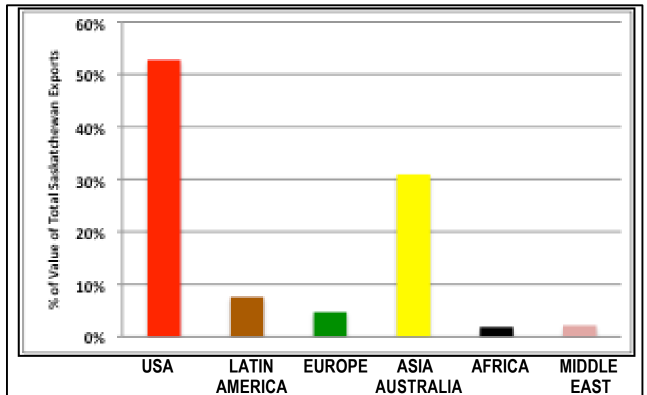
Figure 8 Trade Dependence of Major trading Nations & Saskatchewan, Average, (2012-2016)



These are all provincial exports into a global market place and across most continents. While half of Saskatchewan's international goods exports go south of border into the United States, the Province has already made a good start in entering the rapidly growing markets in an expanding developing world. (Figure 9)

It is significant since developing world markets will also be the source of most economic and population growth through the first half of the 21st century. The United Nations May 2018 forecasts a world population in 2050 of 9.8 billion with developing countries accounting for 98.4% of global population growth - an additional 2.14 people to feed, fuel and house.

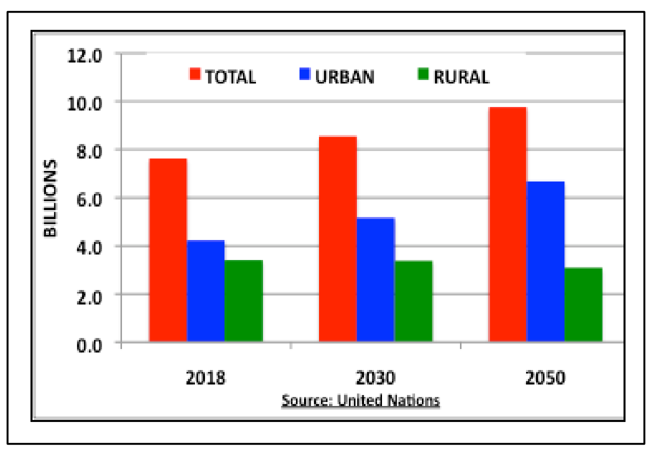
Figure 9. Saskatchewan's Export Trade by Continent



Source: Statistics Canada. Table 12-10-0012-01 International merchandise trade by province, commodity, and Principal Trading Partners

Some 87% of global population growth (2.5 Billion) will be in urban areas further expanding demands for food and fuels. Thus while the global population growth rate continues to decline there will be a steady growth in the demands for Saskatchewan foods, fuels and fertilizers through the first half of the 21st Century and beyond.

Figure 10. World Population Growth to 2050. Total Urban Rural



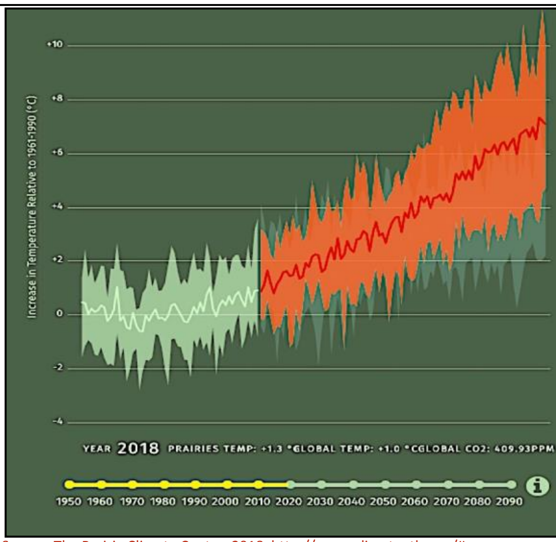
Location Does Not Change

Saskatchewan's geographic location remains distant from these growing global markets. In the past, the transportation technologies of steam, internal combustion, rail, road, rail, bulk movement and containerization on land, sea and air all contributed to reducing the cost of long distant movement and achieving the scale of product movements to access distant global markets. In the 21st Century transportation technologies and the related infrastructure will be an essential pre-requisite for any expansion of markets. Much more work is required.

Saskatchewan's Climate Is Warming, Changing & Volatile

Climate forecasts for the Canadian Prairies predict increasing average annual temperatures over the 1961-1990 average and increased levels of annual volatility. The Prairie Climate Center (PCC)[2] produces the Prairie Climate Atlas with past climate records and the expected Prairie climate forecasts from twelve Global Climate Models. The results document rising temperatures that are changing climatic regimes that will affect Saskatchewan agriculture and environment through the 21st Century.

Figure 11 Projected Increase in Annual Temperature for the Prairies, 1950 – 2006 Actual & Forecast High Carbon to 2095.



Source: The Prairie Climate Centre, 2018. http://www.climateatlas.ca/#

Table 8 Estimated Increases* in Prairie Annual Temperatures Compared to the 1961-1990 Average, High & Low Outlooks

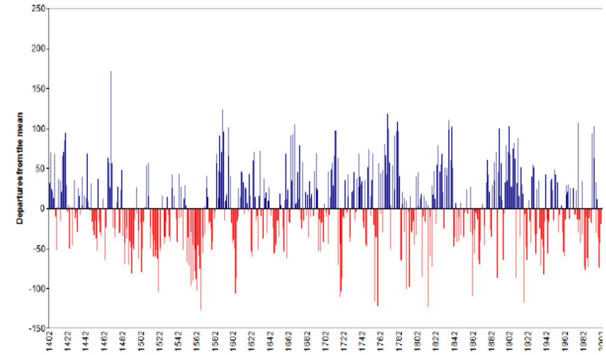
Outlook Scenario	Forecast Year	°Celsius Increase Above 1961-1990 Average	Range Of Increase °Celsius	
			LOW	HIGH
HIGH	2020	+1.9°C	+1.3°C	+2.9°C
	2050	+3.1 C	+1.9°C	+4.7°C
	2090	+6.9°C	+3.9°C	+9.6°C
LOW	2020	+1.6°C	+0.1°C	+4.0°C
	2050	+2.8°C	+0.4°C	+4.4°C
	2090	+4.3°C	+2.4°C	+5.7°C

* Derived from 12 Global Climate Model Forecasts. Source: The Prairie Climate Centre, 2018. http://www.climateatlas.ca/#

Saskatchewan's climate is one of the most volatile in the world. There are wide annual and monthly variations in climatic performance and expectations. The simulated historical record dating back to the 1400s shows very large annual variations in river flow, often for periods of multiyear droughts and driven by the wide fluctuations within the climate for any one year.

Figure 12

Reconstructed Flow of the South Saskatchewan River



Reconstructed Flow of the South Saskatchewan River, 1402-2004, plotted around the mean annual flow(m3/sec). Wet years in blue and dry years in red.

Source: Axelson, J., Sauchyn,, D.J. , Barichivich, J., (2009)

A review of the Saskatchewan's climate and outlook under global warming reinforces the broader Prairie regional findings.[7] The most plausible climate future for Saskatchewan includes a declining net surface and soil water balance in summer, as water loss by evapotranspiration potentially exceeds precipitation to an even greater degree than in the past. Increased aridity from more frequent and/or sustained drought is expected. Sustained drought has cumulative impacts preventing recovery from intervening years of normal to above-average precipitation. Prolonged droughts, like those from Saskatchewan's pre-settlement history are forecast under global warming and are more likely to exceed soil moisture thresholds where landscapes become vulnerable to disturbance and potentially desertification, not unlike the experiences of the Dirty Thirties.

An increase in growing degree-days may support expansion of agriculture in Saskatchewan's North, requiring assessment of the sensitivity of the northern soils to climate change and a changing surface cover. Conversely, as the semiarid southwest becomes even more arid, the soil landscapes may be at greater risk of desertification.

Soils are the basis for Saskatchewan's agricultural economy and provide the largest farmland base in Canada with 39% of all of Canada's farmland.

Water scarcity and security is increasingly one of the most serious provincial risks for agriculture, the economy and society. Projections of temperature increases are more confident than the slight annual precipitation increases, and the resulting higher evaporative demand is a strong driver of water scarcity.

2 A collaboration of The University of Winnipeg and the International Institute for Sustainable Development (IISD)

Although warming winters generally favor livestock production and management, increasing threats of stresses related to heat, water, insects and diseases, and other climate hazards may offset gains.

Agricultural food security is therefore threatened by climate change in Saskatchewan where climate may change more rapidly than in other competing agricultural regions.

Water management and distribution will become a central policy objective to provide solutions to managing too much (flood) and too little (drought) water supplies. In the 1940s engineers and the best science of the day were the foundation for recovering from the droughts. In the 21st Century it will be necessary to once again apply today's engineering and science to address these issues.

ECONOMIC DRIVERS OF THE ECONOMY

Components of Gross Domestic Product

The drivers of the Saskatchewan economy are no secret. Provincial budgets outline the structure of the economy and the source of fiscal revenues and public and private capital investment. The Gross Domestic Product (GDP), the bundle of good and services produced in the Province, is calculated in both current and real (inflation adjusted) dollars.

The formula for calculating the GDP is well known and can be stated short as:

$$GDP = C\ (PC+GS) + GI + TB\ (X - M)$$

Where:

C= Private Consumption (PC) plus Government Spending (GS).

GI = Gross Investment (Government Investment plus Private Investment)

TB = Trade Balance of Exports (X) minus Imports (M)

Equals

GDP = Gross Domestic Product

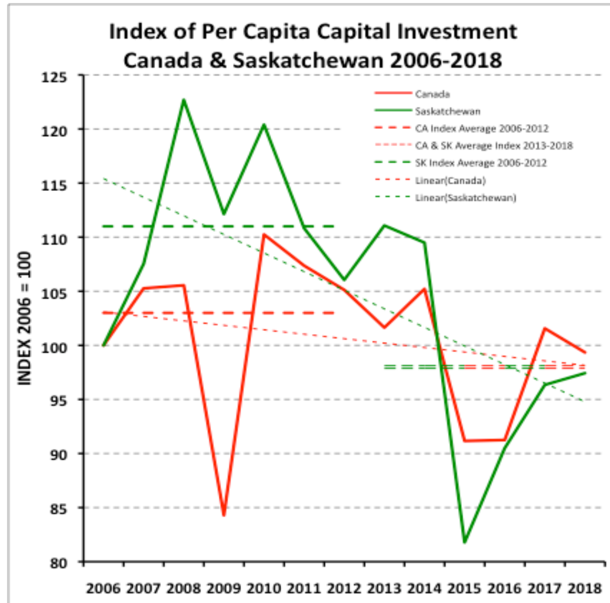
Saskatchewan Domestic Consumption

Saskatchewan is a small province with relatively stable consumption by its small population of a little over one million people. However, government spending, an element of consumption, has been, extremely volatile, creating uncertainty for the economy, particularly in what is already an extremely volatile climate complimented by what can also be an extremely volatile and uncertain international trading framework.

Public and Private Capital Investment

Saskatchewan investment shows high year over year volatility. Capital investment consists of both public (Government) investment and Private investment. An Index of the changes in per capita investment for Saskatchewan and Canada is shown below for 2006 through 2018.

Figure 13. Index of Per Capita Public and Private Investment 2006-2018



During the 2006-12 period Saskatchewan per capita capital investment was about 7% higher than Canada. However, in the 2013-18 period Saskatchewan it fell to much lower levels and by 2015 was much lower than Canada. Significantly, these short-term changes mask a steady decline in Saskatchewan investment. In part this decline reflects the end of the potash investment boom, but also a fiscally led reduction in government infrastructure spending.

The Basis for Trade - Global Market Demand for a Growing World Population Living in the Developed and Developing Economies

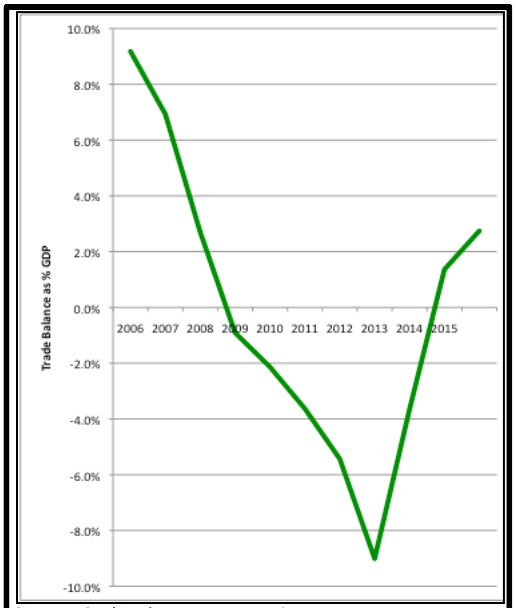
The balance of trade, the difference between imports and exports, determines whether there is a net addition or reduction in provincial GDP. In most years the exports of Saskatchewan natural resources into global markets – foods, fertilizers, forests and fuels – provide a large net contribution to provincial production, that accounted for between nearly 69% and 62% between 2006 and 2016 and showed high levels of year over year volatility and a clearly declining trend over the period. (Figure 14 next page) Significantly, however, the net Trade Balance has ranged from a large surplus of 9% to similarly sized deficits over the same period. (Figure 15)

Saskatchewan's trade position, however, is firmly grounded in expectations for future markets, and in particular, by the underlying demands from a growing world population through the next decades. Demands for food, fertilizers, forests and fuels are fully apparent. Whether Saskatchewan can supply its resources to market will depend heavily on the emerging challenges to overcome its land locked location with new innovations and technologies to be competitive against global competitors, many of whom may have:

Figure 14 Exports as a Share of Gross Domestic Product, 2006 – 2016.

Source: Saskatchewan Economic Accounts

Figure 15 Trade Balance as a Share of Gross Domestic Product, 2006 – 2016.



Source: Saskatchewan Economic Accounts

- Geographic advantages over the province in terms of their location and climate;
- Better access to capital;
- Higher levels of investment in science, technology and education;
- Economies of scale from larger local markets and domestic populations;
- Clearer visions for their economic future;
- More competitive regulatory and fiscal environments; and,
- Advanced Infrastructure platforms in support of economic growth and development.

Overcoming these fundamentals will be a central challenge for Saskatchewan through the 21st Century. To ignore the issues will deny the province the fiscal and economic resources to maintain the quality of life and public services Saskatchewan residents have come to expect.

THE CHALLENGES

Location & Transportation

Saskatchewan's geographic location does not change. Transportation has been the key engineering intensive technology that effectively reduced the economic distance to accessing distant markets from Saskatchewan.

The 21st Century has a large number of new and emerging technologies and market disruptions. Transport system and network flexibility are particularly critical to participate in rapidly changing global trade patterns, competitive pricing and market access.

The Canadian Transportation Research forum notes that: *"Canadian transportation is at the nexus of technological, social and economic changes that are impacting the expectations of transportation users, the capabilities of existing and emerging transportation service providers and the priorities for transportation policy. Are the past assumptions and historical patterns that underlie public and private sector decision making relevant or is there a new normal? What in the past was abnormal but is becoming commonplace? Indeed, is rapid change the hallmark of the new normal in the transportation environment? Among the changes that impact the transportation sector are:*

- ***Changing trade patterns and relationships*** *that influence the spatial pattern of transport demand and subsequently the capacity and infrastructure needed to meet demand.*
- ***Evolving societal values in sustainability****, the environment and indigenous rights.*
- ***New vehicle and information technologies*** *changing the relative efficiency, safety and effectiveness of competing modes of transportation, creating new variations of transport services to serve the public.*
- ***Improving information collection and processing technologies*** *that improve the analytical capacity of researchers, transport decision makers and policy institutions and the implementation of policy implementation such as mobility pricing.*[8]

Many of the transport challenges facing decision makers in the private and public sectors will be different from those addressed in the past. The ability to address these challenges may have changed and the status quo approach will not work. Increasingly it becomes necessary to adapt to the new norms of a changing climate, distant market competition, new transport technologies and fiscal and financial practices.

Emerging transportation challenges to overcome Saskatchewan's locational disadvantage increasingly involves new engineering and information technologies and changing approaches to government and financing. New approaches to technology, organization and innovation in the public and private sectors will be necessary to adapt to the rapidly changing and emerging conditions that include in the transportation sector:

- International trade & transport gateways & corridors;
- Energy supply chains;
- Road, Rail and Pipeline Capacity Constraints;
- Transportation infrastructure investment;
- Mobility pricing;
- Transportation network platforms;
- Autonomous vehicles, drones and airships;
- Information technology innovations such as Cloud Sourcing, Artificial Intelligence, Block Chains;
- Diverse modes of land, air and water transportation;
- Competitive Network, Routing and Pricing Options;
- Multi-jurisdictional export routes;
- Integration of transport within logistics and supply chain decision-making;
- Green transportation systems;
- Climate Change adaptation;
- Changing public and private sectors roles and responsibilities for transportation infrastructure, movement, financing and regulation;
- Transportation demands and transportation services supply including infrastructure; and,
- Transportation policy, regulation; and,
- Fiscal & transport investment funding approaches.

Saskatchewan markets are located around the globe where Saskatchewan producers face intense competition. The Provincial Government derives a significant source of provincial income from the income from these distant markets. It is, therefore, no longer sufficient to consider the transportation challenge solely in terms of provincial technologies and networks. Considerations of the longer inter jurisdictional transport routes and networks, gateways and corridors are a requirement for Saskatchewan to overcome it's locational realities that locate the province distant from market.

Such long-term commitments to expanded transport gateways and corridors are underway around the world with large scale, long distance, transport trade infrastructure plans. These include the Russian expansion of port infrastructure for the northwest passage to link Asia and Europe, long distance road, rail, water and air corridors in Europe and now joining Asia, Europe and Russia – China's Belt and Road initiative geographically structured along six corridors and a maritime silk road.

Figure 16 Asia's Belt and Road Initiative

Including:
Eurasian Land Bridge, running from Western China to Western Russia **China–Mongolia–Russia Corridor**, running from Northern China to Eastern Russia **China–Central Asia–West Asia Corridor**, running from Western China to Turkey **China–Indochina Peninsula Corridor**, running from Southern China to Singapore **China–Myanmar–Bangladesh–India Corridor**, running from Southern China to Myanmar **China–Pakistan Corridor**, running from South-Western China to Pakistan
Maritime Silk Road, running from the Chinese Coast through Singapore to the Mediterranean

Source: New China Daily

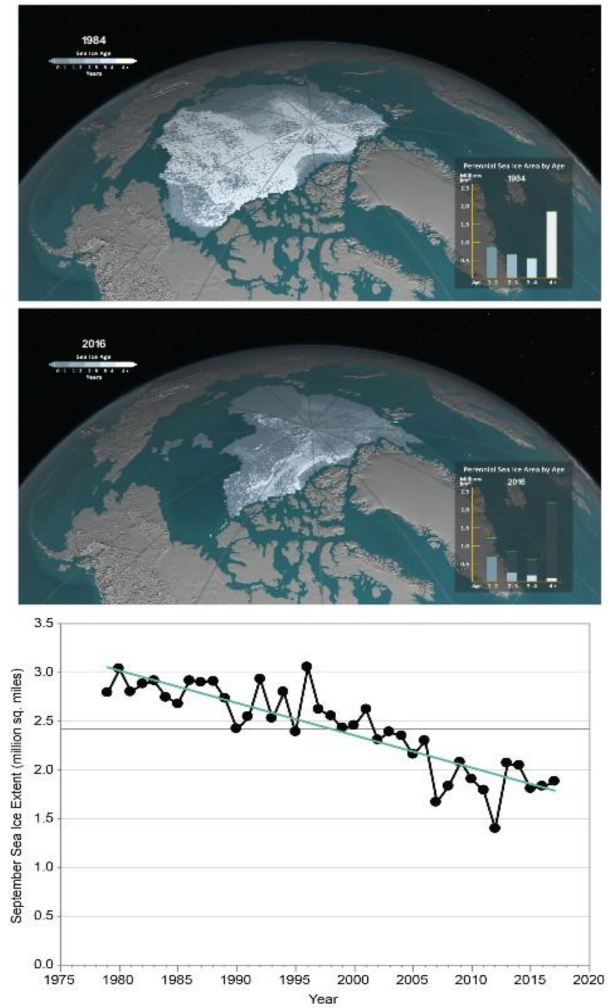
Transportation networks in Saskatchewan must grow and expand capacity to make strategic links to distant new markets. Such connections could include twinning highways to the south to access additional rail export capacity on the Burlington Northern & Santa Fe Railroad providing new export corridors into U.S. and global markets. Road, rail, pipeline and air routes must all expand capacity.

Saskatchewan needs to consider its own strategic Gateways and Corridors into its growing global marketplace.[9] Increased container traffic for manufactured and bulk goods is in the future for provincial export and import traffic. West coast container traffic forecasts suggest this could grow by as much as 60% by 2025. In the two decades to 2016 exports through Vancouver of special crops, many from Saskatchewan grew by 563%. Further development of inland multi-modal container ports like the Global Transportation Hub in Regina will be required to meet the anticipated future growth.

Saskatchewan's trade export routes have traditionally been seen in the context of the east west connections to West Coast, Great Lakes and East Coast tidewater by road and rail and the southern road and rail connections south to the United States. However, to the North of the continent new trade routes are emerging as the North

Pole melts and sea ice recedes. As the Arctic warms, sea ice is shrinking and becoming thinner and younger. Figure 17 shows how the summer minimum ice extent changed from 1984 (top) to 2016 (middle). The bottom panel graph shows the September sea ice extent from 1979 (when satellite observations began) to 2016 revealing an annual rate of 13.3% ± 2.6% per decade. These changes are already allowing sea freight from Asia to Europe. [10]

Figure 17 Melting North Pole and Diminishing Sea Ice



Source: Taylor et al., (2017)

Looking ahead as the sea ice recedes in the Arctic and Hudson's Bay the Northwest Passage may open to provide Saskatchewan with northern export routes to complement west coast and Lakehead routes to Asia and Europe.

The new northern sea routes, already being developed by Russia, are opening as the North Pole melts creating a changing economic geography with infrastructure to northern tidewater through Churchill and the Northwest Passage. Such export routing, much of which is distant from Saskatchewan, is also critical in creating competitive options for Saskatchewan producers and accessing new market demands. (Figure 18)

Figure 18
Saskatchewan Access to Opening Northern Sea Routes

Addressing these issues requires vision, innovation and technology – all foundations of engineering.

Adapting To A Changing Climate

A warming climate in Saskatchewan implies higher temperatures, more moisture and an increase in the already highly variable climate. Most recently in November 2018 the US Global Change Research Program issued its 4th National Climate Assessment Report.[11] They found:

- *Global climate is changing rapidly compared to the pace of natural variations in climate that have occurred throughout Earth's history. Global average temperature has increased by about 1.8°F from 1901 to 2016,*
- *Earth's climate will continue to change over this century and beyond. Past mid-century, how much the climate changes will depend primarily on global emissions of greenhouse gases*
- *With significant reductions in emissions, global temperature increase could be limited to 3.6°F (2°C) or less compared to preindustrial temperatures. Without significant reductions, annual average*
- *Global temperatures could increase by 9°F (5°C) or more by the end of this century compared to preindustrial temperatures*
- *Annual precipitation since the beginning of the last century has decreased across much of the southern and western United States. Over the coming century, significant increases in precipitation are projected in winter and spring over the Northern Great Plains.*
- *Observed increases in the frequency and intensity of heavy precipitation events in most parts of the United States are projected to continue. Surface soil moisture over most of the United States is likely to decrease, accompanied by large declines in snowpack in the western United States and shifts to more winter precipitation falling as rain rather than snow.*

Many of the findings have direct application to Saskatchewan conditions and expectations. Perhaps the greatest challenge facing in the province is adapting to the new climatic realities. Some of the emerging challenges from the changing climate are identified as requiring the attention of engineers are:

- GHG emissions regulation (Environmental Engineers)
- Where will fuel efficiencies to lower global GHG emissions come from? (Energy/Utility Engineers)
- How can carbon stored in oil fields be permanently stored? (Geological Engineers)
- How could carbon capture become economical for smaller industrial GHG emitters? (Industrial Engineers)
- How will housing infrastructure become fuel efficient? (Civil Engineers)
- Will engineering standards be adapted to the warmer climate? (All Engineers)

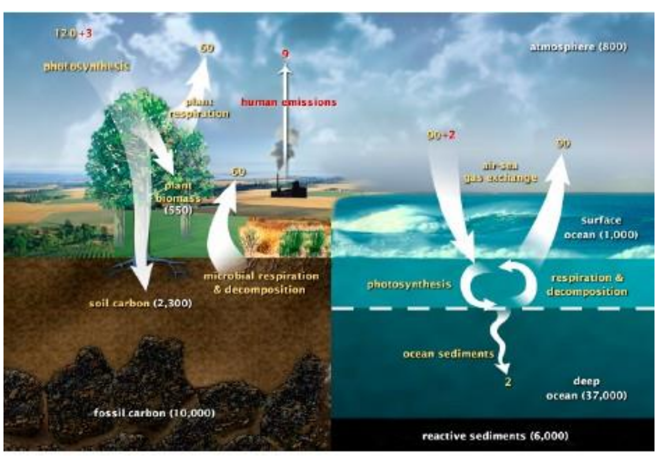
Climate Change Policy

Climate Change policy has been preoccupied with the misguided federal carbon pricing approach. Engineering science based on climate principles would provide an approach on complete carbon cycle accounting defined as Carbon Emission Less Carbon sinks = Net Carbon. A negative contribution indicates the jurisdiction is NOT adding to carbon emissions.

Reducing emissions makes sense not in a carbon taxation framework, but rather as a framework for:

1. **Full Cycle Carbon Accounting and Reporting** not solely focused on anthropogenic emissions taking into account the role of sinks in storing carbon in agricultural lands, wetland, oceans, water bodies, forests and peat bogs. *Saskatchewan probably stores more carbon than it emits in this framework.*

Figure 19 Full Cycle Carbon Accounting



Source: U.S. DOE, Biological and Environmental Research Information System.)

Within Full cycle Carbon Accounting the health of both sinks and emissions are factors determining levels of global warming. Saskatchewan's role of providing large carbon sinks within its territory far outweighs its relatively small federal carbon measurement conventions do not see fit to recognize a scientifically based full carbon cycle accounting framework, instead relying on a partial carbon emissions pricing and tax framework.

Climate science does not consider carbon as pollution as the Prime Minister of Canada refers to carbon emissions. Rather the NASA Earth Observatory notes: *Carbon is the backbone of life on Earth. We are made of carbon, we eat carbon, and our civilizations—our economies, our homes, our means of transport—are built on carbon. … We need carbon, but that need is also entwined with one of the most serious problems facing us today: global climate change. Carbon flows between each reservoir in an exchange called the carbon cycle, which has slow and fast components. Any change in the cycle that shifts carbon out of one reservoir puts more carbon in the other reservoirs. Changes that put carbon gases into the atmosphere result in warmer temperatures on Earth.* [12]

The U.S. Europe and China have out of control net emissions from both massive industrial and urban development that not only increased their carbon emissions and has already destroyed many of the natural carbon sinks on the planet through excessive urbanization of agricultural lands and centuries of destruction of wetlands and forests. This is not the case in Saskatchewan with the most agricultural lands and wetland concentrations in Canada.

2. **Technological Advancement and Economic Efficiency** consistent with family and company normal capital planning activities is an approach embedded in the Saskatchewan Technology Fund in the original provincial Climate Change Legislation. Significantly the approach represented an innovative public policy framework that did not involve public sector taxation but rather a non- governmental structure to create an incentive to investment and emissions reduction.

3. **Adapting to Climate Change Realities** with infrastructure and regulatory changes protecting and supporting the public and the environment can develop increased economic opportunities. This could include advancing a water management agenda to increase irrigated agricultural exports, drought proof and developing new regulatory standards with industry and municipalities consistent with the emerging climate realities.

Many of the historical building and construction standards from the 20th Century are no longer appropriate for the 21st

contributions to carbon emissions. However, 21st century. Managing increased snowfalls and floods requires new approaches to water and soil management. Following the 1930s droughts PFRA was the public institutional response to climate change adaptation. As in the past, engineers will again be at the forefront of real solutions to these issues.

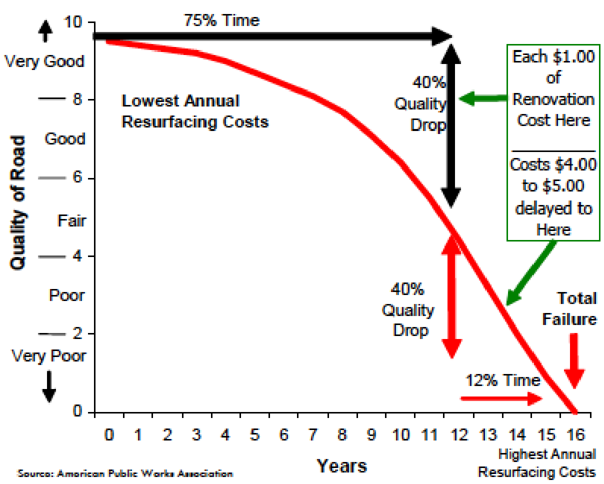
Today new approaches towards carbon management and new construction and engineering standards are required. In both cases, engineering science will be at the foundation of the changes.

Governments too must address these issues with a deep understanding and knowledge of the scientific and engineering foundations for action. Too often government decisions on these matters through short- term fiscal accounting backgrounds have ignored these realities. In this sense there is an urgent need to also consider government practices and organization.

Engineering Value for Money Considerations

The provincial government spent $12.4 billion on infrastructure in the eleven years between 2008/9 and 2018/19, an average of $1.1 billion a year. Expenditures are on a variety of infrastructure projects, from roads and bridges, to hospitals to water infrastructure. The annual list of projects can be diverse. Collectively, in any one year all of these projects may account for a large portion of provincial spending.

Figure 20 Road Maintenance & Renewal Costs Related To The Age And Quality Of A New Road.



The simple illustration above of the timing of maintenance and capital renewal costs for a new road shows the significance of timing for the cost and life of the project. Maintenance costs can increase five times as a result of delays in decisions on the work. Without timely maintenance and renewal, end of life renewal and replacement costs rise substantially.

Getting value for such high levels of spending is an important consideration for governments and the public. Value for money is about maximizing the impact of money spent. However, it does not mean always doing the cheapest things. It is important to understand the main drivers of the costs and revenues of a project and how to get the desired quality at the lowest price usually involving four basic elements that consider:

1. **Time** - the Life Cycle of the Project including construction, maintenance and replacement
2. **Purpose** – the intended use of the projects and the clients/markets that it serves; and,
3. **Impacts** – definition and timing of the impacts of the costs and revenues associated with the project; and,
4. **Options** – Alternatives for undertaking the project and sources of supply.

The application of these concepts can be seen clearly in road construction and repair decisions.

The timing of contract administration and procurement too often delays construction, creating inefficiencies for project management and decision-making. Highway asset deterioration cannot be ignored. Life Cycle Infrastructure planning is required to extend asset life and reduce life cycle costs. Decisions based solely on lowest short-term current costs ignore the life cycle requirements of the road and can increase total costs.

It matters quite a lot when the roads are repaired and rebuilt for at least three reasons:

1. Governments spend more money and get fewer road works when maintenance spending is delayed for short-term fiscal purposes. Delayed maintenance may be a short-term saving, but ultimately increases both maintenance costs of the life of the road and the more expensive capital costs at the end of life of the road. Specifically every $1 of road maintenance spent on fixing roads in relatively good condition requires $4 to $5 dollars when the maintenance is delayed. The Commissioner for Ottawa-Carleton noted that: Those who carry out low cost rejuvenation and resurfacing before rapid deterioration begins extend the pavement life for a fraction of the cost compared to those who just ***"wait a couple of years."*** Ask why they waited and the universal answer is ***"to save funds."***
2. When road surfaces are allowed to deteriorate the bad roads result in higher costs for road using public and on commercial users reducing the competitive position of those industries. Bad roads are a disincentive for investment in the province by increasing the location costs to investors. The province is no longer fully competitive with other jurisdictions.
3. Poor roads also increase fuel consumption and the levels of greenhouse gases returned to the atmosphere.

Timely long term planning reduces both the maintenance and the renewal costs and saves money for both government and the driving public.

When roads approach the end of their life, the costs of bad roads are not only a cost to government. The driving public and commercial activity pays extra costs for operating their vehicles seen most frequently in broken windshields from loose road chips, damaged shocks and struts and increased fuel consumption. Accidents may increase. In addition, roads in poor repair or networks without good connectivity increase the time spent traveling for the public and the economy.

Delayed and deferred construction has direct effects on many other areas of the economy and society, beyond highways.

For example, deferring decisions on a dam or a canal in Saskatchewan holds consequences for reliable water supplies for communities, industry, irrigated acres, higher value added crops and food processing investments.

Similarly, potash mines in the Qu'Appelle Valley deferred investments when water licenses could not be issued due to a lack of water supply infrastructure. Together these constraints on development in industrial and agricultural areas limit employment growth and financial returns to individuals and governments reducing future economic growth.

Infrastructure construction creates new, more efficient platforms for economic growth and social advancement. It enables transformational changes in the quality of life and sustainable long-term economic and social opportunity for Saskatchewan residents.

Construction infrastructure is far more than moving dirt, setting rebar, pouring concrete and paving roads. It is the transformational platform for the next generation of economic growth in Saskatchewan. Today's construction investments improve the competitive position of the province and introduce new industries and technologies for long-term growth. The essential question for governments is:

"Which new or expanded infrastructure platforms are essential of long term growth?"

Saskatchewan is a small Province of a little over one million people and does not always require the administrative tendering complexity that is built into national and international government systems.

Different public sector administrative models are required. One such example is the new Saskatchewan Environmental Code summarized briefly below.

ENGINEERS MAKING PUBLIC SERVICES WORK BETTER

An Environmental Code Replaces Traditional Environmental Assessment Practices

In 2007, there was a large backlog in issuing environmental permits, without which development could not proceed. Engineers adopted a new logic to approach this issue based on the long established practices of Canada's building code and the Latin American experience with Legal Codes of Practice in many of their laws, derived from the Napoleonic Code. For example, Mining law would include a Mining Code and Environmental Law an Environmental Code.

Engineers therefore developed for the Provincial Government an Environmental Code with industry to establish the standards and procedures required for environmental projects to be started and completed in the field without the months, and sometimes years, waiting for the provincial government to issue permits.

This approach combined the best environmental and engineering science as the basis for a new permit issuing system for more efficient government. Significantly, however, it required a major reform of Government practices that had been in place for years and were no longer capable of handing the environmental permitting demands of growth.

Engineering experience is at the centre of effective value decision making, decision making inside of government often relies on short-term financial accounting with limited attention to the fundamentals of value for money decision making, the latest science and technology with benefits for long term decision making and the wider implications of the investment decisions that are fundamental to economic progress.

Infrastructure Platforms for Sustainable Long Term Economic Growth.

Saskatchewan's infrastructure platforms have been foundations for much of past economic success. As previously noted railways and the steam engines were central to the growth of the agricultural export economy that remains in place today. Potash mine development required both mining engineering technology to sink shafts and solution injection and extraction wells and to move product thousands of miles to distant export destination points. Similarly, the expansion in oil production arose from a combination of changes to provincial royalty frameworks and the development of horizontal drilling and flooding. All of these past successes were supported by engineering intensive professional support.

In today's 21st century, it is clear that the existing infrastructure platforms are challenged by changes in the climate and global competitiveness. Further development and expansion of the provincial natural resource base can be a reality in terms of production, but means little unless supported by an increased capacity in four areas of infrastructure development. These are:

1. Water Infrastructure
2. Transportation Infrastructure.
3. Communications Infrastructure
4. Carbon Management Infrastructure

1. Water Infrastructure

Climate change and water will be at the heart of one of Saskatchewan's greatest challenges through the 21st Century. The basic water infrastructure to address questions of drought and flood was established with the building of the Gardiner and Qu'Appelle dams to create Lake Diefenbaker in the 1960s. However, the project has never been finished.

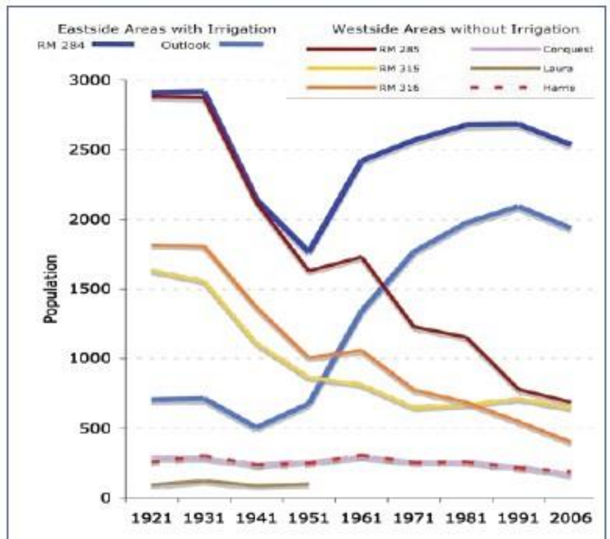
Accordingly, there remains a requirement to complete the work by building the Upper Qu'Appelle Conveyance, the West Side Canal and related water distribution systems. In doing so there could be a start on a province wide water management system to provide water security throughout the agricultural south of Saskatchewan for industry, communities and the environment.

This expanded water management system can represent the next major infrastructure platform for Saskatchewan economic development with major long term drought and flood proofing benefits for the economy and the environment that have been identified as:

- Increasing existing agricultural crop production through increased yields and reliable annual crops;
- Drought proofing for irrigated acreage;
- Crop diversification based on reliable water supplies, particularly in a warmer climate;
- Increased value added for livestock and food processing based on the increased, reliable production;
- Water security for non-agricultural water uses including communities, industries, mines, wildlife, wetlands and the natural environment;
- Creating a regional framework for water storage, distribution and drainage to directly address water supply and storage issues arising from drought and on farm flooding; and,
- Large scale economic benefits that continue for decades based on construction investment, increased production values and economic diversification opportunities.

In depth, long term assessments of these water infrastructure projects suggest larger positive cost benefit ratios that can easily exceed 20:1 when the full range of consequential economic, social and environmental activities are taken into account over the life of the new infrastructure platforms.[13]

Figure 21 Population Trends for Selected Municipalities on the Irrigated Eastside and Non-Irrigated West Side of Lake Diefenbaker, 1921-2006



Source: Statistics Canada

(From 19 1921 to 1951 population declined on both sides of the Lake. After 1951 Population grew on the irrigated east side of the lake and continued its decline on the west side.)

The scope of this major Saskatchewan environmental and economic opportunity based on an expanded water infrastructure platform is well known. However, governments federal and provincial have been unable to commit and develop the full scope of the project due to many of the issues identified earlier involving short-term thinking and financing, public ownership and financing constraints and a lack of understanding of the long term benefits of water infrastructure platforms.

It is significant, however, that in spite of these constraints much of the engineering for a comprehensive regional water infrastructure platform has been completed and awaits a supporting public policy framework to get underway. It is worth noting that in spite of completing the Water Wealth 50 Year Water Development Plan for Saskatchewan[14] over 13 years ago governments have been unable to take decisions on the project in spite of the large long-term social, economic and environmental benefits.

The years ahead will challenge the dryland farming base for Saskatchewan agriculture. Completing the unfinished work of provincial water infrastructure development, planning, management, ownership and construction provides:

- Insurance against major climate losses that already approach a billion dollars of public funding with every major drought;
- Long term diversification of the economy beyond the natural resource production sectors;
- A basis for long term trade development to meet the national and provincial goals for increased global food exports;
- Protection of the natural environment that can also be devastated through floods and droughts taking years to recover; and,
- The repopulation of some of rural Saskatchewan through increased irrigation and increased intensity of agricultural production.

2. Transport Infrastructure.

Saskatchewan's transport infrastructure remains based on slowly but surely moving away from a transportation network established for agricultural settlement in the last century. Today it is challenged with increasing capacity constraints in major cities and between communities within the province and a continuing need for more capacity to move increasing volumes of goods to distant international markets.

As in other areas, long term transport planning has not kept up with the pace of change in the economy – global, national and provincial. Once again transportation infrastructure platforms cannot be managed or developed effectively within short-term, fiscal cycles. Nor can they be managed effectively within narrow provincial frameworks.

The current limited export capacity in moving oil to export markets by pipeline is already requiring solutions involving both more pipeline capacity and other modes of transportation – currently additional railcars on an already constrained rail system. However, none of these are stable long term solutions for Saskatchewan's trade and transport needs. Indeed, while moving oil by rail car may provide a short-term solution, it is also likely to lead to further rail capacity constraints on grain car movement, already challenged to get to export points.

New long term transport infrastructure platforms are required to support the province's growing export demands in a growing province. These would involve:

- Multi-modal network solutions particularly in congested and constrained routes;
- Application of new technologies of information and communications to address in real time bottlenecks in the systems;
- Introducing physical and regulatory infrastructure for new modes of transport with regulations to provide alternatives to existing modes of movement including lightweight air containers, automated vehicles and airships.
- Development of multi-jurisdictional routes originating in Saskatchewan and extending to tidewater or air connections to:
    - Supplement the current limited and constrained export routes;
    - Provide competitive alternatives for Saskatchewan shippers thereby lowering transportation costs and increasing Saskatchewan's competitive position in world markets; and,
    - Accessing containers backhaul movements through the province.

Since Confederation Saskatchewan has had limited transportation options to move its agricultural and natural resource exports to tidewater and export. These have been the two transcontinental railways – Canadian National Railway and the Canadian Pacific Railway and the two main east west roads – the Yellowhead and TransCanada Highways.

This Saskatchewan transportation reality effectively provides the transportation carriers on the limited number of export routes with good transport returns regardless of the economic circumstances of the provincial shippers - a situation commonly supported by governments federal and provincial.

Developing a more comprehensive and competitive provincial multi-model transportation platform with related network communications and information infrastructure could significantly increase returns to shippers.

Evidence of the benefits of increased competition for Saskatchewan shippers became apparent with the move to inland terminals and increased trucking where farmers were offered trucking premiums and grain company premiums to deliver to specific locations. New transport platforms can increase the level of competition and return benefits to farmers and shippers, rather than continuing the age old practice of allowing railways to capture the lion's share of hard earned provincial rents from export production.

Addressing these issues cannot be achieved through an annual and incremental addition, change or renewal to the existing road and rail networks. Bigger thinking is required extending beyond provincial boundaries and adopting new technologies of movement and information. The foundation for this work lies in a new long term transportation plan and infrastructure for the province that will bring new modes, new routes to the west coast, the arctic and the south into play.

Engineers with experience and vision will play a central role in developing a new far reaching, long-term transportation infrastructure platforms working with government, industry and transportation visionaries. This will be based not only on the next round of infrastructure spending, but also the foundations of increased competition, efficiency and export logistics. Value engineering based on long term construction and operating costs and benefits will underlie the process.

Finally, transportation like many other sectors of our world is undergoing dramatic change, considering and testing new technologies. Jurisdictions like Saskatchewan where transportation costs to market can often equal 30% to 50% of the delivered price will benefit from improved transport infrastructure platforms. Realizing these platforms however requires innovation and flexibility to address some fundamental and emerging transportation engineering challenges including:

- Aeroplane and Airship Design, Fuels and Regulation to improve market access and replace northern roads for food delivery and reducing northern food costs;
- Container redesign for land and airships to access employ new lighter yet durable materials and containerize a wider range of commodities and refrigerated movements;
- Low cost airport and airship landing sites;
- Northern road alternatives in the air (planes and airships) on rails and by water;
- Cold climate engineering for roads and rails;
- Highway congestion, logistics and efficient borders controls;
- Network connectivity to address congestion combined with improved real time movement information; and,
- Low cost urban transit options.

All of these issues in Saskatchewan can benefit from transport engineers, although the closest training courses to the Province are to be found in Calgary at the van Horne Institute, in Manitoba at the Transportation Institute in the Asper School of Business or in British Columbia at the Centre for Transportation Studies at the Sauder School of Business in Vancouver.

2. Communications Infrastructure

The 20th Century developed huge advances in information communications infrastructure and developed a foundation of computer and software engineers to implement the advances. In the 21st Century the information revolution is being extended into resource production with continuing advances in information technology, artificial intelligence, robotics and precision agriculture. Many of these advances are essential for the global competitiveness for Saskatchewan's agricultural and natural resource industries.

For example, artificial intelligence in underground mining can improve the safety of miners and access mineral beds without endangering human life. Major oilsands projects have already developed automated trucking with improvements in safety and reduction of costs. Many Saskatchewan farmers already operate automated combines.

Precision agriculture connects real time plant information regarding moisture and nutrient levels to improve plant performance and yields. In irrigated systems this can allow water soluble fertilizers, pesticides and nutrients to be customized to the plants real time growing conditions with savings in fertilizer, nutrient and pesticide costs increasing returns to farmers while also reducing carbon emissions. All of these systems can be automated and controlled remotely.

The full-scale development and application of these systems, however, requires widespread rural communications networks and the supporting rural human engineering infrastructure. Currently, there are too few engineers combining the knowledge of agriculture with the new sciences of plant growth and computer controls. Plant genetics and engineering is also rapidly advancing to provide for another green revolution in agriculture, just in time to support the growing global demands for food from an additional billion or more people.

Developing the human and physical communications networks and research is therefore closely connected to the engineering profession and its educational and training requirements discussed in more detail below.

3. Carbon Management Infrastructure

Approaches towards carbon management have been taken over recent decades as a response to international and federal requirements to measure, report and put a price on carbon emissions. In practice as noted earlier full carbon cycle accounting requires a change in approach to measuring carbon sinks as well as emissions and encouraging technological efficiency in carbon management. To date, the fundamental science based accounting and measurement of sinks has been completed to compare with emissions and provide a net carbon balance for the province. Carbon is not a pollutant as referred to by the Prime Minister. Carbon has always been a part of a planetary carbon cycle where:

- **Natural Carbon Emissions** (e.g. volcanoes and forest fires) and Man-Made contribute to emissions; and ,

- **Carbon Sinks** on the earth's surface vegetation (forests, wetlands, peat bogs etc.) and in geological formations store carbon lead to:
- **A Net Carbon Balance** that is either positive (emissions > sinks or negative (emissions < sinks)

The infrastructure to measure the net carbon balance in Saskatchewan has not been completed due to a continuing federal policy preoccupation with only focusing on emissions. In practice it is likely that Saskatchewan, even with coal, oil, gas, mining and industrial emissions will be a net carbon sink given the size of agriculture, forests and wetlands. However, for this to be determined requires further scientific inquiry followed by appropriate regulatory frameworks.

Engineers are proficient in the skills required to make the estimates of both carbon emissions and the identification, definition and measurement of the sinks capable of sequestering both natural (forest fire) and human (housing/industrial/transportation etc.). This work has yet to be completed and requires changes in both the provincial, national and international measurement at all stages of the carbon cycle.

Just as engineers were able to develop and implement the more efficient practices of the environmental code, so too can new carbon management practices reform the current simplistic approaches to global carbon management.

4. Human Infrastructure for the 21st Century

The Right Supports for Innovation, Science, Technology & Engineering

Human resource decisions have clear effects on Saskatchewan's ability to access the best emerging science, technology and innovation required for effective construction tendering, construction and operation of infrastructure, systems and facilities. Two areas are of critical importance.

Engineering Involvement in Public Tendering & Major Development & Management Projects.

Too often decisions on major infrastructure projects are taken with limited advice from engineering professionals. In their place accountants looking at the lowest cost bids have taken control of the tendering procedures leading to many decisions that are suboptimal. In particular:

a. Lowest cost bids on infrastructure project may provide a short-term fiscal benefit, but incur longer run costs.

b. Knowledge of the latest equipment and technology on engineering projects is generally not contained within the government decision making bureaucracies, but very few attempts are made the purchase this advice on an independent consulting basis to better assess the projects.

c. Seniority hiring practices within the public service often still staffs position without reference to the current engineering skills required in the field.

Table 9/ Numbers of Saskatchewan Degrees Granted in Engineering Disciplines Widely Used in Saskatchewan, Averages for 2000-04, 2005-09, 2010-13

Engineering Discipline	Number of Saskatchewan Engineering Degrees			Average Percent Distribution for Each Period		
A	verage 2000 2004	Average 2005 2009	verage 2010 2013	Average 2000 2004	Average 2005 2009	Average 2010201 3
Civil	26	61	96	9.0%	19.4%	25.9%
Mechanical	59	66	70	20.5%	21.0%	18.9%
Electrical & Electronics	52	44	27	18.1%	14.0%	7.3%
Chemical	27	37	48	9.4%	11.7%	12.9%
Industrial & Manufacturing	33	28	31	11.5%	8.9%	8.4%
Metallurgical & Materials	0	0	0	0.0%	0.0%	0.0%
Mining	0	0	0	0.0%	0.0%	0.0%
Geological	12	13	21	4.2%	4.1%	5.7%
Petroleum	0	0	0	0.0%	0.0%	0.0%
Aerospace	0	0	0	0.0%	0.0%	0.0%
Computer	49	37	27	17.0%	11.7%	7.3%
Software	0	1	13	0.0%	0.3%	3.5%
Other	30	28	38	10.4%	8.9%	10.2%
Total	288	315	371	100.0%	100.0%	100.0%

Source: Engineers Canada (2015)

The province looks for leadership in its two universities in providing the research and people trained in the engineering and related research skills to meet the current and future conditions of the Saskatchewan economy and society. Several important issues for the provincial future in engineering exist however and will not be resolved by continuing the status quo.

- The post World War II engineering immigration streams into Canada and Saskatchewan established a base of individuals and companies that are today retiring from the profession after a lifetime of contributing to building the province. Existing levels of graduation cannot replace the decades of experience and management overnight.
- Curriculum development in Saskatchewan universities has not kept pace with the changes underway in Saskatchewan's economy. Thus even though the potash mining and solution extraction industry became a major industry in the province contributing millions in resource revenues, engineering curriculums did not keep pace. It took decades before courses appeared for undergraduate or graduate students.
- Current university classes offered by the Colleges of Engineering at the University of Regina and the

University of Saskatchewan in Saskatoon are shown below and while providing a solid foundation in engineering principles are not developed to meet the emerging challenges the province faces in water, agricultural, transportation or mining engineering that are required now for future growth.

Figure 22. Engineering Graduate and Undergraduate Classes and Degrees Offered by Colleges of Engineering at the Universities of Regina and Saskatchewan, 2018

University of Saskatchewan	University of Regina
Undergraduate Chemical Engineering Civil Engineering Computer Engineering Electrical Engineering Engineering Physics Environmental Engineering Geological Engineering Mechanical Engineering **Graduate** Biological Engineering Biomedical Engineering Chemical Engineering Civil Engineering Computer Engineering Electrical Engineering Engineering Physics Mechanical Engineering	**Undergraduate** Electronic Systems Engineering Environmental Systems Engineering Industrial Systems Engineering Petroleum Systems Engineering Software Systems Engineering **Graduate** Master of Applied Science Master of Engineering Master of Engineering with Co-operative Education Process Systems Engineering
Source: University of Regina and Saskatchewan Websites. 2018.	

- As a small province Saskatchewan has trouble attracting foreign engineering graduates to come and work in the province. A larger provincial population would likely resolve some of these issues.

The future of Saskatchewan requires improvements in the numbers and skills of its human resources trained in the province. While the consulting engineers hire most of their staff from Saskatchewan sources, the numbers obtained are well below the numbers needed to replace retirees, attracted to out of province positions and meet the growing requirements of the provincial economy.

The 2018 Annual survey of engineering shortages ACEC-SK suggests fourteen engineering disciplines with shortages, a number that will only grow if the Province is to meet its growth agenda.

Significantly, many of these skill gaps occur in sectors that will be critical to the long-term economic development and diversification of the Province.

In the second half of the 20th Century when addressing major engineering demands following the 1930s droughts the Province was able to turn to the federal government and its drought proofing agency, PFRA staffed with several hundred water, civil and environmental engineers. This resource is no longer available to address Saskatchewan's water engineering challenges and must be replaced using alternative and innovative models of training, education and scientific application.

Table 10. Saskatchewan Survey of Future Engineering Discipline Gaps in the Next 2 to 5 Years by ACEC-SK Members.

Engineering Discipline	% Reporting Shortage	Significant to Emerging SK Development Challenges (x)
Geotechnical	42.9%	x
Electrical	28.6%	x
Project Management	28.6%	x
Planning	28.6%	x
Municipal	28.6%	x
Transportation	28.6%	x
Water Resources	28.6%	x
Geomatics	14.3%	x
Structural	14.3%	
Mechanical	14.3%	
Environmental	14.3%	x
Environmental Geoscience	14.3%	x
Occupational Health & Safety	14.3%	x
Communications/ Telecommunications	14.3%	x
Source: ACEC-SK, 2018		

The human resource requirements associated with higher rates of sustainable economic growth will become a critical element in moving the province forward. A reassessment of the future requirements for skilled people and trades can easily become a constraint to continued economic development.

Doubling Saskatchewan's Population

Today, doubling the provincial population from one to two million people is entirely possible, but only with higher annual sustained rates of growth. Between 1901 and 1931 Saskatchewan grew at an annual average rate of
3%. Between 1931 and 2018 the rate dropped to 1%. There is a solid foundation for growth in sustained natural resource expansion and increased levels of agricultural development and diversification as outlined in the Provincial Growth Plan. Such continued growth is unlikely occur, however, without new platforms for infrastructure and new approaches to government planning, structure and reform. A status quo 1% annual rate of growth would only result in a population of 1.6 million by 2050. Alternatively a 3% annual growth rate results in a 2050 population of 3 million. (See Information Annex A)

Moving beyond the status quo will be required and a commitment to a wider participation of both public and private stakeholders in Saskatchewan's future. Coupled with this will be a willingness to consider making changes to make a start

Innovative Reform & Engineering

Saskatchewan has had its fair share of innovative leadership in public policy that included the early social and educational building blocks introduced by Walter Scott (Votes for Women, University of Saskatchewan) and visionary infrastructure projects (South Saskatchewan River Project, rail financing incentives, and farmer owned cooperatives).

Engineers in their role as problem solvers have brought scientific information and discipline to resolve challenges at home and abroad. These have included for example, Saskatchewan engineers resolving landslides in Hong Kong with bar codes or designing and building earthen dams on the South Saskatchewan River and in Ghana to secure reliable water supplies.

Looking ahead it is clear that new developments in science and technology related to provincial development priorities will require an expanded role for engineers to develop innovative solutions to very real challenges.

Areas of innovative public policy reform based on public private cooperation and engineering have already involved the Technology Fund and the Environmental Code. Further challenges exist in developing new infrastructure platforms, innovative financing options and carbon management.

V. MEASURING ECONOMIC, FISCAL & SOCIAL IMPACTS OF ENGINEERING IN SASKATCHEWAN

Saskatchewan Economic Impact Indicators

The economic, fiscal, social and environmental impacts of engineering have been substantial and large in Saskatchewan. Direct measures of the impact of the sector can be seen in terms of employment, wages, expenditures and purchases. Some of these are summarized below.

Table 11 Summary of Some Economic Impacts of Engineering in Saskatchewan.

Direct Impacts	Value	Year
Number of Sectors Purchasing Engineering Services as % of All (34) Sectors	32 Sectors 94% of total	2011
Value of All Purchases by Sectors Using Engineering Services	$4.3B	2011
Value of Provincial Industrial Sectors Influenced by Engineering Purchases	$122.5 B	2011
Engineering Contributions to Final Demand	$9.3 B	2011
Value of Engineering Services to Trade	$2.6B	2011
Value of Trade Affected	$204.7B	2011
Engineering Labour Force Engineering Technicians Total Engineering Labour Force	4,105 4570 8675	2016 2016 2016
Estimated Wages and Salaries – Current Forecast	$404M $456M	2018 2025
Source: Statistics Canada , Census of Population 2016 and Provincial Symmetric Input-Output Tables, Saskatchewan, Economic Accounts Division. 2011.		

More detailed estimates of engineering impacts of the effects of engineering on the Province are seen in the current and future wage expenditures of Professional engineering. These suggest that in 2018 the nearly four thousand engineers generated over $400 million in wages that is expected to rise to $456 by 2025.

Evaluation of the Statistics Canada Provincial Input-Output table for Saskatchewan measured for 2011 in current dollars shows how engineering is fully engaged in all aspects of the Provincial economy. 94% of Saskatchewan purchasing sectors in the public and private sectors use engineering services purchasing some $4.3 billion in 2011 and influencing a much larger $122.5 billion of total provincial purchases.

Engineering is also fully engaged in Saskatchewan's trading economy providing some $2.6 billion of services in 2011 and influencing some $204.7 billion of trade. Saskatchewan employs some four thousand engineers and a further 4,500 engineering technicians for 8,675 total engineering Labour Force. The wages paid to the sector amount to a little over $400 million in 2018, but is expected to rise to nearly half a billion dollars by 2025. The majority of these payments of wages and salaries accrue directly to the Saskatchewan economy.

Table 12 Estimated Saskatchewan Wage Impacts of Professional Engineers in Saskatchewan, 2018, 2025

Engineering Discipline	# Employed 2018	Median Annual Wage		Wage Impacts	
		2018 ($'000s)	2025 (000's)	2018 ($M's)	2025 ($M's)
Civil	1,140	$104	$118	$118.7	$134
Mechanical	825	$97	$110	$80.0	$91
Electrical & Electronics	770	$100	$113	$77.2	$87
Chemical	185	$111	$125	$20.5	$23
Industrial& Manufacturing	225	$93	$105	$21.0	$24
Metallurgical & materials	40	$127	$144	$5.1	$6
Mining	195	$126	$143	$24.6	$28
Geological	60	$127	$144	$7.6	$9
Petroleum	180	$100	$111	$18.0	$20
Computer engineers	185	$95	$107	$17.5	$20
Other	100	$137	$155	$13.7	$15
TOTAL	**3,905**			**$404**	**$456**
Source: Source: Statistics Canada, 2016 Census of Population, Statistics Canada Catalogue no. 98-400-X2016295. Occupation - National Occupational Classification (NOC) 2016 (693A)					

Within the provincial engineering employment base the wage impacts vary from $95K median annual wage to $144K for geological, metallurgical and materials engineering and $155K for some specialist engineering skills contained within the other engineering category. It is significant that only two engineering skill categories realize have a median annual wage lower than $100K in 2018. By 2025 all engineering categories will be offering salaries in excess of $100K.

The input output structure of the Saskatchewan economy shows engineering to be directly involved in most sectors of the provincial economy, although often to a small extent when compared to the size of each sector. This is consistent with both the very broad base of the engineering profession and the essential requirement for engineering skills to develop and complete new projects and to maintain or re-engineer old and current projects to meet the new conditions of the marketplace. Infrastructure projects in both the private and public sectors cannot proceed without engineering leadership and technology. Engineering is often a catalyst for the smooth running of the economy and trade base for wealth creation in Saskatchewan.

More measures of engineering impacts on the province are seen in the direct, indirect and induced effects of expenditures on engineering services shown in the 2014 Input Output engineering sector multipliers[3]. Statistics Canada multipliers estimate the effect of an exogenous increase in spending in Saskatchewan engineering services on Saskatchewan and the rest of Canada for their direct, induced and total economic impacts.

Table 13 Estimated Direct & Indirect and Total Effects of a $1M Increase of $1M of Engineering Expenditures, Saskatchewan and Rest of Canada, 2014

MULTIPLER IMPACT AREA	SASKATCHEWAN		Rest of Canada	
	Direct & Indirect Effects	Total Effects Direct, Indirect & Induced	Direct & Indirect Effects	Total Effects Direct, Indirect & Induced
GDP Basic Price	$1,519,799	$1,809,780	$561,136	$845,070
Labour Income	$1,435,117	$1,611,384	$486,784	$698,685
Jobs	1.53	1.85	0.53	0.85
Source: Statistics Canada, 2018				

The results show that engineering expenditures nearly double within the Province, although as would be expected they do not have a major direct or indirect effect on employment growth. However, Saskatchewan engineering expenditures do have a major effect outside of the Province where over 40% of the benefits accrue. This effect is discussed in more detail later in the paper in connection with the size of Saskatchewan and depth of its engineering and other resource industry support sectors.

Implications of Some Recent Engineering Economic Studies for Saskatchewan's Economy.

A number of International and Canadian studies of the economic impacts of engineering are presented below along with a short summary, where appropriate, of their implications for Saskatchewan's future.

INTERNATIONAL ANALYSIS

Engineering & Economic Growth: A Global View
Royal Academy of Engineering (2016)

Engineering is crucial in helping developing countries 'catch up' with high-income countries through improved infrastructure. In turn this can lead to more households with electricity, improved life expectancy, and higher literacy rates, directly impacting economic growth and the quality of life.

Engineering has been instrumental in the technological development that has helped create modern society. It helped create infrastructure and transportation systems, enabled industrial production, and played a key role in technological innovations such as computers and communication systems, as well as the internet.

Economic literature highlights several 'waves of innovation', or **"Kondratieff Waves",** which act as game- changers in the history of economic development. Each wave has clear ties to engineering. To date, five major economic cycles associated with the waves have been identified as the:

1. Industrial Revolution (1771)
2. Age of Steam and Railways (1829)
3. Age of Steel and Heavy Engineering (1875)
4. Age of Oil, Electricity, the Automobile and Mass Production (1908)
5. Age of Information & Telecommunications (1971)

As part of this move towards sustainability there is predicted to be development of new forms of technology, such as green chemistry, renewable energy and nanotechnology. In addition and equally significant, the

application of the 20 Century technological waves may be applied to new industries in the 21st Century. Thus

[3] Engineering Sector Multipliers are defined for this evaluation as the average effects of Transportation engineering construction; Oil and gas engineering construction; Electric power engineering construction; Communication engineering construction; Other engineering construction; Architectural, engineering and related services; Computer systems design and related services; Management, scientific and technical consulting services; Scientific research and development services.

agriculture may be entering a new era of on farm, electronically/computer controlled plant growth and machinery operation – Precision Agriculture.

An Engineering Index was constructed to measure and compare the strength in engineering across 99 countries from five different regions across the globe. The Engineering Index combines nine separate indicators of capacity and strength in engineering, using historical information from The World Bank, the ILO and other data sources. Two key findings from this analysis are:

1. There appears to be a correlation between GDP per capita and the Engineering Index for 2013 data. That is, higher output per capita is associated with higher Engineering Index scores.
2. Evaluating the effect of the Engineering Index scores on four econometric forecasting models found that changes in the Engineering Index Score yields a positive and significant relationship with GDP per capita in each version of the econometric model used for evaluation.

   A 1% increase in Engineering Index scores is associated with a 0.85% increase in GDP per capita. While this relationship will vary from country to country in the United Kingdom a 1.1% increase would result in an increase in would be associated with a GDP per capita increase of $366, from $39,111 to $39,477 in 2013.

If this relationship held true in Saskatchewan it would yield a per capita increase of $5,000 or nearly $6 billion.

Infrastructure quality is a key component of the Engineering Index and suggests that low engineering index jurisdictions could potentially raise their index scores by raising more investment and directing it towards upgrading infrastructure options.

Table 14 Econometric Analysis of Growth in per capita GDP and the Engineering Index.

Factor	Change	Associated with GDP per capita Growth of:			
		Model #1	Model #2	Model #3	Model #4
GDP per Capita	+1%	0.89%	0.75%	0.57%	0.38%
Change in Business Inventories	+1%	-	-	0.25%	0.23%
Access to Credit	+1%	-	-	-	0.10%
Engineering Index Score	+1 %	-	+1.30%	1.77%	1.87%
Source: CEBR Analysis					

An economy's size is strongly associated with levels of investment. A 1% growth in GDP per capita is associated with a 0.38% growth in investment. Crucially, the association between investment and the Engineering Index remains positive in each of the econometric models evaluated in the UK study. Model 4 found a 1% increase in a country's Engineering Index was associated with a 1.87% increase in investment per capita. In the UK this increase was associated with an investment per capita increase of from $5,473 to $5,586. [4] In Saskatchewan this translates into half a million dollars in 2016.

[4] Expressed in Purchasing Power Parity Terms.

IRELAND - ECONOMIC IMPORTANCE OF ENGINEERS, DKM Economic Consultants Ltd, DUBLIN, Engineering contributions to economic output are identified as:

- Direct addition to economic output from work undertaken and contributions of the sectors in which they work.
- Engineers represent 2.3% of the workforce on the island of Ireland with estimated earnings of €5.5 billion or 3.4% of total Irish Gross Value Added (GVA; equivalent to GDP), and €2.16 billion or 6.7% of total GVA in Northern Ireland.
- Generate GVA of €42.3 billion in Ireland in 2007, 25% of total GVA for the entire economy.
- The engineering sector is a major element of the Northern Ireland economy, with approximately 40,000 persons engaged in 2008 in 1,780 establishments, approximately 5% of total employment in Northern Ireland. The sector accounts for 8.1% of total GVA in Northern Ireland.
- Irish-owned engineering accounts for 17% of exports and approximately a quarter of the payroll, employment and value-added generated by indigenous manufacturing.
- Long run returns to the economy of improvements in physical infrastructure, in which engineers have played a vital role
- Contributions engineers make to the knowledge economy and to sustainability.
- Engineering roles in the high-tech industrial sectors (chemical, pharmaceutical, healthcare, electronics, ICT). Together accounting for almost 80% of merchandise exports, 40% of industrial employment, and between themselves and their suppliers approximately 40% of industrial output.
- At a broader level, the sectors of the Northern Ireland economy where engineers are most active generate 33% of total employment, 45% of payroll, 25% of GVA and 70% of total expenditure.
- The indirect and multiplier benefits from expenditure by the engineering-related sectors support large sections of the wider economy north and south. This is of particular significance now that the economies are moving

Conference Board of Canada (2015)
Infrastructure in Saskatchewan Assessing the Benefits

Over the last 25 years, Saskatchewan has lowered its investment in public infrastructure, even in comparison with that of other provinces. Public investment in Saskatchewan averaged just 2.9 per cent of GDP during the 1990s and 2000s. In comparison, the national average spending was 3.5 per cent over those same decades. Despite a recent pickup in investment over the 2010–15 period, Saskatchewan's spending continued to lag that of most other provinces.

Table 15 Public Infrastructure Investment Share of Real GDP, (average over period)

	60s	70s	80s	90s	2000	2010 2015
Canada	5.8	4.5	3.7	3.4	3.5	4.2
Atlantic	8.6	6.5	5.5	4.9	4.1	5.3
Quebec	5.4	4.9	3.3	3.5	4.0	4.7
Ontario	5.9	4.3	3.4	3.4	3.5	4.3
Manitoba	6.6	4.4	3.8	3.6	3.7	4.8
Saskatchewan	**5.5**	**4.5**	**4.0**	**2.9**	**2.9**	**3.6**
Alberta	4.9	3.4	4.0	2.3	2.8	3.6
British Columbia	5.7	4.4	3.6	3.7	3.4	3.7
Source: Statistics Canada, CANSIM table 031-0005;						

The ratio of public to private capital has been in sharp decline in Saskatchewan in recent years in comparison with a stable national performance. Analysis suggests that if Saskatchewan's infrastructure investments had been on par with the national average over the past 25 years, Saskatchewan's GDP would have been roughly 1.6 per cent higher in 2015—an increase in GDP per household of just under $2,500 (in current dollars).

VI. CHALLENGES AND OPPORTUNITIES AHEAD ENGINEERING IN SASKATCHEWN'S FUTURE

Today Saskatchewan is a part of a rapidly changing global economy. Engineers have been central to meeting the challenges of Saskatchewan's past. New generations of engineers will again be required in coming decades for the Province to address its significant development challenges and realize its full potential for economic growth in support of continuing improvements in Saskatchewan's quality of life.

In the past Saskatchewan rose to these challenges. When droughts in the 1930s struck, bankrupting the province and destroying many of the foundations of its mainstream rural agricultural economy and society, leaders came forward to build new infrastructure platforms that have lasted nearly a century.

Much of this work on water infrastructure, crop diversification, drought proofing and rural electrification was led by, and enabled by, engineers, many working in the federal Prairie Provinces Rehabilitation Agency (PFRA).

Today at the end of the second decade of the 21st Century there is a requirement to look forward again and establish a framework and roadmap for future generations of sustainable economic, social and environmental development. This will require vision and new thinking about how governments and industry and society can best re-engineer the provincial future for growth, including new and expanded engineered platforms for growth.

Saskatchewan history has shown the province to grow when farmers and business invest in response to growth opportunities. Such approaches have involved a cooperative dialogue between governments (federal, provincial and municipal), private sector businesses, investment communities and leading edge scientists, technologists and engineers.

The challenges and opportunities facing Saskatchewan are large. Global markets will offer continuing demands for provincial food, energy and fertilizer resources. Saskatchewan can only benefit if there is competitive access to these distant markets. Global warming will challenge life in the province with too much and too little water. The financial demands for capital investment (public and private) will dwarf the 20th Century experience.

Society and the private sector are already adjusting and adapting to the emerging economic and environmental realities, adopting new technologies, science and engineering solutions. Government frameworks for the economy, society and the environment are all important for success in the global economy. As economic theory shows government regulatory and administrative approaches matter and are critical to realizing a Saskatchewan social, economic and environmental future with sustainable, stable growth.

This paper on ***Engineering Our Future*** looks forward at some of the opportunities and issues facing engineers in the coming century. It is hoped its contents can open a discussion on the future economic, social and environmental priorities for Saskatchewan.

In a province with wonderful opportunities to supply food, fertilizers and fuels to the world there are also great challenges in the distance from market, the size of the province, the effects of climate change and its rapidly changing human resource base. New platforms for economic development in the fields of water, transportation, carbon management and human resources are identified as early priorities for reform.

ACEC-SK feels it will be important to open a wider dialogue on future policy and administrative reforms that can ready Saskatchewan for 21st Century success.

The approach outlined in this report identifies a series of obvious challenges and priorities for action. Others may have alternative priorities. However, it is worth noting that waiting until ***"the time is right"*** has been a characteristic of too much Saskatchewan economic and social development.

For many years prevarication led to the delay in developing the provincial oil industry. At other times it opposed changes to the Crow's Nest Freight rates and the abolition of the Canadian Wheat Board that once removed led to the reinvestment in agricultural transportation both on and off the farm and the diversification of the crop base. Massive irrigation development opportunities have never been realized as the province waited for the *"right time."*

Few of us like change. Too often it is difficult to accommodate but often a prerequisite for a better future.

The planet and the global marketplace are in turbulent times. Developing a plan of action and roadmap for the future always provides some clarity and certainty on the way ahead. Yet for all who accept the need for change there will be many who sit on the status quo and oppose reform.

Many of the challenges faced by Saskatchewan people, their economy, society and environment are real and gaining momentum. The Province will not experience the endless sustainable growth without adjusting to the new realities of the global marketplace and natural environment of which it is a part.

Charting a path forward is an honorable vocation requiring leadership to take the first steps in reform. This report is intended to open a wider discussion on a new sustainable growth trajectory for Saskatchewan in the 21st Century.

In the 21st Century the requirements for engineering led technological change and innovation remains a central foundation for economic progress.

Government, industry and society all have interests in Saskatchewan's future direction. As in investment, past performance is no guarantee of future performance or success.

Consider Saskatchewan's population history. Rapid growth between 1901 and 1931, followed by declines and very slow growth through much of the 20th Century, and some modest growth and declines again over the past decade.

The challenges for Saskatchewan's long term economic future are well known. Engineering skills can contribute to resolving them working with many other provincial stakeholders.

Decisions taken today can determine where Saskatchewan will be for the rest of the 21st Century.

It is time for a wider dialogue on Saskatchewan's future to ready the Province 21st Century success.

The Association of Consulting Engineering Companies – Saskatchewan therefore invites interested parties from government, industry and society to continue this dialogue and continuing the engineering successes of the 19th and 20th Century into the 21st Century.

Table 16. Ten Realities in Considering Saskatchewan's Engineered Future

1. Location leaves Saskatchewan distant from its major global markets.
2. Growing the province either requires access to those markets or a much larger provincial population and economy.
3. Economic development in Saskatchewan arises from both public and private sources. There are mutual interests in maintaining dialogues with all stakeholders in the provincial economic, social and environmental future.
4. Saskatchewan's natural resources are not unique and also exist in many other competing jurisdictions.
5. Economic development is a long-term process.
6. New Infrastructure platforms create income and employment opportunities for generations when arising from, and integrated into, a long-term vision.
7. The status quo is not an option in a globally competitive world.
8. Successful innovating economies embrace and support new technologies, science, infrastructure and engineering.
9. Engineering will be at the centre of the new infrastructure platforms that will transform and grow Saskatchewan's economy. The strength of the provincial engineering sector in the Province matters.
10. In the past provincial growth in Saskatchewan has been accompanied by long-term visions of what was to be achieved. *"Just as sure as the sun shines there will be within this Province alone someday a population running into the tens of millions" and "This is a great country. It needs big men with large ideas." (Premier Walter Scott 1905-1916.)*

INFORMATION ANNEX A, ENGINEERING SKILLS AND SPECIALIZATIONS OF ACEC-SK MEMBERS

ENGINEERING SECTOR	ENGINEERING SECTOR SPECIALISATION
AGRICULTURAL ENGINEERING	Rural Area Organic Waste Disposal Agrology Drainage Studies Surveys Draining & Irrigation Systems Irrigation Networks Farm Buildings Farm Machinery & Equipment Farmland Resources: Surveys & Improvement Works Food Processing & Storage Grains & Feeds: Drying, Cleaning, Handling, Processing & Storage Water & Soil Conservation Irrigation, Land & Drainage Nutrient Management Rural Planning & Development
BUILDINGS& BUILDING SCIENCE	Commercial Design for Arctic Conditions Acoustics Architecture Capital Planning Ergonomics Fire Protection/Prevention Inspections Investigations LEED -Leadership in Energy & Environmental Design Preliminary/Final Design Repair/ Restoration Residential Roofing & Waterproofing Walls, Cladding & Windows Inspections / Investigations Roofing & Waterproofing Technical Audits
CHEMICAL ENGINEERING	Desalination Food Processing Plastics Process Design Synthetic Fibres
COLD CLIMAT ENGINEERING	Building Design for Arctic Conditions Diesel Power Generation Ice Core Dams Ice Road Design Permafrost Investigations Petroleum, Oil & Lubricant Storage & Handling Storage & Handling Thermosyphons
COMMUNI-CATIONS-TELECOM-MUNICATIONS	AM FM Broadcasting Data Transmission Systems Fibre Optics Program Production Facilities Terrestrial & Satellite Links TV&CATV Wireless Systems
COMPUTER SCIENCE	Computational Mechanics /Controls Database Management Internet Intranet Process Automation S oftw"are Development Robotics
ELECTRICAL ENGINEERING	Alarm & Security Systems Motors & Generators Building Systems Energy Conservation Illumination & Lighting Power Transmission & Distribution Residential
ENERGY GEOSCIENCE	Coal Bed Methane Coal Exploration/Mining Energy Reserves Petroleum Development
ENERGY	Biomass Wood Electric Power Generation - Nuclear Electric Power Generation- Thermal Renewable Wind & Solar Co-Generation Coal Processing & Transportation District Heating & Co-Generation Conservation Oil & Gas Pipelines, Gas Production/Storage/Distribution/ Refineries/Processing/ Steam Power Generation
ENVIRONMENTAL	Groundwater Resources Hydrogeology Industrial Wastewater Treatment Laboratory & Treatability Studies LEED -Leadership in Energy & Design Noise & Vibration Physical Mapping & Analysis Surface Water Resources Air Quality Management
ENVIRONMENTAL (Contined)	Assessments Litigation Support Site Assessments & Audits Groundwater Resources Hydrogeology Industrial Hygiene & Safety Industrial Wastewater Treatment Mould Studies Noise & Vibration Physical Mapping & Analysis Record of Site Condition Risk Assessment Solid Odorous Waste Management Surface Water Resources Underground Storage Tank Management
ENVIRONMENTAL GEOSCIENCE	Hydrogeology & Groundwater Terrain Analysis Remote Sensing Waste Management/Mitigation/Disposal
FISHERIES	Marine Biology & Oceanography Maritime Harbour Engineering, Trans-shipment Equipment Remote Sensing Fishery Resources: Evaluation, Development, Operations, Aquaculture Maritime Harbour Engineering, Trans-shipment Equipment Monitoring, Control & Surveillance Fish By-products: Processing/Storage Fishery Resources: Evaluation, Development, Operations, Aquaculture
FORENSIC	Accident Reconstruction Cladding Failures Electrical Mechanical Failures Fire & Explosions Investigation & Settlement of Claims Structural Failures Wind & Water Damage
FORESTRY	Forestry Building Materials: Plywood, Lumber, Manufacturing, etc. Forestry Engineering Pulp & Paper Plants, Products Forest Building Materials: Plyw'Ood, Lumber, Manufacturing, etc
GEOPHYSICS & GEOTECHNICAL	Seismic Acquisition/ Analysis Aggregate Exploration & Evaluation Earth Structures Foundations Laboratory Testing In Site Investigations Soil & Rock Mechanics
INDUSTRIAL	Ergonomics Product & Process Design Transportation Automotive Equipment Hydraulic Engineering Machine Design /Analysis Manufacturing Facilities Materials Handling & Storage Plant Maintenance Product & Process Design Time Motion Studies
MATERIALS	Analysis Corrosion Control & Remediation Design & Selection Quality Issues Specifications & Manuals Testing & Certification
MECHANICAL	Computational Fluid Dynamics Computer Aided Engineering Cranes & Derricks Finite Element Analysis Fire Protection Systems Heating, Ventilation, A-C Machine Design Plumbing & Piping Refrigeration Residential Software development
MINING & MINERALS ENGINEERING	Ore Dressing Blasting Control Iron & Steel Works / Rolling / Casting/Forging etc. Metallurgy Extractive- Ferrous Metals Metallurgy Extractive Non-Ferrous Metals Fabricating\Rolling/ Forging/Casting/ Extruding etc Open Pit Settling ponds Underground Mining
MINING GEOSCIENCE	Reserves Mining Geology Rock Mechanics Infrastructure Rehabilitation Residuals Management
MUNICIPAL ENGINEERING	Roads & Streets Storm water Management Wastewater Collection & Treatment Wastewater Management Water Supply & Treatment
OCCUPATIONAL HEALTH & SAFETY	Area Classifications Hazardous Materials Management
PETROLEUM ENGINEERING	Acquisitions & Divestitures Evaluations Expert Witness Exploitation Feasibility Studies Reservoir Engineering Well Test Analysis Pressure Vessels Process Piping Design Petroleum, Oil & Lubricant Storage & Handling
PLANNING	Site Plans Drainage Studies Industrial Parks Land Use Site Plans Subdivision Plans Urban & Rural Design
PROJECT MANAGEMENT	Construction Management Construction Quality Control Contract Administration Design Management Procurement Management Project Control & Risk Management Related Management Services Contract Administration Value Engineering Construction Management Construction Quality Control Related Management Services
RESEARCH	Research Feasibiity Studies Research Technology Assessment
STRUCTURAL BUILDINGS	Commercial Foundations Highrise Industrial Inspections & Investigations Institutional Lowrise Parking Facilities Restoration & Repair Seismic Retrofit
STRUCTURAL OTHER	Bridges Bunkers & Silos Dams & Locks Nudear Tanks & Shells Towers
SURVEYS &MAPPING	Aerial Photography Photogrammetry Photo Interpretation Cartography Construction Layout Surveys Geographic Information Systems Land & Surveying Cadaster Remote Sensing Satellite Data Interpretation Imagery Resource Surveys, Exploration & Planning Topographic Surveys Construction Layout Surveys
TEMPORARY WORKS	Excavation Enclosures Formwork Lifting & Moving Scaffolding Structural Shoring
TRANSPORT ENGINEERING	Airports Highways & Road Safety Intelligent Systems Long Distance Rail PavemenIDesign Pavement Management Services Ports & Harbours Roads & Highways Terminals & Service Centres Traffic Engineering & Control Planning Urban Public Transit Network Evaluation Congestion Solutions Highway Maintenance

Source: ACEC-SK Special Tabulation, 2018

INFORMATION ANNEX A
ACEC-SK Corporate Members 2018

COMPANY	COMPANY
AECOM	McElhanney Consulting Services Ltd.
ALFA Engineering Ltd.	Missinipi Water Solutions Inc.
Allnorth Consultants Limited	MPE Engineering Ltd.
Arrow Engineering Inc.	NEES Consulting
Associated Engineering	P.Machibroda Engineering Ltd.
BBK Engineering Saskatoon Ltd	PINTER & Associates Ltd.
Beckie Hydrogeologists (1990) Ltd.	Prakash Consulting Ltd.
Brownlee Beaton Kreke Ltd.	PWA Engineering (2013) Ltd.
Building Solutions Apogee Inc.	R.J. England Consulting Ltd.
Bullée Consulting Ltd.	Rempel Engineering & Mgmt Ltd.
Catterall & Wright	Resource Mgmt International Inc.
CIMA Canada Inc. (CIMA)	Ritenburg & Associates Ltd.
Clifton Associates Ltd.	Robb Kullman Engineering LLP
Clunie Consulting Engineers Ltd.	Rockford Engineering Works Ltd.
D-Code Engineering Ltd.	SAL Engineering Ltd. -
Daniels-Wingerak Engineering Ltd.	SRK Consulting (Canada) Inc.
Dillon Consulting Limited	Stantec Consulting Ltd.
DKM Engineering Ltd.	Tetra Tech Canada Inc.
DL Minter Engineering Inc.	Thurber Engineering Ltd.
ENGCOMP Engineering & Computing Professionals Inc.	Topping Engineering Ltd.
Golder Associates Ltd.	TRON Engineering Inc.
Ground Engineering Consultants Ltd.	Urban Systems Ltd.
HDA Engineering Ltd.	Walker Projects Inc.
Inertia Solutions Inc.	JC Kenyon Engineering Inc.
ISL Engineering and Land Services Ltd.	Key West Engineering Ltd.
J.D. Mollard and Associates (2010) Limited	KGS Group

Engineered Platforms for Economic Growth
COOP Oil Refinery and Upgrader, Regina

Summary Engineering Disciplines Offered by ACEC-SK Corporate Members.

Engineering Disciplines		
Aerospace	Geo-technical	Hydrological Engineering
Agriculture	Industrial	Civil Engineering – Roads, Bridges
Building Science	Marine and Coastal	Environmental Engineering
Chemical Engineering	Materials	Structural Engineering for Buildings & Industry
Cold Climate Engineering	Mechanical	Surveying and Mapping
Communications Telecommunications	Mineral Geoscience	Interpretation Imagery
Computer Science	Mining Engineering	Resource Surveys
Electrical	Municipal	Transportation
Energy	Occupational Health and Safety	Surveying & Mapping
Environmental Geoscience	Petroleum Engineering	Interpretation Imagery
Fisheries	Planning	Resource Surveys, Exploration
Forensic	Pressure Vessels	Planning Temporary Works
Forestry	Project Management	Exploration and Planning
Geophysics	Research	Temporary Works

SASKATCHEWAN DEMOGRAPHIC HISTORY
1931 -2018 , ESTIMATED FOR 2050 AT PAST GROWTH RATES

		GROWTH RATES	
YEAR	**POPULATION**	**% CHANGE/DECADE or COMPARISON PERIOD**	**AVERAGE ANNUAL % CHANGE**
1901	91,279		
1911	492,432	**439%**	**44%**
1921	757,510	**54%**	**5%**
1931	921,785	**22%**	**2%**
1941	895,992	**-3%**	**0%**
1951	831,728	**-7%**	**-1%**
1961	925,181	**11%**	**1%**
1971	926,242	**0%**	**0%**
1981	968,313	**5%**	**0%**
1991	988,928	**2%**	**0%**
2001	978,933	**-1%**	**0%**
2011	1,066,349	**9%**	**1%**
2018	1,163,925	**9%**	**1%**
PERIOD GROWTH RATES			
1901-1931		102%	3%
1931-2018		87%	1%
FORECAST ESTIMATES FOR 2015 from 2018			
At 1% per annum		1,600,328	1%
At 3% per annum		2,997,203	3%
Source: Statistics Canada, Census of Canada, Saskatchewan Bureau of Statistics Annual Economic Review. Forecasts estimated.			

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